UNITED STATES DISTRICT COURT
DISTRICT OF MASSACHUSETTS

L. JOHN DAVIDSON and PASTEURIZED EGGS LIMITED PARTNERSHIP, by and through its General Partner, THE DAVIDSON GROUP SHELL EGG CORPORATION,
PLAINTIFFS

00CV 10859 DPW
Civil Action No.

v.

MICHAEL FOODS, INC.,
DEFENDANT

COMPLAINT FOR DECLARATORY RELIEF

The PLAINTIFFS, pursuant to Fed. R. Civ. P. 57, hereby seek a Declaratory Judgment of Non-Infringement of the DEFENDANT'S patent rights.

PARTIES

1. The Plaintiff L. JOHN DAVIDSON (hereinafter "DAVIDSON") is an individual residing in the State of New Hampshire.

2. The Plaintiff PASTEURIZED EGGS LIMITED PARTNERSHIP, by and through its General Partner, THE DAVIDSON GROUP SHELL EGG CORPORATION (hereinafter "PELP"), is a limited partnership formed under Delaware statute with a place of business in the state of New Hampshire, and it does business in the Commonwealth of Massachusetts.

3. The Defendant MICHAEL FOODS, INC. (hereinafter "MICHAEL

FOODS" or "DEFENDANT") is a Delaware Corporation that does business in; has purposeful and substantial contacts in; and is subject to personal jurisdiction in the Commonwealth of Massachusetts.

ALLEGATION OF JURISDICTION

4. Subject matter jurisdiction in this Court is founded upon the existence of a federal question. The action arises under the United States Code, Title 35, § 271, and the United States Code, Title 28, § 1338(a), as the claims relate to the issue of patent infringement.

FACTUAL BACKGROUND

5. On December 31, 1996, United States Patent Number 5,589,211 issued to its inventors, James P. Cox, R.W. Duffy Cox, and Jeanne M. Cox, (hereinafter "Cox patent") claiming "methods for processing poultry shell eggs." (A copy of United States Patent Number 5,589,211 is annexed hereto as Exhibit "A" and incorporated herein by reference.)

6. The Plaintiff PELP owns the Cox patent.

7. On December 1, 1998, United States Patent Number 5,843,505 issued to its inventor, DAVIDSON, (hereinafter "Davidson Patent") claiming a "method for production of pasteurized in-shell chicken eggs." (A copy of United States Patent Number 5,843,505 is annexed hereto as Exhibit "B" and

incorporated herein by reference.)

8. The Plaintiff DAVIDSON owns the Davidson patent.

9. On December 21, 1999, United States Patent Number 6,004,603 issued to its inventors, Joseph M. Vanderpopuliere and Owen J. Cotterill, and its assignee, The University of Missouri, (hereinafter "Missouri Patent") claiming a "method of controlling Salmonella in shell eggs." (A copy of United States Patent Number 6,004,603 is annexed hereto as Exhibit "C" and incorporated herein by reference.)

10. Upon information and belief, the DEFENDANT is the exclusive licensee of the Missouri Patent.

11. The Plaintiff PELP is also a licensee for three patents issued to Louis Polster, United States Patent Number 5,916,617, Number 5,993,886, and Number 6,035,647, claiming, respectively, a "process for heat treating food product," a "method and control system for controlling pasteurization of in-shell eggs," and a "method and apparatus for chilling in-shell eggs." (Copies of United States Patent Number 5,916,617, Number 5,993,886, and Number 6,035,647 are attached hereto as Exhibits "D", "E", and "F", respectively, and incorporated herein by reference.)

12. The consuming public has a compelling interest in egg safety and pasteurization, and PELP, by arrangement with ISE America, Inc.(hereinafter "ISE")and others and with the

participation of DAVIDSON, is in production of "Davidson's Pasteurized Eggs" and has entered several markets in the eastern United United States, including Massachusetts.

13. Upon information and belief, the DEFENDANT is a diversified food processor and distributor, claims to be the dominant leader in the egg products industry in the United States, and advertises, markets, distributes, and sells its products in the Commonwealth of Massachusetts.

14. On February 17, 2000, the DEFENDANT sent a letter to ISE stating as follows:

(a) the DEFENDANT is aware of ISE's "arrangement with [DAVIDSON, THE DAVIDSON GROUP SHELL EGG CORPORATION or PELP] for the production of pasteurized eggs in the shell;"

(b) the DEFENDANT and ISE entered a confidentiality agreement on March 3, 1997;

(c) the DEFENDANT is the licensee of the Missouri patent and that "MICHAEL FOODS believes that the process that you intend to use may infringe this patent;"

(d) "MICHAEL FOODS will vigorously defend its intellectual property rights if necessary;"

(e) the DEFENDANT demands a description from ISE of "why you believe that the process you are about to use does not employ the information disclosed by us to you under the confidentiality

agreement and why you believe it will not infringe our patent;" and

(f) the DEFENDANT demands that, if ISE is unable to describe why it is not employing confidentially disclosed information or infringing the Missouri Patent, that it "not commence, or discontinue if [it has] commenced, sale of products produced using the infringing process." (A copy of the February 17, 2000, letter is annexed hereto as Exhibit "G" and incorporated herein by reference.)

COUNT I: (DAVIDSON)

15. The Plaintiff DAVIDSON hereby repeats, realleges and incorporates herein by reference the allegations of Paragraphs 1-14.

16. The February 17, 2000, letter creates and illustrates an actual controversy between the parties because it gives DAVIDSON a reasonable apprehension that the DEFENDANT will file a patent infringement action against him and/or others engaged with him in the production and sale of "Davidson's Pasteurized Eggs."

17. DAVIDSON and others engaged with him in the production and sale of "Davidson's Pasteurized Eggs" are operating within the PLAINTIFFS' own patent rights.

18. DAVIDSON and others engaged with him in the production and sale of "Davidson's Pasteurized Eggs" are in no way

21. PELP and others engaged with it in the production and sale of "Davidson's Pasteurized Eggs" are operating within the PLAINTIFFS' own patent rights.

22. PELP and others engaged with it in the production of "Davidson's Pasteurized Eggs" are in no way infringing the Missouri Patent or any other intellectual property rights of the DEFENDANT.

WHEREFORE, the Plaintiff PELP prays that the Court:

(a) Issue a Declaratory Judgment of Non-Infringement of the Missouri Patent or any other intellectual property rights of the DEFENDANT by PELP and those engaged with it in the production and sale of "Davidson's Pasteurized Eggs."

(b) Restrain the DEFENDANT from instituting any action against PELP and others engaged with it in the production and sale of "Davidson's Pasteurized Eggs" for patent infringement arising out of such production and sale.

(c) Order that PELP recover its costs.

(d) Order any further relief it deems warranted by the evidence.

JURY DEMAND

Pursuant to Fed. R. Civ. P. 38, 39 and 57, the PLAINTIFFS hereby demand a trial by jury on all issues so triable.

SPEEDY HEARING

Pursuant to Fed. R. Civ. P. 57, the PLAINTIFFS hereby request a speedy hearing in this matter.

The PLAINTIFFS,
By Their Attorneys,
COOLEY MANION JONES LLP,

Earle C. Cooley, BBO# 097900
John B. Manning, BBO# 559707
21 Custom House Street
Boston, MA 02110
(617) 737-3100

Dated: May 3, 2000

VERIFICATION

I, L. John Davidson, being duly sworn, hereby depose and say that I am an individual plaintiff and the President, CEO, and Chairman of the Board of The Davidson Group Shell Egg Corporation, which is the General Partner of the Plaintiff Pasteurized Eggs Limited Partnership in the within action; that I have read the foregoing Complaint for Declaratory Relief; and that the allegations thereof are true, except those alleged to be on information and belief, which matters I believe to be true.

L. John Davidson

Then personally appeared before me L. John Davidson and acknowledged the execution of the foregoing to be his free act and deed.

Date: 5-3-2000

NOTARY PUBLIC

My Commission Expires: July 24, 2000

50024.00

US005589211A

United States Patent [19]

Cox et al.

[11] Patent Number: 5,589,211

[45] Date of Patent: *Dec. 31, 1996

[54] METHODS FOR PROCESSING POULTRY SHELL EGGS

[76] Inventors: James P. Cox; R. W. Duffy Cox; Jeanne M. Cox, all of 246 E. Bartlett Rd., Lynden, Wash. 98264

[*] Notice: The portion of the term of this patent subsequent to Aug. 19, 2011, has been disclaimed.

[21] Appl. No.: 156,273

[22] Filed: Nov. 22, 1993

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 746,940, Aug. 19, 1991, which is a continuation-in-part of Ser. No. 674,495, Mar. 25, 1991, Pat. No. 5,283,072, which is a continuation of Ser. No. 349,974, May 8, 1989, abandoned, which is a continuation of Ser. No. 196,878, May 19, 1988, abandoned, which is a continuation of Ser. No. 70,597, Jul. 8, 1987, abandoned, which is a continuation of Ser. No. 758,086, Jul. 23, 1985, abandoned.

[51] Int. Cl.[6] A23B 5/005

[52] U.S. Cl. 426/298; 426/300; 426/614; 426/521

[58] Field of Search 426/614, 298, 426/300, 521

[56] References Cited

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4,524,083	6/1985	Liot	426/330.1
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4,957,759	9/1990	Swartzel et al.	426/399

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72454	4/1953	Netherlands	53/5

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Carter et al. 1986. The New Good House–Keeping Cookbook. pp. 288–289.

E. M. Funk, Maintenance of Quality in Shell Eggs By Thermostabilization, Research Bulletin 467, University of Missouri, College of Agriculture, Agriculture Experiment Station, Dec. 1950.

E. M. Funk, Pasteurization of Shell Eggs, Research Bulletin 364, University of Missouri, College of Agriculture, Agricultural Experiment Station, May 1943.

E. M. Funk, Stabilizing Quality in Shell Eggs, Research Bulletin No. 362, University of Missouri, College of Agriculture, Agriculture Experiment Station, Apr. 1943.

Murphy and Sutton, Pasteurization of Shell Eggs to Prevent Storage Rot and Maintain Quality, A Progress Report of Experimental Work, Publication No. 3317, Department of Agriculture, New South Wales, Austrailia, 1947.

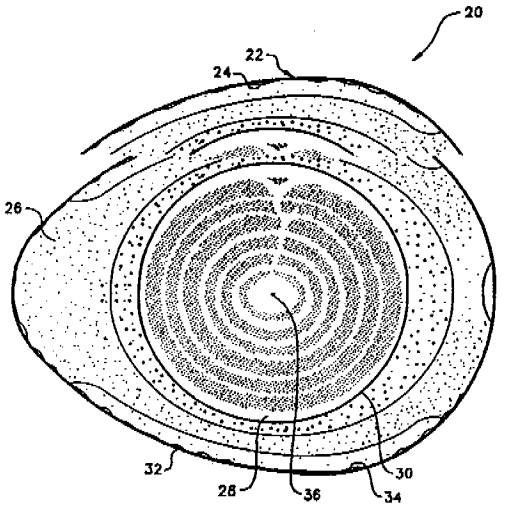
Primary Examiner—Anthony J. Weier

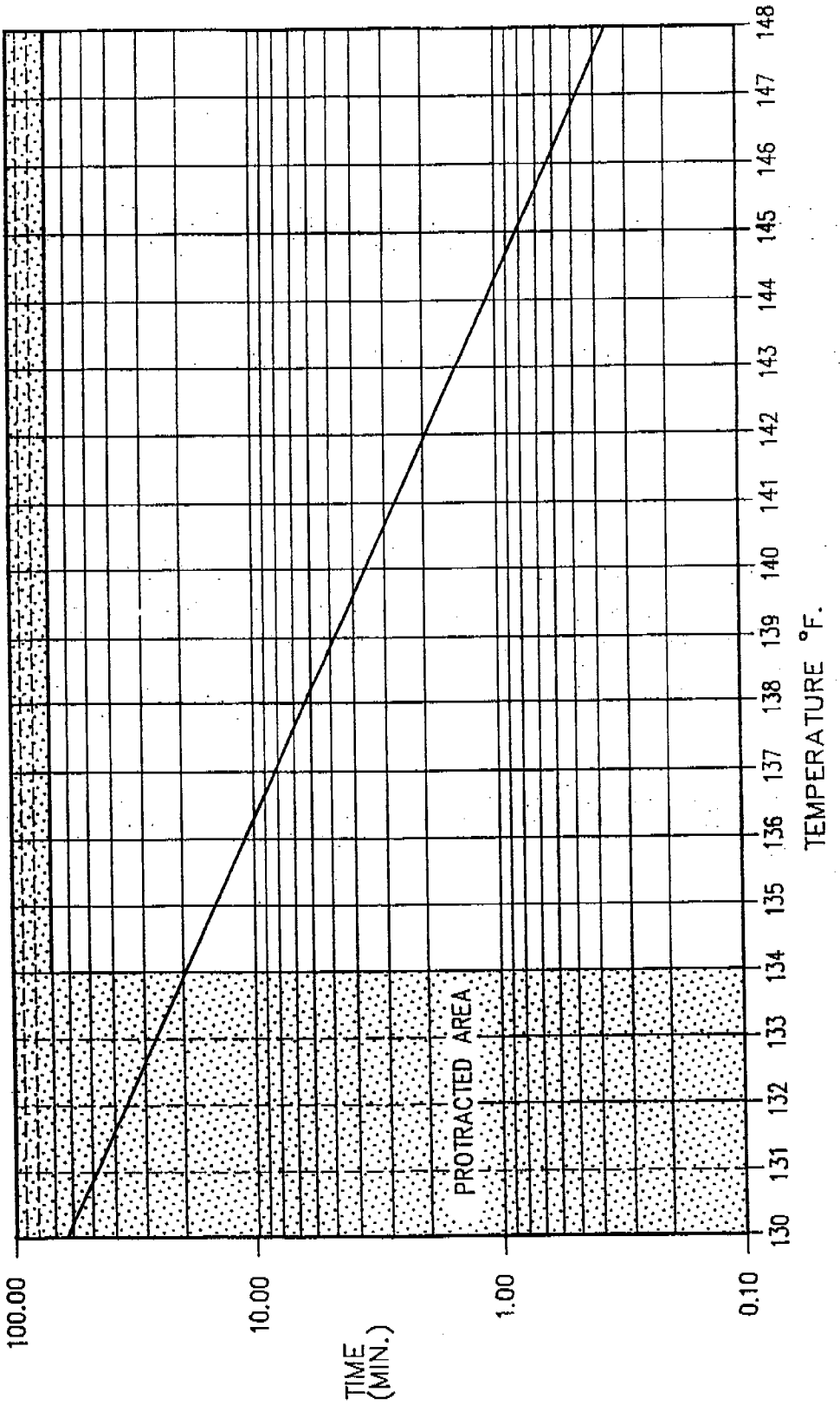
Attorney, Agent, or Firm—Hughes, Multer & Schacht

[57] ABSTRACT

Time at temperature methods of treating whole eggs which make them safer to eat without affecting the functionality or organoleptic properties of the eggs. The keeping quality of the eggs is also improved.

3 Claims, 12 Drawing Sheets




148
147
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145
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138
137
136
135
134
133
132
131
130
TEMPERATURE °F.
PROTRACTED AREA
100.00
10.00
1.00
0.10
TIME (MIN.)

FIG. 1

FIG. 2

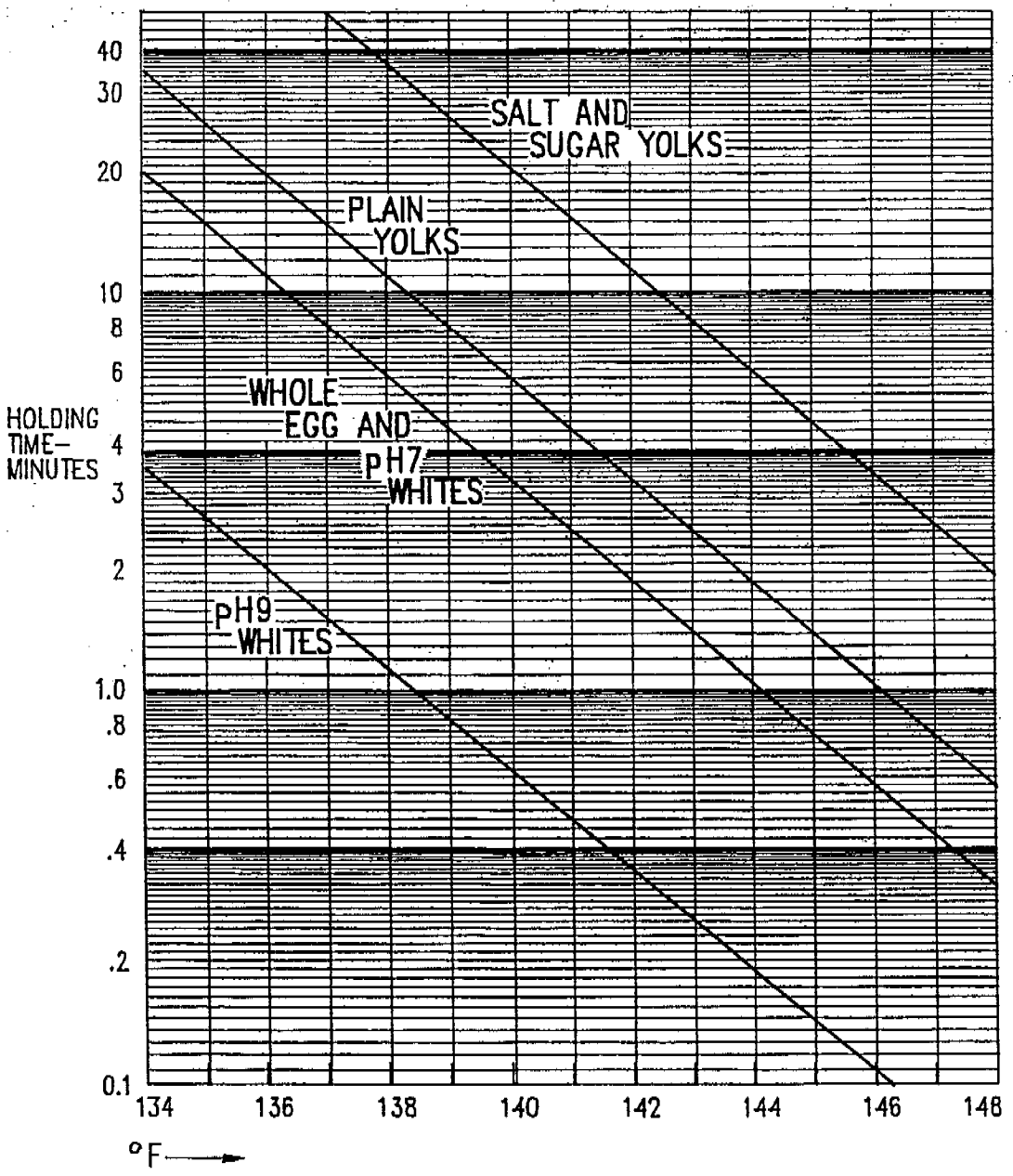
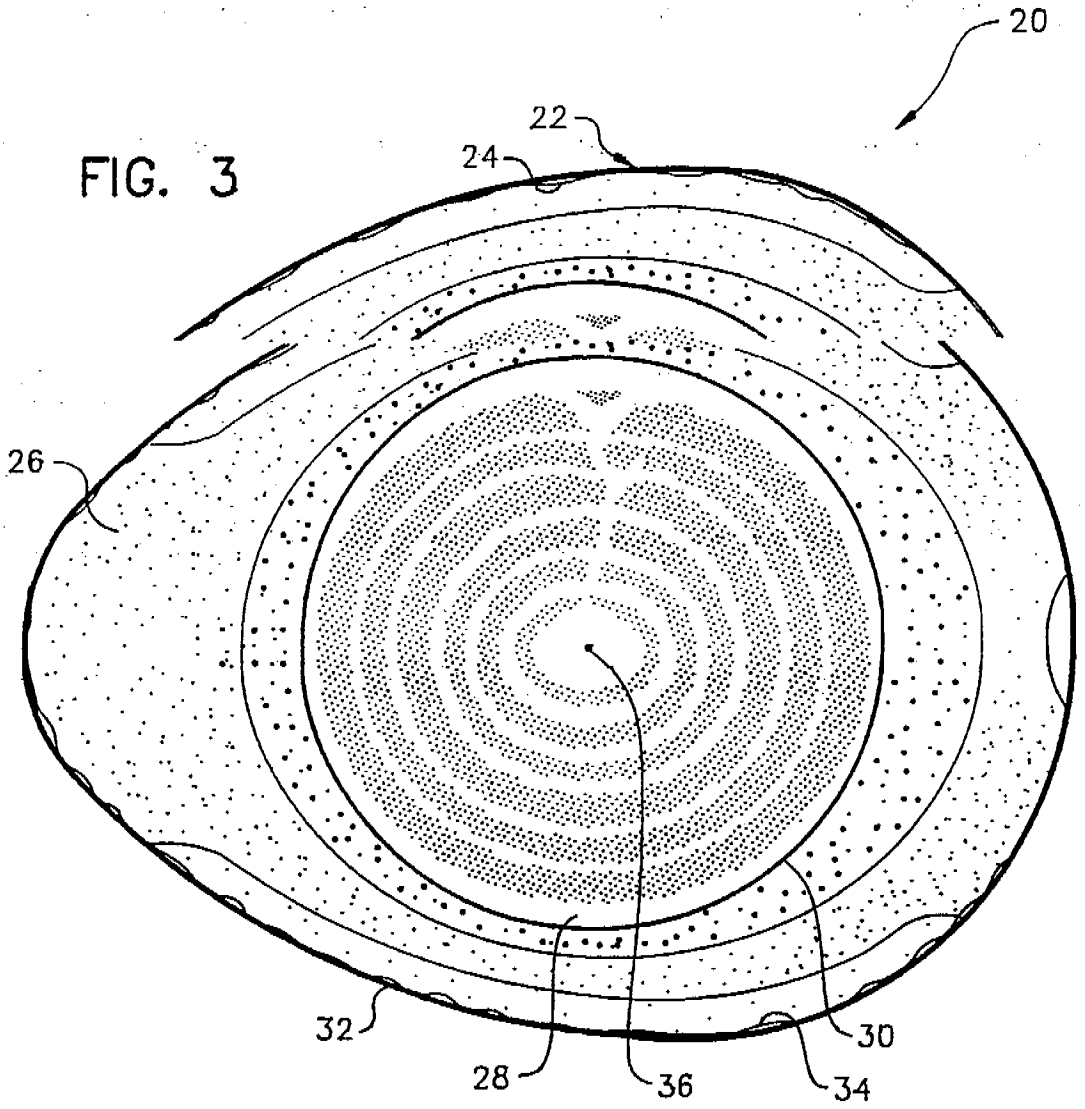
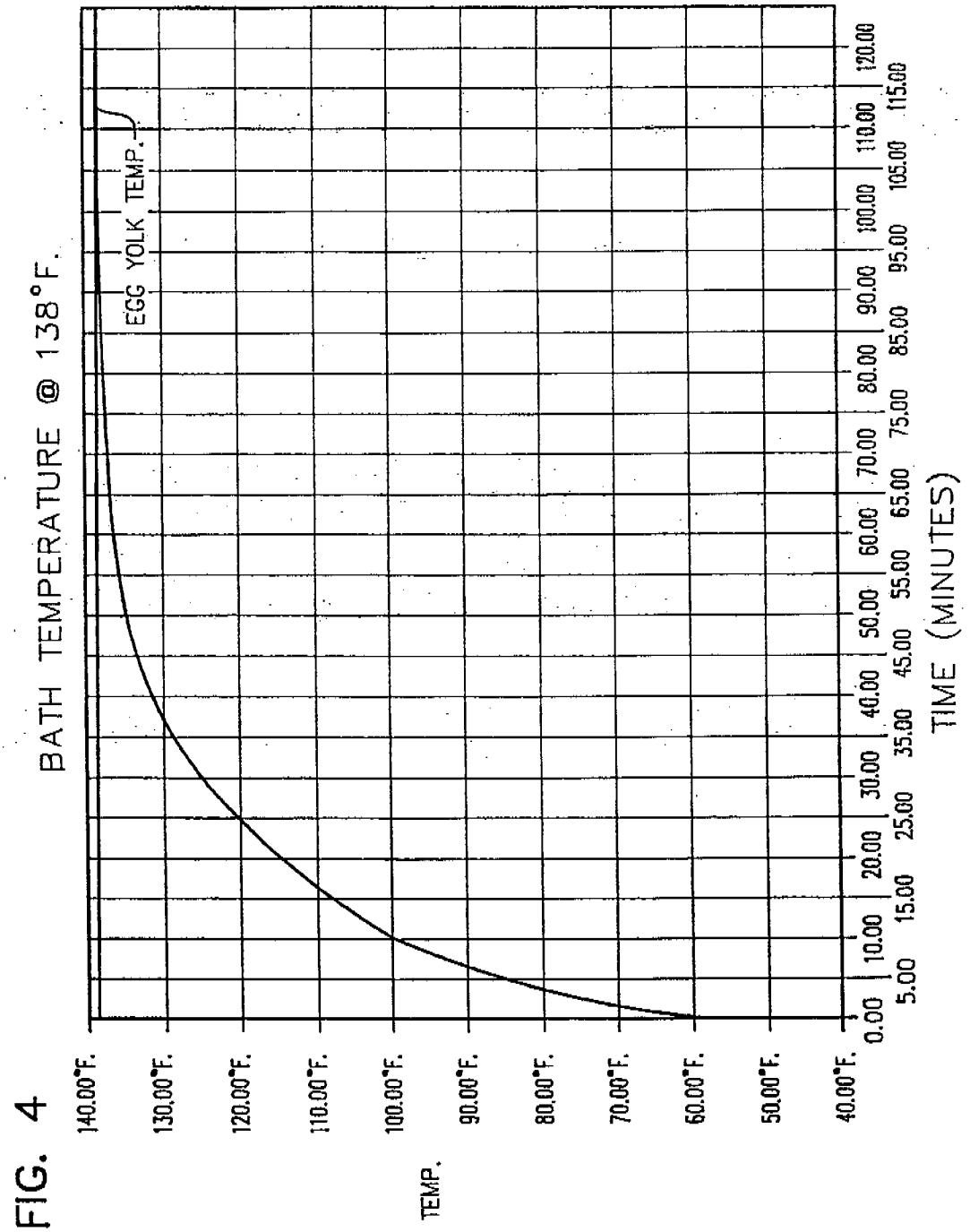

40
30
20
10
8
6
4
3
2
1.0
.8
.6
.4
.2
0.1
HOLDING TIME— MINUTES
SALT AND SUGAR YOLKS
PLAIN YOLKS
WHOLE EGG AND pH7 WHITES
pH9 WHITES
134
136
138
140
142
144
146
148
°F

FIG. 3

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110.00°F.
100.00°F.
90.00°F.
80.00°F.
70.00°F.
60.00°F.
50.00°F.
40.00°F.
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
55.00
60.00
65.00
70.00
75.00
80.00
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95.00
100.00
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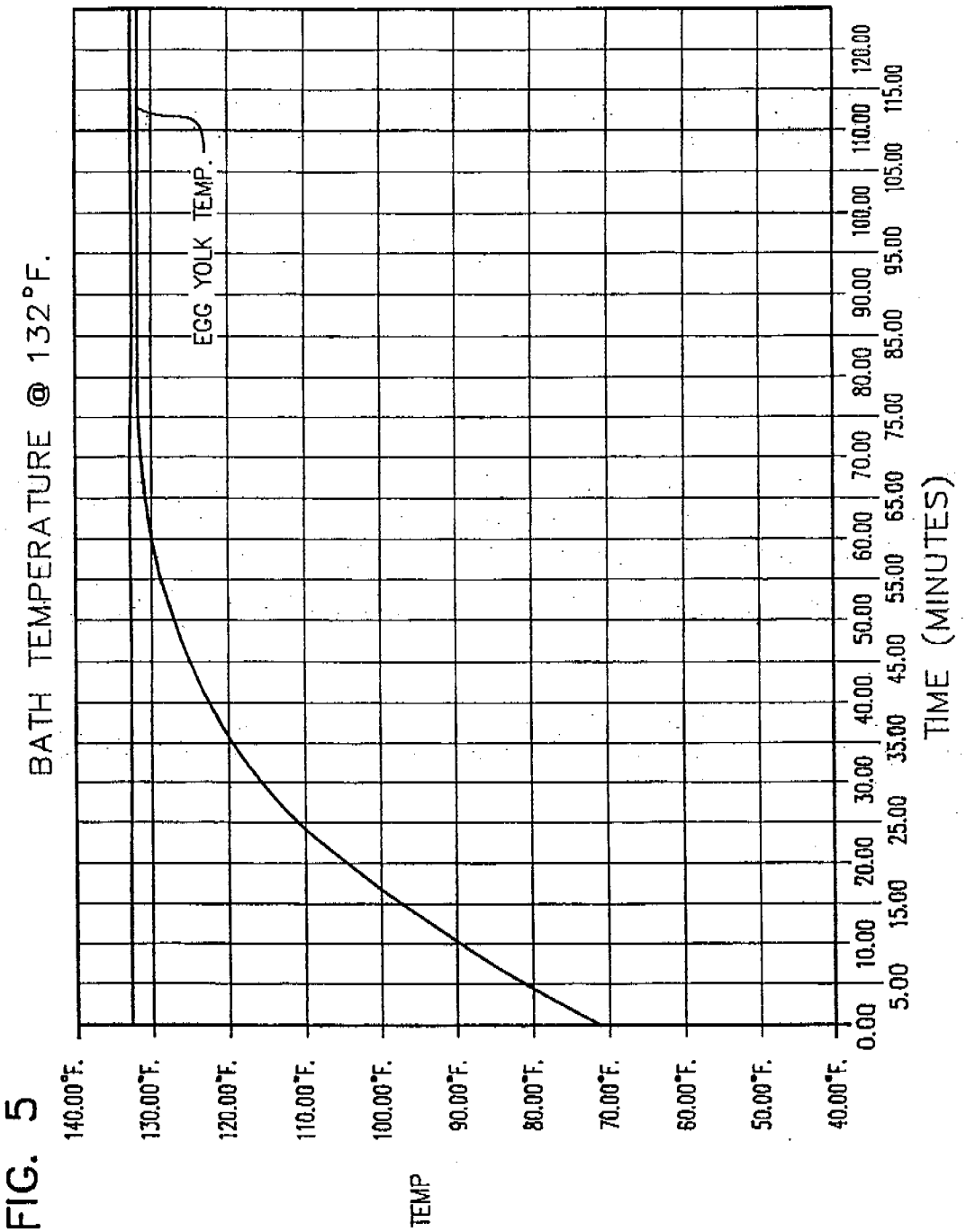
110.00
115.00
120.00
TIME (MINUTES)

FIG. 4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80.00°F.
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60.00
65.00
70.00
75.00
80.00
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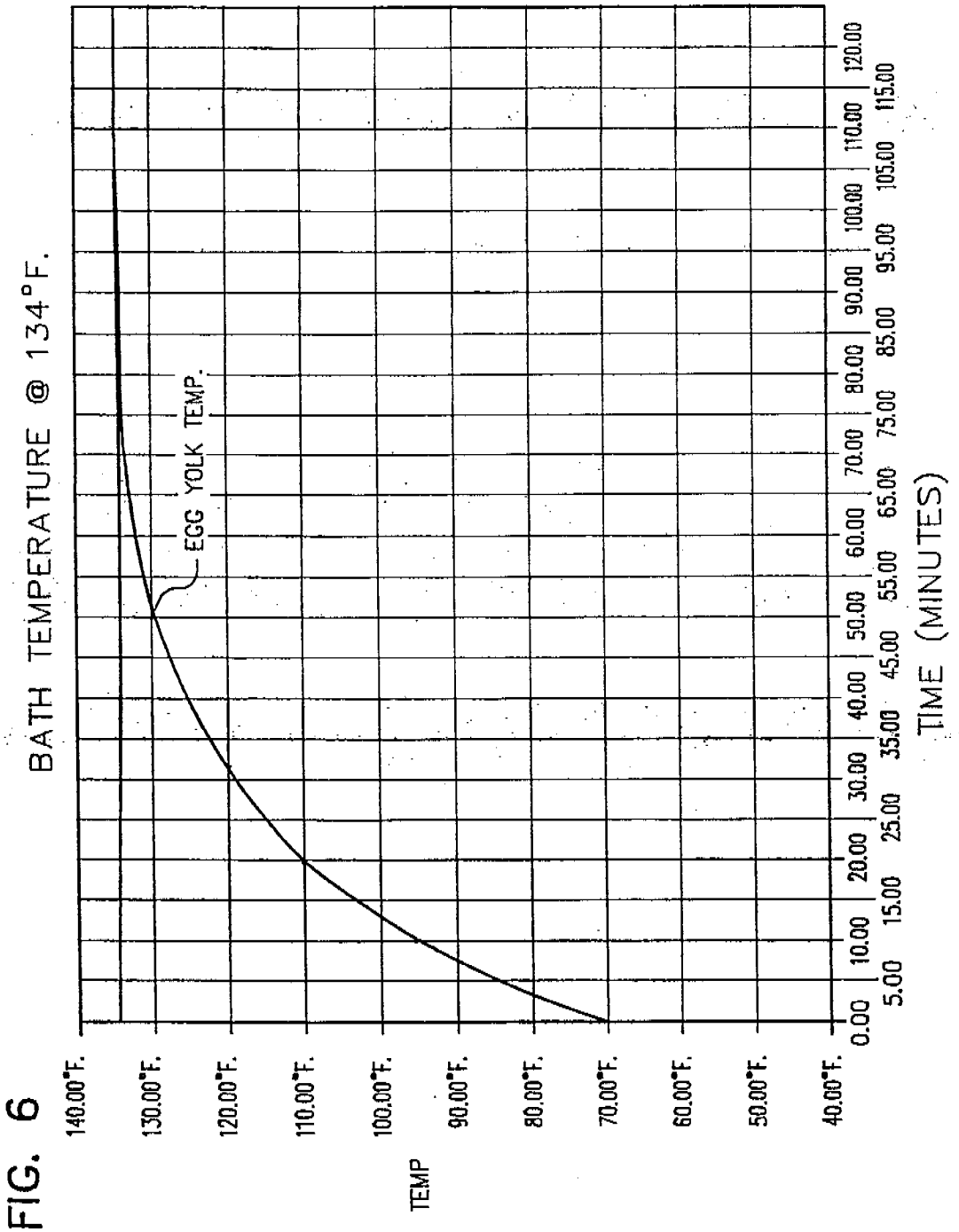
95.00
100.00
105.00
110.00
115.00
120.00
TIME (MINUTES)

FIG. 5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EGG YOLK TEMP.
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100.00°F.
90.00°F.
80.00°F.
70.00°F.
60.00°F.
50.00°F.
40.00°F.
TIME (MINUTES)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
55.00
60.00
65.00
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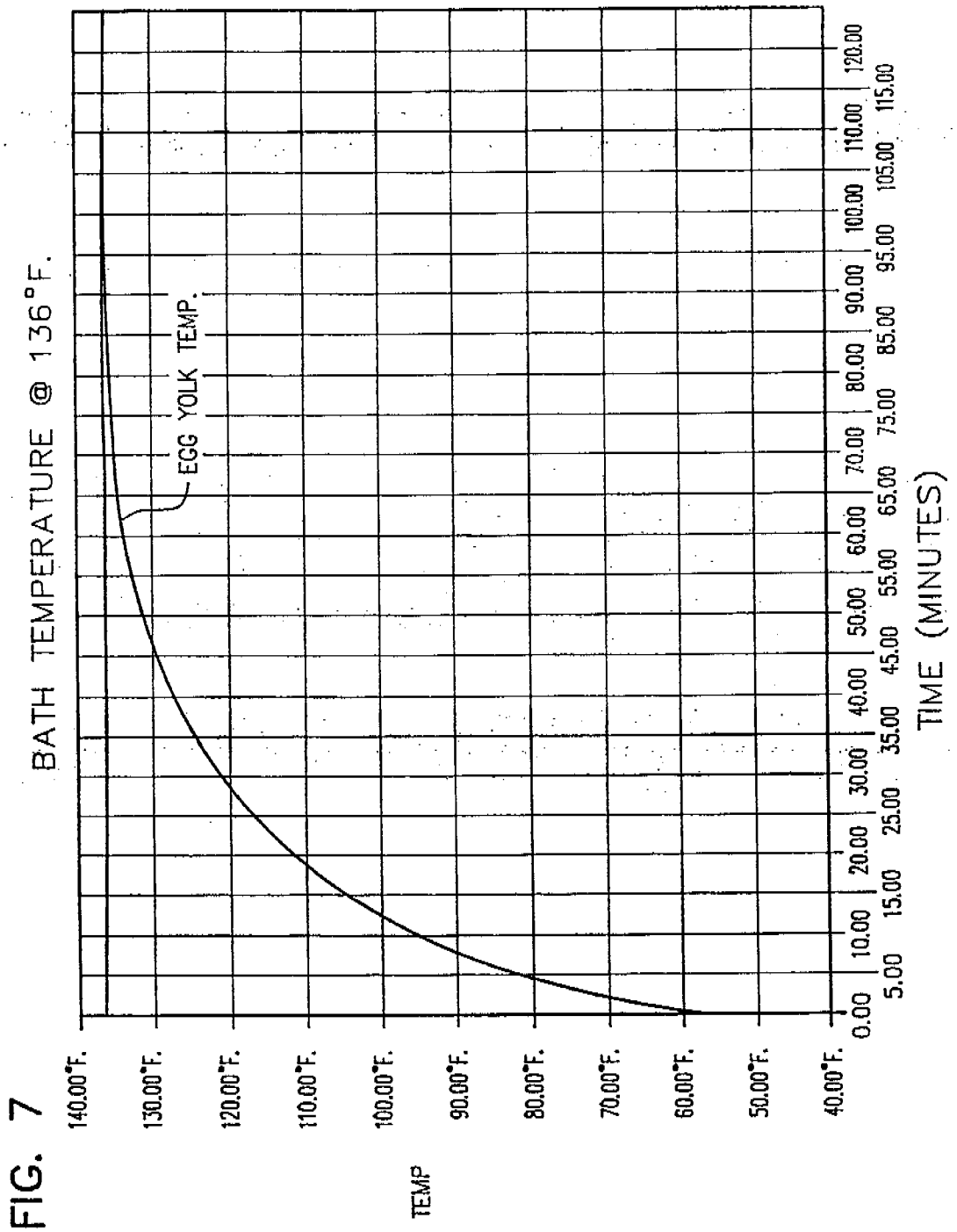
100.00
105.00
110.00
115.00
120.00

FIG. 6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EGG YOLK TEMP.
TEMP
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110.00°F.
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65.00
70.00
75.00
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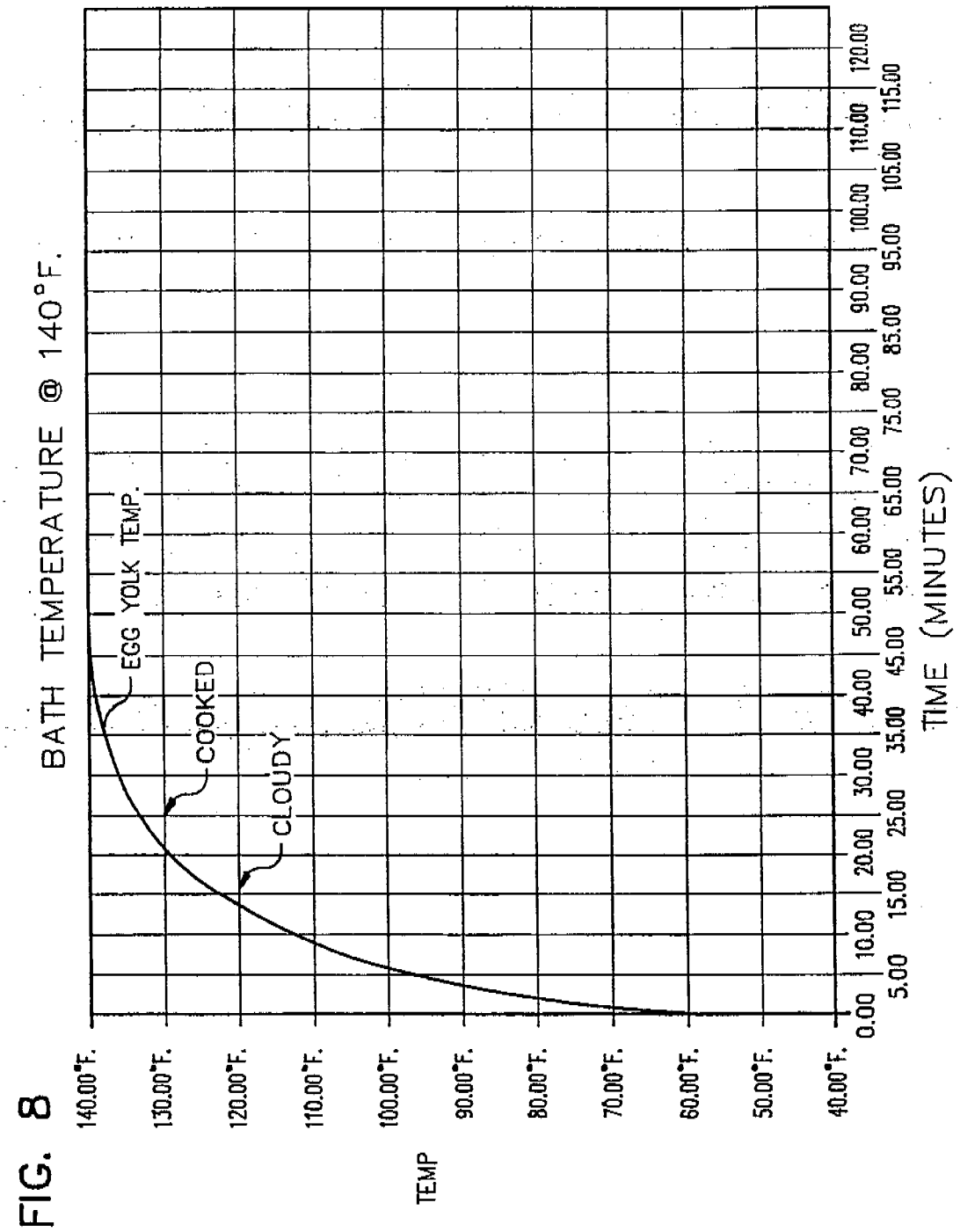
110.00
115.00
120.00
TIME (MINUTES)

FIG. 7


BATH TEMPERATURE @ 140°F.
EGG YOLK TEMP.
COOKED
CLOUDY
TEMP
140.00°F.
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110.00°F.
100.00°F.
90.00°F.
80.00°F.
70.00°F.
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40.00°F.
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75.00
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100.00
105.00
110.00
115.00
120.00
TIME (MINUTES)

FIG. 8

FIG. 9

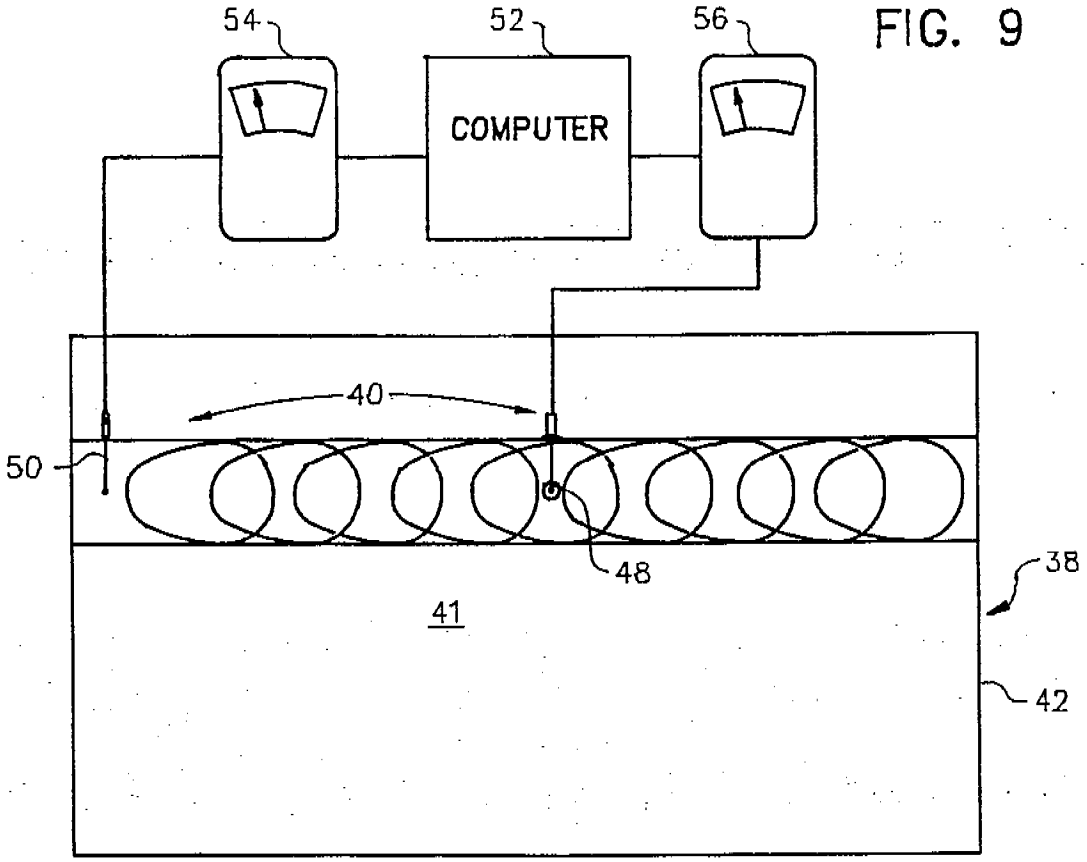


FIG. 10

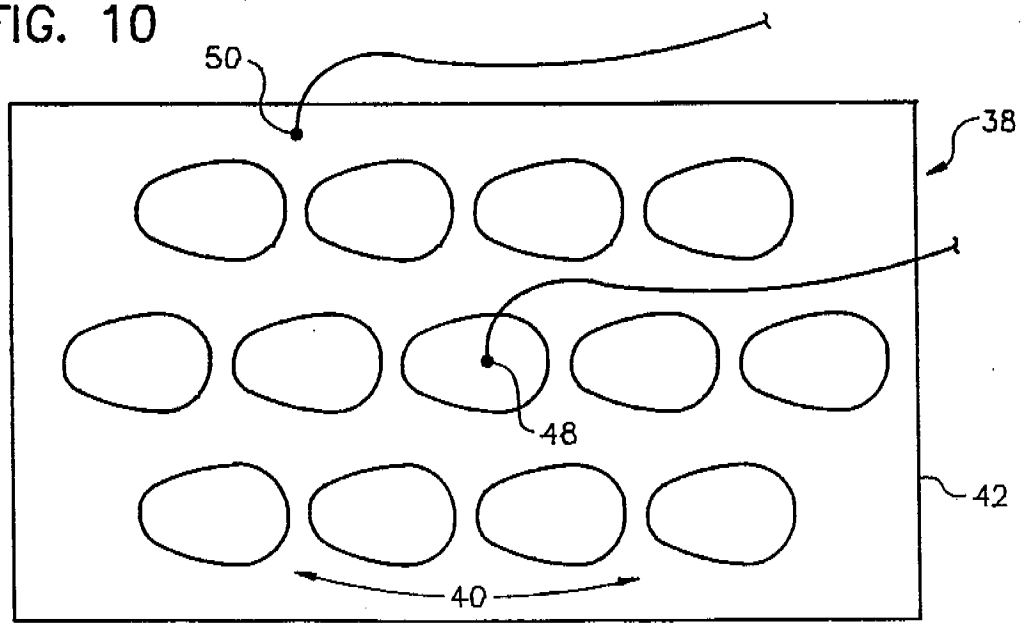
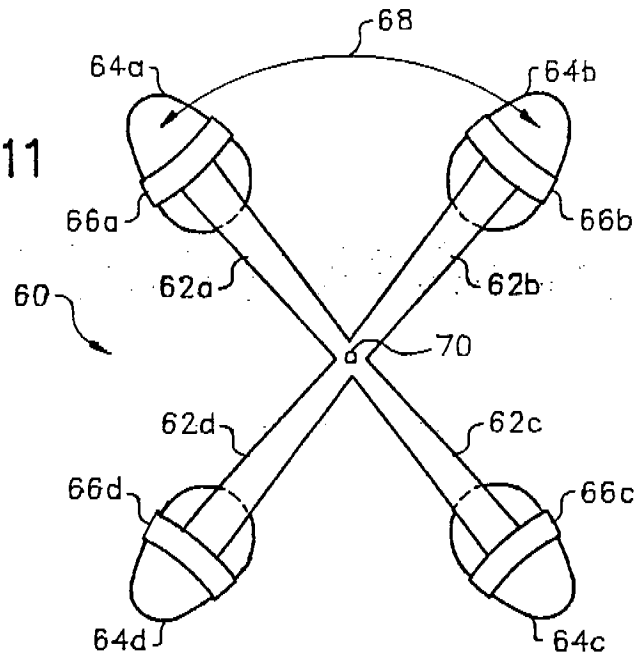


FIG. 11



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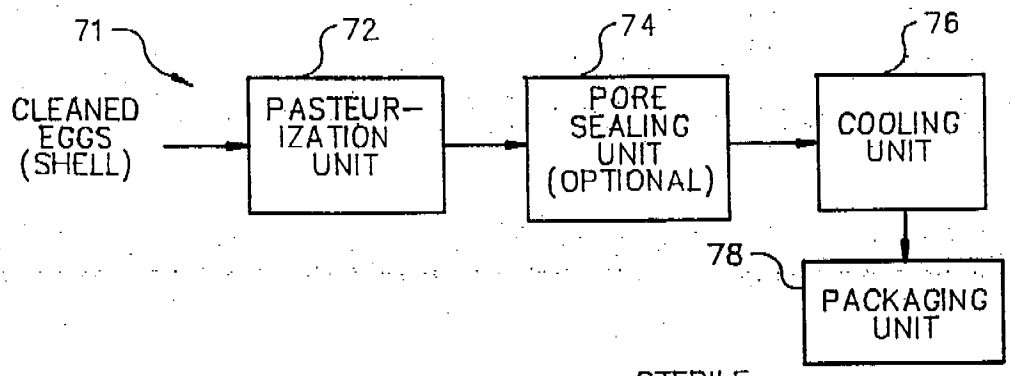
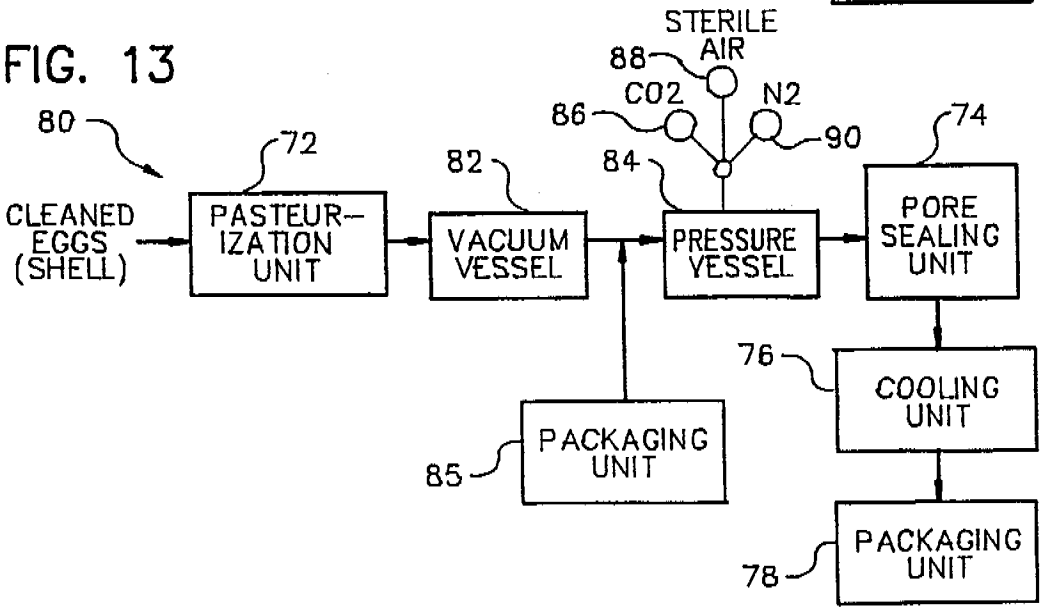
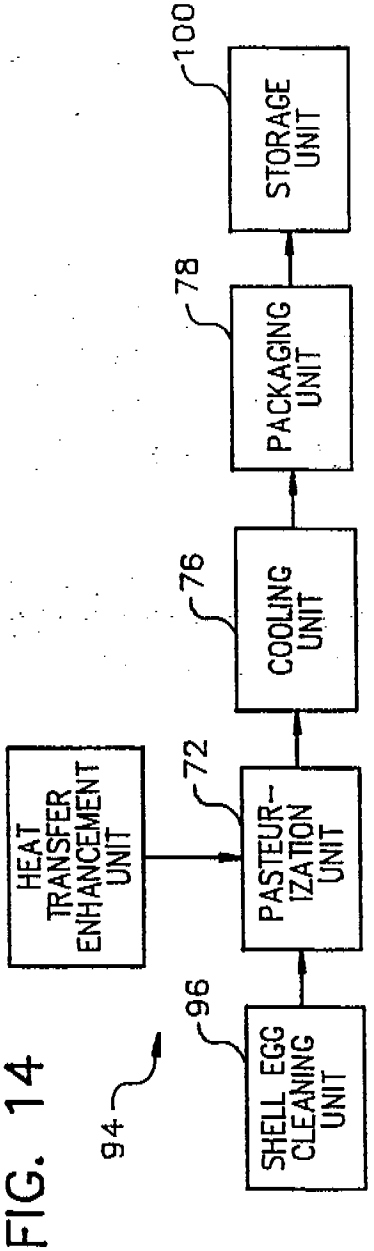


FIG. 13




94
96
SHELL EGG CLEANING UNIT
72
PASTEUR-IZATION UNIT
HEAT TRANSFER ENHANCEMENT UNIT
76
COOLING UNIT
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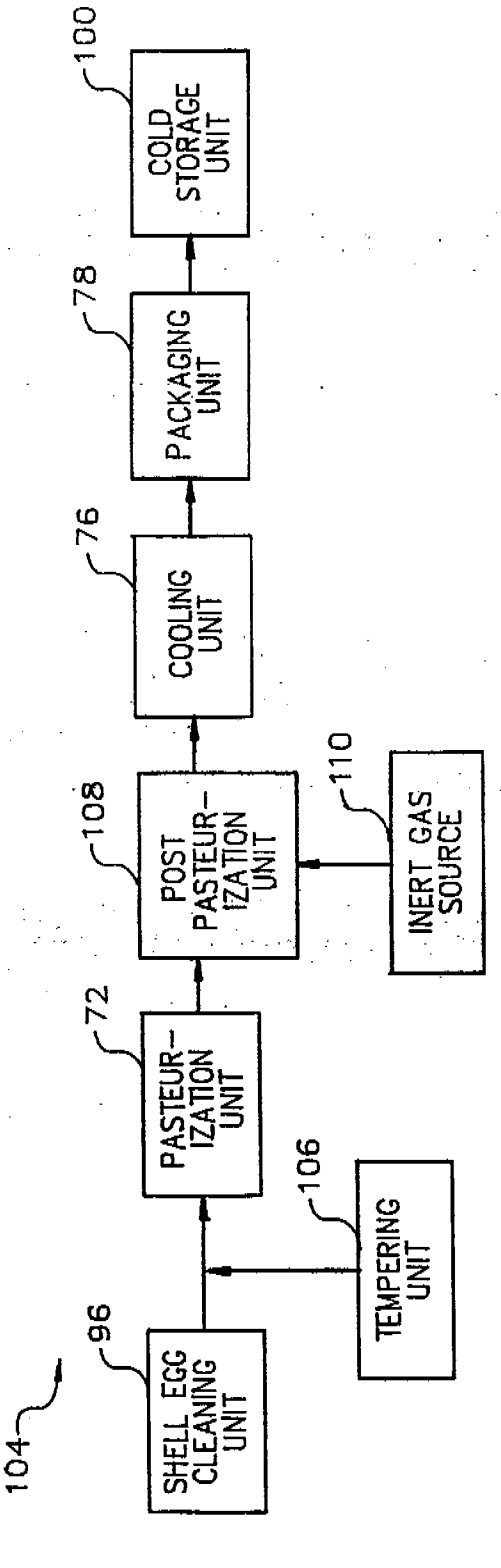
PACKAGING UNIT
100
STORAGE UNIT

FIG. 14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TEMPERING UNIT
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POST PASTEUR-IZATION UNIT
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INERT GAS SOURCE
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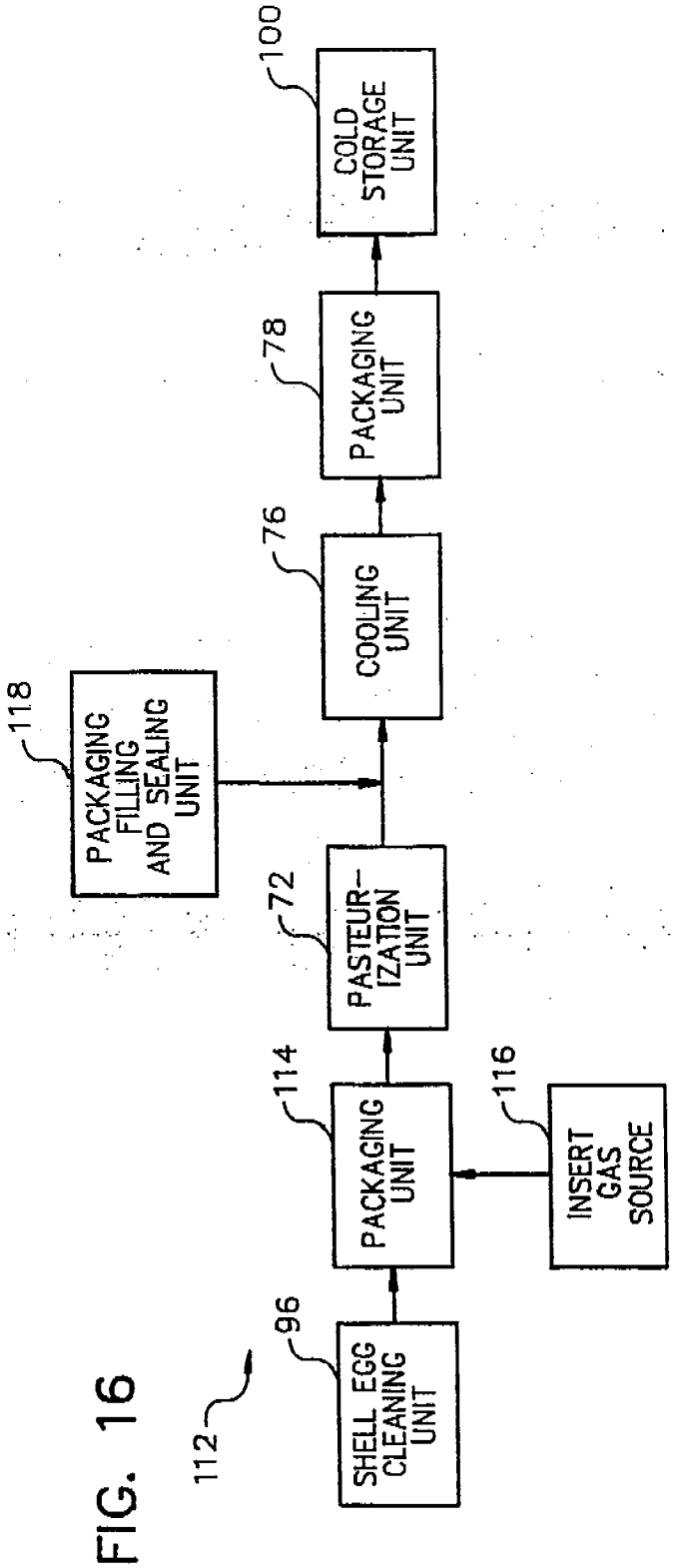
COOLING UNIT
78
PACKAGING UNIT
100
COLD STORAGE UNIT

FIG. 15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96
SHELL EGG CLEANING UNIT
114
PACKAGING UNIT
116
INSERT GAS SOURCE
72
PASTEUR-IZATION UNIT
118
PACKAGING FILLING AND SEALING UNIT
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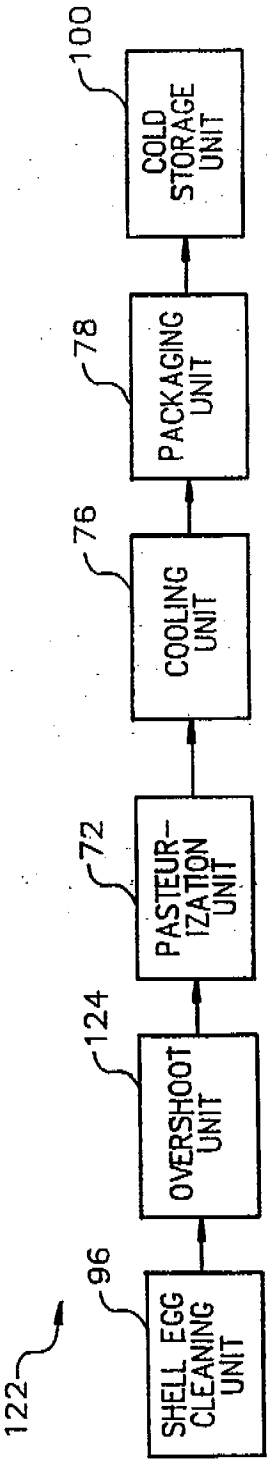
COOLING UNIT
78
PACKAGING UNIT
100
COLD STORAGE UNIT

FIG. 16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96
SHELL EGG CLEANING UNIT
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OVERSHOOT UNIT
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PASTEUR-IZATION UNIT
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COOLING UNIT
78
PACKAGING UNIT
100
COLD STORAGE UNIT

FIG. 17

METHODS FOR PROCESSING POULTRY SHELL EGGS

CROSS REFERENCES TO RELATED APPLICATIONS

This application is a continuation-in-part of U.S. application Ser. No. 07/746,940 filed Aug. 19, 1991. The parent application is a continuation-in-part of U.S. application Ser. No. 07/674,495 filed Mar. 25, 1991, now U.S. Pat. No. 5,283,076 which was a continuation of U.S. application Ser. No. 07/349,974 filed May 8, 1989, and abandoned, which was a continuation of U.S. application Ser. No. 07/196,878 filed May 19, 1988, and abandoned, which was a continuation of U.S. application Ser. No. 07/070,597 filed Jul. 8, 1987, and abandoned, which was a continuation of U.S. application Ser. No. 06/758,086 filed Jun. 24, 1985, and abandoned.

TECHNICAL FIELD OF THE OF THE INVENTION

The present invention relates to poultry shell eggs of overall improved food safety quality and to shell egg pasteurization methods with time and temperature process parameters equivalent to or exceeding those minimum standards established by the United States Department of Agriculture (USDA) for whole liquid eggs.

DEFINITIONS

Functionality or Functional Properties: Eggs contribute to the volume, structure, texture, and keeping quality of baked products. The coagulation of egg proteins during heating brings about the thickening of custards and pie fillings and the binding of pieces of food together as in loaves or croquettes. When eggs are whipped, the proteins form elastic films and incorporate air that provides the leavening and volume needed in such products as angel food cakes, souffles, sponge cakes, and meringues. The foam structure of these products is made rigid by coagulation of the protein during baking. The elasticity of egg protein films is also important in popovers and cream puffs; the protein films stretch when steam is produced during baking and later coagulate to form the framework of the product. Lipoproteins of the yolk are good emulsifying agents. They make it possible to disperse the oil in the other ingredients and thereby contribute to the consistency of mayonnaise and salad dressings and the structure of cream puff shells.

Whole eggs are used in sponge and layer cakes, bread, and rolls. Yolks are used in mayonnaise and salad dressing, sweet goods, doughnuts, and cakes in which more yellow color is desired. Whites are used in angel food cakes, meringue toppings, puff pastry, white pound cakes, layer cakes, cupcakes, certain candies, and a number of premixed products.

The extent to which the functional properties are affected by pasteurization is determined by testing the performance of the eggs under conditions in which damage is readily observed.

Pasteurization (or Pasteurization Process) Temperature: The temperature at which a pasteurization medium (air or other gas, water, oil, or other fluid, etc.) is maintained for an RPT such that a destruction of any infections present in an egg at least equal to that obtained by observing the minimum or protracted standards mandated by the USDA for liquid whole eggs is obtained on the shell of the egg and throughout and in the furtherest reaches of the egg interior including the egg yolk. Pasteurization temperatures range from 130° F. to a temperature approaching but less than 140° F. (<140° F.).

EqT: The point at which all particles throughout the mass of a shell egg reach equilibrium with the selected pasteurization medium temperature and the point at which RPT begins. EqT time is the time required to obtain EqT of an egg.

Real Process Time (RPT): That part of the TPT after all particles throughout the mass of a shell egg have reached a selected pasteurization temperature enabling the meeting of the U.S. Department of Agriculture standards for liquid whole eggs.

Total Process Time (TPT): That total length of time for which an egg is heated beginning with the egg at an initial preprocessing temperature and ending when the application of heat to the egg is terminated. TPT equals EqT time plus RPT.

Throughout the mass of an egg: encompasses all matter in the shell of an egg and within the shell.

Temperatures are often expressed hereinafter in the form xxx to yyy° F. (±z° F.). This is to be interpreted as a temperature range in which the lower limit is a nominal xxx° F. with a tolerance of ±z° F. and the upper limit is a nominal yyy° F. with a tolerance of ±z° F.

BACKGROUND OF THE INVENTION

For many years minimum food safety processing standards for various commodities have been promulgated and enforced by the United State Department of Agriculture. While long enforced for liquid whole eggs and egg products of a wide variety, based upon minimum standards of pasteurization processing, food safety standards have never been established for shell eggs. Indeed, as a review of the prior art identified in this specification has shown, there has not heretofore even been available technology for successfully pasteurizing shell eggs to acceptable standards, that is, to standards equaling USDA guidelines established for the other egg products mentioned above.

Shell eggs are an important commodity affording the consumer many nutritional advantages unparalleled by any other food product. These advantages include very favorable costs per nutritional unit of food value, convenience of preparation, gastronomic enjoyability, culinary usefulness, and availability.

It has long been known that some shell eggs contain infectious organisms such as *Salmonella* which, from a food safety standpoint, is of primary concern. Techniques for improving the food safety of shell eggs by destroying these infectious microorganisms have been proposed. However, aside from those effective for external sanitation, none are known to have ever been successfully employed. Instead, processing, handling, and other aspects of egg production have been emphasized in an effort to indirectly reduce the magnitude of the problem.

Awareness and concerns regarding infectious organisms in the yolk of a shell egg have been slow in developing. Both awareness and concerns have been amplified increasingly over the past decade as a result of numerous outbreaks of food poisoning irrefutably attributable to such yolk-associated organisms.

Advanced social programs and medical care have made a vastly enlarged percentage of the population dramatically more vulnerable to toxic effects of such food borne infec-

tions. At increased peril are those significant segments of the population of increased longevity or those who are immunocompromised due to organ transplants, immunosuppression therapies, and diseases caused by or causing compromised immune systems such as AIDS.

Increasingly, concerns over the safety of eggs consumed as a food illuminate the issue of transovarian infection developed deep inside the egg as it is formed in the oviduct. In addition, infectious organisms are known to penetrate the pores of shells and perhaps even the vitelline membranes of eggs, contaminating deeper proteins including the yolks. Also, for reasons not entirely clear, diseased hens are now known to excrete microorganisms inside the egg. The offending microorganism currently identified with this problem is *Salmonella enteritis* (*S. enteritis*).

Salmonella are small, gram negative, nonsporing rods. They are indistinguishable from *Escherichia coli* (*E. coli*) under the microscope or on ordinary nutrient media. All species and strains are currently presumed to be pathogenic for man.

As a disease organism, *Salmonella* produces a variety of illnesses depending on the species. *S. typhimurium*, which translates to "*Salmonella* from Typhus Mary", needs no other explanation. *S. typhi* causes enteric fever. *S. paratyphi* type A and type B cause a syndrome which is similar to but milder than typhus.

Reported cases of severe gastroenteritis (stomach flu) have implicated *S. bareilly, S. newport,* and *S. pullorum* as well. The mortality range is primarily based on the victim's age and general health. *S. choleraesuis* has the highest reported mortality rate at 21%.

S. senftenberg is reputedly the most heat resistant specie of *Salmonella*. It is reportedly destroyed at 130° F. (54.4° C.) after 2.5 minutes. It is estimated that *S. senftenberg* 775W is 30 times more heat resistant than *S. typhimurium*. Turkeys (10 to 11 lbs.) inoculated with 115,000,000 microorganisms of *S. pullorum* required holding at an average internal temperature of 160° F. (71.1° C.) for four hours and 55 minutes before the bacteria were destroyed.

Over 2,000 other species of *Salmonella* are known. The number increases yearly.

Among the most common vehicles for food poisoning caused by Salmonella are eggs. Widespread publicity on illnesses and deaths attributed to contaminated eggs containing *S. enteritis* in Europe over the past few years has reportedly resulted in a reduction in egg consumption. In some distinct marketing areas the reduction has been estimated to be as great as 50 percent. The problem is being perceived in Europe and in the United States as chronic, spreading, and a major public health challenge. Nevertheless, in the United States alone, approximately 240,000,000 dozen eggs are still consumed annually.

A recent article in the Nutrition Action Health Letter published by the Center for Science in the Public Interest (July/August 1991 edition, Volume 18, number 6, "NAME YOUR (FOOD) POISON") relates a current trend of growing concern. The article reports that, according to government estimates, 80,000,000 cases of food poisoning yearly result in about 9,000 deaths and several billions of dollars in health costs.

The article claims that the primary causative foods are, in order: dairy products, eggs, poultry, red meat, and seafood.

The article reports that 1 in 10,000 eggs is contaminated with *Salmonella enteritis*. The average American consumes about 200 eggs per year. If your egg consumption is average, your chance of downing an egg contaminated with one or more species of *Salmonella* is 1 in 50; or, put another way, it is likely that you will eat four contaminated eggs this year.

If you are over 65 or have a disease such as cancer or AIDS associated with a weakened immune system, the article advises: don't eat raw eggs; don't drink egg nog; don't eat Caesar salads, home made mayonnaise, ice cream, or "health" drinks that call for raw eggs. Cook all eggs thoroughly—solid white and yolk.

Compounding the contamination problem is the improper handling of eggs in institutional and even home settings. Often cited is the all too frequent observation of eggs setting out at room temperature for long periods of time in institutional kitchens. Such unknowledgeable treatment promotes bacterial advancement in even the freshest egg.

Little is known about virology inside the egg. It has long been and is still believed by some that shell eggs are sterile inside the shell. Needle puncture samples of the inside of an egg including both yolk and white taken under aseptic conditions usually do demonstrate a negative plate count when cultured. Nevertheless, it is well known that, when eggs are broken in quantity, they immediately demonstrate significant gross populations of infectious microorganisms. It is not unusual to find plate counts ranging from several hundred to many thousands, even when the surface of the egg shells have been cleaned of filth and washed in the best antiseptics known to food science. The occurrence of *S. enteritis* inside the shell egg is now also well documented.

One source of infection arises from the fact that egg shells have numerous pores which permit the egg to breathe. Pore holes vary in size. When the egg is laid, those holes come into contact with organic refuse in the cage. It is very likely that some microbes contacting the egg are of a size which allows them to fit through the pores. Once inside, the microbes are not uniformly spread around the interior of the egg but are retained in small patches on the inner shell membrane, which has yet smaller pores than the shell.

Washing actually spreads microbes more evenly, increasing contamination through greater surface contact with entry pores in the egg shell. When the eggs are cracked, the shell membranes may be ripped and torn loose. And, when the shells are subsequently emptied, the eggs may be peppered with this stored inoculum in addition to airborne bacteria.

Also, as egg temperatures vary, there is active and ongoing gas and vapor exchange between the yolk and white via the vitelline membrane, between the white and the inside of the shell via the outer and inner shell membranes, and also between the shell and the outside environment. Airborne microorganisms can also reach the interior of the egg through these mechanisms.

Finally, as discussed above, eggs can be, and frequently are, contaminated by transovarian infection. The extent of this problem is still not known. Thus, an egg may be unsafe to eat even if there is no transport of harmful microorganisms from the exterior of the egg to its interior. Worse yet is when both of the egg infecting mechanisms—pore penetration and transovarian infection—are at work.

U.S. Pat. No. 4,808,425 issued Feb. 28, 1989 to Swartzel et al. elaborates on the USDA standards for pasteurizing liquid eggs, summarizes the disclosures of many references, identifies resources relative to egg pasteurization, and adequately points out many of the problems associated with available techniques for making liquid but not shell eggs of safer food quality. Swartzel et al. employ a conventional pasteurization technique—time at temperature—to treat liquid egg products. The products are contacted against a

heated surface at high temperatures; i.e., above 140° F. (60° C.) for short durations of less than 10 minutes. This approach is not applicable to a shell egg.

The minimum time at temperature processing mandated by USDA standards produces liquid eggs which are safe to eat because all particles have been exposed to RPT; and, if the liquid eggs are carefully processed, an at least acceptable degree of functionality and other valued properties can be retained. Standards for shell eggs are lacking because, up to now, a reliable time at temperature technique for making shell eggs safe to eat has not existed. In particular, there is not known to exist any effective process which can be employed to process whole eggs to the standards mandated for liquid eggs; i.e., to ensure that all particles throughout the mass of the egg—which includes the shell, the outer shell and egg membranes, the albumen layers or egg white, the chalaza, the vitelline membrane, and the yolk to its innermost reaches or center—are exposed to appropriate temperatures for times adequate for an acceptable kill of any harmful organisms that might be present.

Other researchers have focused their attention on time and temperature treatments for devitalization of vital shell eggs. To a much lesser extent, pasteurization of shell eggs to improve food safety quality has been considered.

Funk (Stabilizing Quality in Shell Eggs, Missouri Agricultural Experimental Station, Research Bulletin no. 362 and Maintenance of Quality in Shell Eggs by Thermostabilization, Missouri Agricultural Experimental Station, Bulletin no. 467) and Murphy and Sutton (Pasteurization of Shell Eggs to Prevent Storage Rot and Maintain Quality—a Progress Report of Experimental Work, Misc. Publication no. 3317, Department of Agriculture, New South Wales, Australia) purported to preserve shell eggs by briefly heating the eggs for 15 or 16 minutes at temperatures ranging from 130° to 135.9° F. (54.4° C. to 57.7° C.) and from 129.2° to 136.4° F. (54° C. to 58° C.). Irrespective of the starting temperature of the shell egg to be processed, these prior art processes cannot possibly provide a *Salmonella* free or *Salmonella* reduced inner egg. Neither can they achieve equivalents of the minimum requirements established by the USDA for processing liquid whole eggs.

The growth of external food poisoning infections are in some of the TPT/temperature ranges provided favorably influenced in the outermost layers of the shell egg. In many other ranges, external food poisoning infections will be significantly worsened. In all cases, temperatures near and at the egg yolk center never achieve the minimum temperature needed for a time effective to kill significant concentrations of infectious microorganisms.

On the contrary, because the internal temperatures reached near or in the center of the yolk are not high enough to destroy *Salmonella* and other infectious microorganisms, these prior art techniques, irrespective of how employed or combined, cannot meet accepted minimum standards for other egg products and by and large can only attain temperatures in the yolk within the times suggested which are in a range that will cause substantial increases of any food poisoning infections present therein. Within a very narrow range of those parameters, processed eggs may or may not become more infected. In all other instances a shell egg carrying a minor, non-lethal infection in the yolk can by use of such methods deteriorate markedly and become a very significant health risk, if not a toxic food.

In his U.S. Pat. No. 2,423,23 issued Jul. 1, 1947, Funk is concerned principally with "sterilizing or devitalizing" embryos in vital shell eggs. Confusingly, Funk ambiguously and interchangeably uses the term sterilization, stabilization, devitalization, and pasteurization in describing this objective. Funk claims that poultry eggs can be pasteurized, stabilized, and devitalized of embryonic life by immersing freshly laid, room temperature eggs in oil or water at temperatures ranging from 110° F. to 145° F. (43.3° C. to 62.8° C.) for times ranging from five to forty minutes or presumably, in the alternative, from 110° F. to 145° F. for from forty to five minutes.

Funk did not account for the fact that infectious microorganisms such as *Salmonella* are to be found throughout and in any or all specific parts of an egg, such as the yolk, whites, and membranes and even at the center of the yolk. Funk is principally concerned with devitiating the shell egg embryo and only with "destroying bacteriological organisms which may have penetrated the egg shell and . . . extended even so far as the yolk . . . ." He did not disclose in his patent or take into account the fact that the time required for processing a shell egg to make it safe to eat at specified temperatures is one thing for the outer, non-yolk portion of a shell egg and quite another for the center of the yolk. The result is that most of the process conditions claimed by Funk only result in conditions which at best can not meaningfully improve any preexisting infectious condition and at worst are certain to significantly increase health hazards from food poisoning infections. As applied to a shell egg, Funk cannot achieve even the minimum USDA processing standards (see FIG. 2) for liquid egg products. Use of other time/temperature combinations embraced by the broad statements in the Funk patent (which also cannot meet the minimum processing standards referred to above) result in the whites of the eggs being visibly cooked (see FIG. 8).

The Funk process parameters are temperature and TPT. As defined above, this is the total time a shell egg is held in a pasteurization medium heated to a selected pasteurization process temperature. This is quite different from the critical RPT, which is that portion of TPT in which all particles throughout the mass of the egg including those at the center of the yolk are at an effective pasteurization temperature measured from the point at which EqT is reached. There is no evidence that Funk recognized or appreciated the criticality of the difference between TPT and RPT. Even if he had, he presumably would not have made this distinction because, for purposes of devitiating an egg embryo, TPT and RPT are one and the same; i.e., there is little or no difference between these two process temperature conditions in pasteurizing, devitalizing, and sterilizing whole eggs to retard spoilage by making viable eggs infertile; i.e., by preventing ongoing embryonic development.

Lethal thermal damage to any part of an embryo, even only at its surface, is adequate for this purpose. Unlike the embryos in vital eggs, infections are composed of a multitude of micro-entities. Lethal damage at some point to a portion of this multifarious milieu is not adequate to destroy the infection as is the case with an embryo which may be killed if even a small part is heated to a high enough temperature. To be effective against infections frequently scattered throughout a substrate, the time at temperature must be adequate to kill large numbers of infectious organisms at these widely scattered locations. In a shell egg, that means that the pasteurization temperature must be reached and maintained for the necessary time throughout all parts of the egg containing the microorganisms. In this case, TPT and RPT are distinct; the distinction becomes increasingly critical as that mass of the egg which is potentially infectable is increased.

Funk's statement of process parameters for the devitalization of an egg embraces many time and temperature

combinations which may be effective to achieve that object. However, when employed to kill food borne infections, those time and temperature combinations which apply to embryonic devitiation cannot adequately kill *Salmonella* or other harmful bacteria commonly found in eggs for reasons just discussed. The unfortunate fact is that most of those time/temperature combinations embraced in Funk can only significantly increase contamination inside the egg because they for the most part result in the egg being under conditions near to or optimal for maximum bacterial growth. An example is Funk's own preferred pasteurization parameters—five to ten minutes TPT at 138° F. (58.8° C.) and twenty to forty minutes TPT at 130° F. (54.4° C.).

Funk's preferred "pasteurization" method for a shell egg never achieves any RPT at the yolk but does achieve active growth range conditions there over a significant period of time. If the initial temperature of the shell egg is significantly lower than 70° F., as is or should always be the case in real world processing, Funk's preferred conditions will more seriously fail, resulting in dramatically favored conditions likely to increase any food poisoning infection present in the yolk.

Funk's preferred "pasteurization" process times and temperatures are not the worst cases suggested to one of ordinary skill in the art by his patent. Indeed, when many, if not most, of the Funk times and temperatures provided for pasteurization, sterilization, and devitalization of vital egg embryos are applied to the "pasteurization" of shell eggs to improve food safety quality, the results as confirmed by tests always fall short of and are often contrary to that objective. Moreover, as measured at the yolk, eggs processed pursuant to the most favorable possible conditions specified by Funk cannot meet the process standards provided in the USDA Protracted Whole Egg Standard for Liquid Whole Eggs (see FIG. 1) or even the minimum standards mandated by the USDA for liquid whole eggs (see FIG. 2).

For example, take a shell egg infected superficially at the inner shell surface (not uncommon) and also in the yolk (estimated to occur in 1 out of every 10,000 eggs). Pasteurize that egg according to Funk's specifications: from 40 minutes at 110° F. to 5 minutes at 140° F. At the lower temperature/longer time—40 minutes at 110° F.—the superficial temperatures even at the inner surface of the shell can be expected to promote the growth of bacteria and result in substantial worsening of any food poisoning infections present. Those temperatures achieved near or at the yolk center could reach but would never exceed the optimal growth conditions for food poisoning infections of *Salmonella*. The result, if infections were present, could easily be catastrophic increases in food poisoning concentrations. At shorter times and higher temperatures such as 134°–136° F., the temperature of an infected yolk center would never exceed about 125° F., yielding only eggs with increased food poisoning potential.

If the above-discussed time/temperature relationships are reversed—5 minutes at 110° F. to 40 minutes at 140° F.—as is equally reasonable from Funk's claim 1 and other statements in his patent, the low temperature/short time relationships constitute what could reasonably be selected as optimal by a bacteriologist to best culture Salmonella in eggs as a growth medium. At the other end of the spectrum—the extreme high temperature/long time combination of 140° F. for 40 minutes—, the "pasteurized" eggs would be "hard-boiled" in at least the exterior layers. All inbetween permutations of Funk conditions are ineffectual at best to meet even the minimum processing conditions required by the USDA for liquid whole eggs as shown in FIG. 2.

At the same time, even starting with shell eggs already at 70° F., let alone at more realistic, lower, cold storage temperatures, shell eggs processed according to Funk in the near extreme regime (>139° F./39.2 to 40 minutes TPT) will never achieve the RPT near or at the egg center needed to meet the basic protracted USDA temperature/time regimes for liquid whole eggs. To make matters worse, when shell eggs are immediately immersed into liquid at extreme temperature differentials (greater than about 65° F.–70° F.) as they could well be in following Funk's teachings, a significant number will crack. Cracked eggs are a loss. They are difficult to handle, unmarketable to consumers and other purchasers of whole eggs, and exceptionally susceptible to contamination.

In short, by even the most generous interpretation, no obvious combination of Funk's sterilization, devitalization, or pasteurization temperatures and times (from 110° F. to 140° F. for 5 to 40 minutes or from 110° F. to 140° F. for 40 to 5 minutes) can achieve even the minimum, FIG. 2 USDA process standard for liquid whole eggs without "cooking" at least the egg whites to some extent; and this is unacceptable because of consumer rejection and resulting loss of functionality. It is more likely, because it is true in the large majority of the available time/temperature combinations, that the Funk process would, if the egg being processed is infected at the yolk and/or superficially on the shell's inner surface, increase rather than decrease, perhaps dramatically, any food poisoning hazard present. The process would surely promote the growth of or at best substantially leave unaffected any harmful microorganisms present in the egg.

Application of the Funk process to eggs almost certainly results in eggs dependably rid of a living embryo. But with respect to pasteurization designed to improve food safety of shell eggs and with the questionable exception of a few time and temperature combinations effective to reduce superficial inner shell infections, Funk's process is only likely to produce infected shell eggs which remain or are made more hazardous to consumers and/or which are visibly partially cooked at the outer layers.

New serotypes of infectious organisms continue to develop. Increased production, mass handling, and widespread distribution of food products continue to increase the risks of food poisoning. Food poisoning incidents related to eggs are not uncommon and may even be increasing. Almost all food products have well developed standards of processing for ensuring food safety. With respect to eggs and egg products, only shell eggs have no standards for pasteurization. The primary reason for this lack of food safety pasteurization standards as required for all other egg products is undoubtedly attributable to the lack of knowledge of an efficacious process for making shell eggs safer to eat. In practice, known processes such as the one discussed above and proposed by Funk are inefficacious and either fail completely to achieve any meaningful benefits or are highly likely if not certain to result in products with substantially increased health hazards from food poisoning.

SUMMARY OF THE INVENTION

Now discovered and disclosed herein are novel, practical methods for temperature and time pasteurization of a shell egg throughout its entire mass with a degree of effectiveness equaling or even exceeding that obtained by employing the USDA minimum and protracted standards for liquid whole eggs, thereby reducing to an acceptable level the possibility that the subsequent ingestion of the processed egg might

cause food poisoning, typically an illness consisting of gastroenteritis and fever lasting for several days but a deadly threat if a person in one of the susceptible categories identified above is infected. At the same time, these novel shell egg pasteurization techniques do not unduly compromise the integrity, functionality, or quality of the egg.

Process temperatures capable of producing this significant advantage for commercial size eggs (54 to 68 grams) with an initial, pre-pasteurization temperature of 45° F. or higher are those in the range of from about 130° F. to near, but less than, 140° F. Temperatures substantially above 139° F. are not useful because: (1) the egg will in too many instances crack upon being subjected to pasteurization, and/or (2) whites will begin to visibly cook before the egg yolk pasteurization temperature at the center of the egg yolk has been achieved, let alone maintained long enough to meet pasteurization standards equivalent to those mandated by the USDA for liquid eggs. At temperatures below the specified minimum, *Salmonella* and other harmful microorganisms including molds, other bacteria, and even viruses are not effectively killed and may even thrive.

Process times employed at the temperatures just identified in the novel pasteurization processes disclosed herein to meet minimum requirements equivalent to those mandated by the USDA for liquid eggs range from a minimum RPT of about 50 minutes at 130° F. to a minimum RPT of about 4.50 minutes at 139.5° F. The time/temperature parameters taken into account include these factors: (1) the temperatures achieved by all particles in and throughout the mass of a shell egg; the time for which all particles are held at that temperature; and the average time that every particle is heated, assuring that each particle is subjected to at least the minimum conditions needed to guarantee effective pasteurization; (2) the minimum-to-maximum process parameters which will avoid or minimize adverse changes in appearance and performance vs. maximum kill of infections; and (3) the attainment of conditions needed to provide the equivalent of the minimum USDA mandated pasteurization standards for liquid whole eggs.

The initial egg temperature at the beginning of the pasteurization processing of whole shell eggs may range from a low of about 38° F. to a high of about 60° F. with a probable average year around temperature of about 55° F. The average preprocessing temperature should be somewhat lower than 45° F. for whole shell eggs destined for consumer distribution.

Effective pasteurization in accord with the principles of the present invention requires that the preprocessing starting temperature be known. This temperature is used to determine TPT. As suggested above, TPT has two components, EqT time and RPT, with EqT time being the time required for an egg to reach equilibrium with the temperature of the pasteurization medium throughout its mass and especially in its most thermally inaccessible portions such as the center of the yolk. Only after EqT is achieved can RPT, the time at a selected pasteurization process temperature equivalent to that mandated for liquid whole eggs, begin. Once the center of the shell egg is at the selected pasteurization temperature, the egg is processed at USDA-mandated temperatures and times to ensure time-at-temperature compliance at the center of the shell egg yolk with at least the minimum USDA standards for liquid whole eggs. This ensures that, completely throughout its mass, the egg is maintained at a temperature high enough to effect the destruction of harmful bacteria for a time long enough for that goal to be realized.

Examination of FIG. 2 shows the following minimum temperature/time requirements for liquid whole eggs, and those parameters may be applied equivalently to shell eggs once the selected pasteurization temperature has been achieved at the shell egg yolk center. The same data appears in tabular form in Table 1. In each instance, the indicated time is the minimum RPT needed for an acceptable or better kill of harmful microorganisms at the corresponding temperature.

TABLE 1

Temperature		Required RPT (min)
130° F.	(54.4° C.)	= 65
131° F.	(55.0° C.)	= 49
132° F.	(55.6° C.)	= 38
133° F.	(56.1° C.)	= 28
134° F.	(56.7° C.)	= 20
135° F.	(57.2° C.)	= 16
136° F.	(57.8° C.)	= 11
137° F.	(57.8° C.)	= 8
138° F.	(58.9° C.)	= 6
139° F.	(59.4° C.)	= 4.75
140° F.	(60.0° C.)	= 3.5

When the Table 1 pasteurization time and temperatures are applied to shell eggs, additional, EqT time must be allocated from the time the egg is placed in a heat transfer or pasteurization medium maintained at the desired pasteurization temperature in order for the center of the yolk to achieve EqT—the initial point of RPT and the point at which the egg reaches temperature equilibrium with the heat transfer medium. The RPT for a given pasteurization regime can only begin after this point has been reached and heat has been transferred through the external portions of the shell egg into the center of the yolk such that the temperature at the yolk center and at every other locus throughout the mass of the egg has reached equilibrium with the process medium.

The total time for the entire egg to come to equilibrium with the process medium or reach a predetermined effective process temperature, EqT, added to the real processing time, RPT, as set forth in FIGS. 1 and 2 and Table 1 equals the total processing time, TPT.

Among factors determining the time required to reach EqT are egg size, the preprocess temperature of the egg, and the selected pasteurization process temperature.

For purposes of achieving heat transfer through the shell to the interior of an egg, one liquid (oil, water, glycol or the like) will work about as well as another provided, of course, that the liquids are safe for this use. A gas such as air, humidified air, or air mixed with gases such as carbon dioxide or nitrogen can be used as a pasteurization medium but is not preferred for heating eggs to EqT. Such gases may be used for the RPT phase of the pasteurization process or for TPT processes which involve both EqT and RPT phases. However, for RPT steps, liquids are also usually preferred. The just-identified gases are frequently preferred for tempering, a technique described in detail hereinafter and optionally employed to ensure efficacious pasteurization of eggs in processes employing the principles of the present invention.

It is not uncommon for eggs in a process lot to be at different temperatures. The ignoring of this significant condition can lead to the selection of inappropriate EqT, RPT, and/or TPT time and temperature combinations. Those parameters providing effective, if not optimal, pasteurization of eggs at one initial temperature may result in the cooking of the whites of eggs at a higher initial temperature. Conversely, if the process batch contains eggs with a lower initial temperature, those eggs may not be subjected to the

minimum RPT for the selected pasteurization temperature specified in FIG. 2 and Table 1.

Tempering may be employed in accord with the principles of the present invention in instances where disparity in initial egg temperatures is evident or even suspected to eliminate the problems the temperature disparity may cause. Tempering is an initial or pre-processing step in which the eggs are held at a sub-pasteurization temperature long enough for the eggs to all come to the same temperature. This promotes uniformity of results in the subsequent pasteurization of the eggs, significantly reducing or even eliminating the likelihood of there being eggs with cooked whites and/or insufficiently pasteurized eggs at the end of the pasteurization process. Tempering can also be employed to reduce, if not eliminate, thermal shock cracking of the eggs being processed.

Tempering can be carried out in air and other gases. The gas can be dry air or air humidified to prevent evaporative losses of water from the egg during tempering, a phenomenon that is preferably avoided because of the weight loss suffered as an egg dries. An alternative, if the pasteurization process medium is not water, is to add water to that medium to make up evaporative losses during pasteurization by restoring water lost from the egg by evaporation.

The shortest effective tempering times are preferred. It is undesirable to hold the egg at any temperature which favors microorganism growth for any longer than necessary; and the tempering temperature might be one of that character.

The basic shell egg pasteurization process takes into account process steps and factors other than those identified above such as: (1) a normal range of egg sizes at any normal ambient preprocess temperature, tempered or untempered, packaged or unpackaged, or coated; (2) liquid and gas or fluid processing; and (3) the use of turbulence or vibration to promote the transfer of heat into the eggs. The process preferably employs primary pasteurization parameters of >134.5° F. to <139.5° F. (± ca. 0.3° F.) for a TPT of from about 23 to about 56 minutes or, for maximum TPT, pasteurization process temperatures of 130.1° F. to 134.6° F. (± about 0.3° F.) for TPT's of from about 46 to about 345 minutes.

Preferred TPT's and pasteurization temperatures for eggs weighing between 35 and 90 gms and at a normal preprocess temperature between 40° F. and 70° F. are 138° F.±1.5° F. at 44±about 8 minutes. Preferred TPT's for eggs weighing between 50 and 80 gms at preprocess temperatures between 45° F. and 55° F. for pasteurization temperatures of 138° F.±0.75° F. are about 44±5 minutes. These time and/or temperature ranges are modified, using test data and routine trials, when intermittent temperature pasteurization as described in succeeding paragraphs of this specification is employed.

There are important versions of the invention in which heating of the egg is accomplished in stages with one or more of the heating steps being followed by a dwell time in which the temperature equilibrates throughout the interior of the egg.

Another, somewhat similar approach is pasteurization in stages with substantial dwell times between the stages. Tests have demonstrated that pasteurization within the ranges of time/temperature parameters described above followed by a second pasteurization treatment may be synergistically effective to provide longer shelf lives.

Because of the virtually unlimited number of options this offers, it is impractical to list the parameters for each and every option. Furthermore, this is unnecessary; the parameters appropriate for a particular option employing intermittent or discontinuous heating can be readily and routinely determined because the critical criteria are known. Specifically, the pasteurization temperature and RPT must be such that, at the end of the pasteurization process, all particles throughout the mass of the egg will have been heated at the selected pasteurization temperature for an RPT equivalent to at least the minimum mandated by a USDA Standard for liquid whole eggs (FIGS. 1 and 2 and Table 1).

Like pasteurized eggs and egg products, a shell egg processed by time-at-temperature pasteurization will typically suffer some diminution of overall sensory properties and some loss of functionality. Generally, in processing shell eggs in accord with the principles of the present invention, any quantitative changes resulting from implementation of the invention under the less extreme process conditions are not noticeable by a consumer of average sensitivity. Under extreme conditions, such as pasteurization at a temperature of 131° F. for 100 to 240 minutes, products which may have some average-consumer-noticeable differences may be produced. For example, a shell egg processed by the foregoing regime will have what appears to be a larger yolk than a control. This is thought to be due to egg lipids thinning and running under the prolonged influence of the process heat, thereby exerting greater hydraulic pressure against the vitelline membrane which contains the yolk matter. The membrane is comprised of protein and consequently can relax and stretch. This condition does not correct itself when the egg is cooled to ambient or to refrigeration temperatures. Without the control for comparison, the enlarged yolk may be noticeable only because it will lay flatter in a pan than a non-pasteurized egg, for example.

While possibly inconvenient, this consumer noticeable fault is minor when compared to the improved food safety of the egg. Nevertheless, more moderate or optimal process conditions such as pasteurization at 138° F. for about 40 to 46 minutes TPT will typically be employed. This yields products which are superior in that they are difficult to differentiate from controls in any qualitative factor.

As with pasteurized liquid whole eggs, some loss of functionality in an egg processed in accord with the present invention will be noticed by a baker. However, the difference can usually easily be made up by small increases in the total amount of egg that is used. This potential diminution of functionality is more than offset by the improved food safety.

TPT may be reduced by introducing turbulence into the pasteurization medium and/or by subjecting the shell eggs to mechanical vibration. Both of these mechanisms—a turbulent pasteurization medium and the application of vibrational energy to the egg—increase the rate of transfer of heat from the pasteurization medium to the interior of the egg. Thus, while not essential, the utilization of turbulence and vibration can result in more effective treatment regimes. A turbulent pasteurizing medium or vibration of the egg should be used where the additional benefits of quicker, more effective processing are desirable.

Ultrasonically induced and other forms of vibration including those produced by cavitation may also be employed to advantage in the microorganism destroying treatment. Such vibration, like that of the mechanical variety, promotes the transfer of heat through the shell and throughout the mass of the egg. This enhances process effectiveness, ensuring more efficient reduction of infectious microorganisms.

Other, advantageous process techniques are deliberate overshooting of the selected treatment temperature when the

egg is initially heated and the pulsing or alternating of the treatment temperature between two different levels.

Heating shell eggs and subsequently holding them at selected temperatures for an appropriate time to effect pasteurization is preferably followed by rapid cooling (or quenching) of the treated eggs. This final step ensures that, as they are cooled, the treated eggs pass rapidly through that portion of the temperature spectrum favoring bacterial growth. If quick cooling is not employed, any remaining harmful bacteria may multiply and negate some or all of the effects of the time-at-temperature treatment, especially if the eggs are allowed to remain for any significant time in a temperature zone favoring microbial growth. For this reason, natural cooling of treated eggs to ambient conditions or even cold storage conditions can allow new growth of any remaining unkilled microorganisms to occur.

Even rapid cooling can have serious drawbacks since microorganisms in the ambient environment of the treated eggs can recontaminate the egg surface and be drawn back inside through shell pores by negative pressure generated inside the shell as the egg cools. Therefore, the more rapid the cooling, the cleaner the environment, and the more sterile the cooling environment, the better.

The best possible way to avoid recontamination of the pasteurized eggs by contact with organisms in the ambient environment, by handling, and by other mechanisms is to package the egg in an impervious film or other package prior to cooling. Examples of appropriate films and package materials are those fabricated of polyethylenes and polyvinylchlorides. Other acceptable packaging which can be used to prevent recontamination includes composite films and readymade, food approved proprietary packaging such as Cry-O-Vac®, Seal-A-Meal®, and the like.

The egg may be processed in the package and the package aseptically sealed after processing, but before cooling; or the package may be sealed prior to pasteurization processing, this being followed by cooling to ambient or a refrigeration temperature. Among the advantages of processing the egg in packaging is that no recontamination can occur during steps requiring cooling or handling. The packaging of eggs before processing, particularly by the dozen or in the other multiples, offers many other advantages including the ability to use modified atmosphere gases such as carbon dioxide, nitrogen, and mixtures as a package filler to: prevent spoilage; reduce breakage during processing; make handling, the automation of production, and standardization of egg moisture levels easier; and facilitate the addition and the diffusion into the egg of process aids such as organic acidification agents including citric, lactic, benzoic, and ascorbic acids, to name but a few. Eggs processed in individual packaging may be slipped into more-or-less standard egg cartons while packages in which eggs are processed in multiples may be wrapped or placed in cardboard sleeves to present the packaged appearance commonly expected by the consumer.

Packages may be filled with carbon dioxide, nitrogen, or a carbon dioxide/nitrogen mixture before pasteurization or after pasteurization and before cooling and then sealed. Upon cooling in the sealed package, the gas will be drawn in through the pores in the egg shell and the shell and vitelline membranes to provide a stabilizing, deterioration inhibiting gas inside the egg.

Storage at acceptable elevated temperature for short durations can be used to effectively pasteurize eggs. Critical parameters for such storage pasteurization are temperatures of ca. 131° to 135° F. (±1° F.) for from about 42 minutes to as long as 390 minutes using water—e.g., in the form of a spray—as a heat transfer medium. Very high humidity air; i.e., air with a relative humidity ≧85% can also be employed as a heat transfer media with the process times then ranging from about 50 minutes to 400 minutes. Prepackaging of the eggs before processing is preferred in this type of pasteurization process due to the many advantages heretofore mentioned.

The important objects, features, and advantages of the invention will be apparent to the reader from the foregoing and the appended claims and as the ensuing detailed description and discussion proceeds in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a chart depicting the USDA Protracted Whole Egg Standard for pasteurizing liquid whole eggs;

FIG. **2** is a chart showing the minimum conditions mandated by the USDA for pasteurizing liquid whole eggs and other liquid poultry egg products;

FIG. **3** is a pictorial cross-section through a whole, uncooked, poultry, shell egg;

FIGS. **4–8** are charts showing the temperatures reached after TPT's of zero to 120 minutes at the center of shell eggs processed in water baths with temperatures of 138°, 132°, 134°, 136°, and 140° F.;

FIGS. **9** and **10** are diagrammatic side and plan views, respectively, of one system which can be employed to pasteurize process poultry shell eggs in small lots in accord with the principles of the present invention;

FIG. **11** is a diagrammatic view of one representative device that can be employed to mechanically vibrate whole shell eggs pasteurization processed in accord with the principles of the present invention in order to increase the rate of transfer of heat to the centers of the eggs and, in some cases, to scramble the eggs in their shells;

FIG. **12** is a schematic view of a second system for processing whole shell eggs for improved food safety in accord with the principles of the present invention; and

FIGS. **13–17** are schematic views of five other systems for processing whole shell eggs in accord with the principles of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings, FIG. **3** depicts a whole, uncooked, poultry egg **20**. From outside to inside, egg **20** includes: (1) an egg shell **22**; (2) outer membranes which are attached to the inner side of shell **22**, include a shell membrane and an egg membrane, and are collectively identified by reference character **24**; (3) viscous layers of albumen collectively referred to as the egg white and identified by reference character **26**; (4) a liquid yolk **28**; and (5) the vitelline membrane **30** which is thin and relatively strong and surrounds and envelops egg yolk **28**. Additional information on the structure of poultry egg components, their functions, and attributes is found in THE AVIAN EGG CHEMISTRY AND BIOLOGY, Burley et al., John Wiley & Sons, Inc., New York, N.Y., 1989, which is hereby incorporated by reference and which may be referred to by the reader if desired.

Heretofore proposed time and temperature pasteurization techniques for poultry eggs focus almost exclusively on the destruction of superficial infections on the outer and inner surfaces **32** and **34** of egg shell **22**. An exception is found in

Funk U.S. Pat. No. 2,423,233 which purports to disclose—but does not document—time and temperature pasteurization processes which are capable of destroying infections present in the white of a poultry egg. Nothing found to date discloses time and temperature pasteurization processes capable of destroying infections in the yolk of a poultry egg, let alone those at the very center **36** of a yolk such as depicted at **28** in FIG. **3**. In fact, when applied to a shell egg which is infected throughout its mass or primarily in its yolk, all known shell egg pasteurization processes are: insufficient to meet minimum effective standards such as those established for liquid eggs; accomplish nothing; or create conditions which are actually conducive to, and frequently optimal for, the increase of food poisoning infections already present in the shell egg.

Infections of the shell egg may be commonly found: (1) concentrated at or in close proximity to the egg shell/egg white interface as a result of migration through the pores of the shell and the outer membranes; (2) indigenous and scattered throughout the mass of the egg; and (3) indigenous but concentrated in the center and other areas of the yolk. Indigenous infections may be a result of: transovarian infection of the yolk, through-the-pore contamination, and generalized infection. While it is convenient to think in terms of *Salmonella* which almost seems to be symbiotic with poultry and egg products, it is also likely true that eggs serve as rich host media for infectious organisms of all sorts under some circumstances.

As discussed above, to meet at least the minimum standards of pasteurization mandated by the USDA for liquid eggs and to retain or enhance the appearance of freshness, functionality, and organoleptic properties, very specific combinations of times and temperatures must be employed. These time and temperature combinations take into account the smallest to largest commercial egg sizes; starting temperatures ranging from 40° to 70° F.; unpackaged processing without process aids or augmentation such as by overshooting and flash tempering; and water as the heat exchange media. The process parameters preferably range from: (a) a minimum TPT of about 34 to 52 minutes at 138.9° F.±0.5° F. to (b) about 75 to 400 minutes at 130.3° F.±0.4° F. Preferred process parameters for shell eggs at a representative 45° F. starting temperature are:

TABLE 2

Weight (gms)	Temperature (°F.)	TPT (min)
40–60	138.5 ± 0.7	40–46
60–80	138.0 ± 0.5	42–48

In many cases, the initial temperature of the eggs being processed will be below the nominal cold storage temperature of 40° F., above the nominal room temperature of 70° F., or at a level between those two nominal temperatures. For example, cold storage eggs left on a loading dock in freezing weather may have an initial processing temperature which is less than 40° F. In those cases, minimum, maximum, and optimal processing times can be extrapolated from the temperatures set forth above, derived by the routine testing of appropriately sized samples, or be derived through a combination of extrapolation and testing steps to determine the EqT time of the eggs and the TPT required to provide the desired RPT.

Holding a shell egg under selected time and temperature conditions as specified above can achieve minimum USDA liquid egg pasteurization standards and can effect significant reductions in, if not entirely eliminate, infections and still yield a consumer acceptable shell egg.

It is entirely practical to process eggs by the novel techniques disclosed herein in lots and to employ in the practice of the present invention continuous techniques similar to some already in use by the egg industry; e.g., continuous egg washing machines, which can clean hundreds of thousands of eggs per day. In such applications, it is commonly impractical to control process temperatures to small fractions of a degree. Consequently, except for processing steps of very short durations, temperatures of less than 139.5° F. are more practical pasteurization temperatures.

In any event, it is essential that the pasteurization process time and temperature be such that the shell egg, throughout its mass including the center of the yolk and other innermost parts of the egg, reach and be maintained at a pasteurization temperature for a RPT equal to at least the minimum USDA required for liquid eggs irrespective of the size, preprocess temperature, freshness, shell thickness, or other characteristic of the egg or the heat transfer medium in which or specific process by which the egg is processed.

The eggs may be treated or processed in accord with the principles of the present invention in any gaseous liquid or fluid, food grade heat transfer medium including air, other gases such as those discussed above, oil, a glycol, or water.

In those tests described in the examples which follow, counts of infections were made with PETRIFILM® aerobic count plates, using the protocol described in the PETRIFILM® Interpretation Guide, with a Millipore® sampler using the protocol described in the instructions for using that product, or with an equivalent device and protocol.

The equipment for the tests described in the bulk of the examples is shown diagrammatically in FIGS. **9** and **10**. It included a Blue M MAGNAWHIRL precision water bath **38** with controls (not shown) which allow the temperature of the bath to be adjusted. A batch **40** of eggs to be processed was placed in the body of water **41** filling the tank **42** of the Blue M apparatus, typically although not always in batches of 13 arrayed as shown in FIG. **10**. Gentle (laminar flow) circulation of the water **41** in tank **42** was employed to eliminate temperature gradients and thereby ensure that all of the eggs in the body of pasteurization water were heated in the same, uniform manner.

The temperature at the center of the yolk of that egg **46** in the center of the batch **40** was measured with a Type K thermocouple **48** at the center of the yolk. A reference thermocouple **50** placed in the body of water **41** in tank **42** was used to measure the temperature of that pasteurization medium. Because of the uniformity of the pasteurization conditions, the center-of-yolk temperatures of the remaining eggs in a batch **40** were assumed to be the same as the temperature measured by thermocouple **48**.

Thermocouple **48** was installed by puncturing the shell, outer membranes, and vitelline membrane (or yolk sac) of egg **46** with a hypodermic needle. The thermocouple **48** was then introduced with its progress being observed through a candling slit, allowing the insertion of the egg to be stopped precisely when the temperature sensing tip reached the center of the egg yolk. Epoxy resin was then applied to the shell of the egg to seal the puncture in the shell and to fix the thermocouple **48** in place.

The center-of-yolk temperature of egg **46** and the bath temperature were continuously monitored, using a personal computer **52** running Quick Log PC software supplied by Strawberry Tree of Sunnyvale, Calif. and Tegam K, J&T, single input thermometers **54** and **56**.

In many of the tests described in the examples, the eggs were inoculated with an infectious organism. The number of organisms stated in the example is the number per gram of egg weight.

EXAMPLE I

Any shell egg subjected to the Funk devitalization process is initially at an ambient temperature typically ranging from about 45° to 55° F. The preferred Funk TPT's and temperatures (5 to 10 minutes at 138° F. and 130° F. for 20 to 40 minutes) cannot provide any RPT in the yolk of an infected egg as demonstrated by the following tests.

TEST 1

Funk Preferred TPT/Temperature of 138° F., 5 to 10 Minutes.

Method

Shell eggs were pasteurized at Funk's preferred TPT and temperature. The eggs had an average size of 60 gms and were at an improbably high pre-process temperature of 70° F. They were processed in the Blue M precision water bath with the water agitated under laminar flow conditions to provide uniform heating (a favorable equivalent of Funk's "rotation").

Results

After 5 minutes, a yolk center temperature of only about 93° F. was reached (see FIG. 4). This is nearly the optimal growth temperature for most *Salmonella* sp. (98.6° F.).

After 10 minutes, the yolk achieved momentarily a temperature of about 125° F., still in the temperature range in which microorganisms actively grow.

Comments

If the yolk of the egg processed in this manner happens to be infected with *S. enteritidis*, for example, such treatment will in effect represent exposure of the infected egg to active infection growth conditions (>~70° to <~120° F.), including some exposure at optimal growth conditions (>~95° to <~105° F.) with absolutely no exposure to effective killing conditions (>~129° to 160° F. for at least 3.0 minutes).

Conclusion

Eggs processed according to Funk's preferred TPT/Temperature conditions can only result in increased severity of any food poisoning infections, except superficial ones.

TEST 2

Funk Preferred TPT/Temperature of 130° F., 20 to 40 Minutes.

Method

Same method as in Test 1 except that the eggs processed in the most favorable of all possible Funk TPT/temperatures combinations—130° F. for 40 minutes.

Results

Starting at the very favorable but improbably high starting temperature of 70° F., the center of the egg yolk reached a temperature of only 130° F. (after ca. 36 minutes). That is, it took 36 minutes to reach EqT and initiate RPT.

Comments

This leaves a RPT of only four minutes before Funk's mandated maximum of 40 minutes TPT is reached. That RPT of 4 minutes at 130° F. is not nearly long enough to pasteurize the egg to a level equivalent to the most minimal USDA liquid egg standard.

Even at a processing temperature of 138° F. an egg acquires an initial temperature throughout its mass which is effective to destroy infectious microorganisms of about 129° to 130° F. only after 36 to 37 minutes. After an additional x minutes (the total RPT), the average of all temperatures over the RPT can be compared to the extended chart of FIG. 2 to determine if minimal process values have been satisfied. Clearly, a total RPT of 4 minutes even at 138° F. is not nearly long enough to pasteurize the egg to a level equivalent to the minimum USDA liquid egg standard.

With the center of the egg yolk reaching 130° F. at the 36th minute and 132° F. at the 40th minute, additional time at temperature would be required for the average temperature to achieve a time at temperature equivalent of the minimum USDA standards shown in the USDA chart.

At least a 50 percent greater RPT of 6 minutes is required at a 138° F. pasteurization temperature to ensure the destruction of infectious organisms throughout the mass of the egg. A far longer time would be required if the temperature at which the egg is heated were only 130° F.

Ignoring Funk's preferred TPT/temperature combinations and sorting through a multitude of possible permutations of other possible Funk TPT/temperature combinations leads to the inevitable conclusion that the most efficacious probable selections fail by significant margins to achieve any meaningful RPT with respect to meeting minimum USDA standard requirements. The many other possible combinations of from 5 to 40 minutes at a temperature in the range of 110° to 140° F. in a majority of cases can only worsen an infectious condition in an egg.

TESTS 3–6

The test was repeated, using water bath temperatures of 132° F., 134° F., 136° F., and 140° F. In the first three of these tests the center of the egg yolk never reached the 130° F. minimum necessary to achieve any RPT whatsoever in Funk's maximum 40 minute TPT (see FIGS. 5, 6, 7, and 8).

Comments

The sixth—140° F. bath temperature test—confirmed that eggs cannot be time-at-temperature processed at a temperature of 140° F. or higher but must be processed for the appropriate RPT at a temperature below 140° F. While the egg achieved initial RPT at 21 minutes of TPT, it also became cooked at a TPT of 25 minutes or after a RPT of only 4 minutes at an averaged temperature of between 130° and 133° F. at the yolk center. The whites of the eggs processed at this temperature were clouded even before the minimum effective EqT of 130° F. was reached, and the eggs were cooked only a few minutes after the minimum 130° F. EqT was reached (see FIG. 8). Clouding and cooking respectively occurred at TPT's of ca. 8 and 24 minutes, both well short of the maximum 40 minutes TPT which the Funk patent disclosure embraces.

Conversely, the 5 minute TPT taught by Funk to be satisfactory is equally ineffective. In none of the tests (132°–140° F., FIGS. 4–8) did the centers of the egg yolks

reach the minimum 130° F. temperature required for microorganism destruction in the Funk-specified 5 minute TPT.

One can only conclude that Funk does not make obvious to one of ordinary skill in the art the time and temperature combinations required to pasteurize shell eggs to a level required for food safety; i.e., to even the minimum level mandated by the USDA for liquid whole eggs.

EXAMPLE II

Two dozen fresh shell eggs at 40° F. (4.4° C.) were placed in a 2-gallon, controlled temperature, water bath preheated to 134.6° F. (57° C.).

Two dozen fresh shell eggs at 40° F. (4.4° C.) were placed in a 2-gallon, controlled temperature bath filled with peanut oil. The temperature of the bath was preset to 134.6° F. (57° C.).

At 5 minute intervals, eggs were punctured with a stem thermometer while still in the bath to determine the temperature at the center of the egg. At 5 minutes, the center-of-yolk temperature of the eggs in both baths still averaged only 40° F. (4.4° C.). At 10 minutes, that temperature of the eggs from both baths averaged 47° F. (8.33° C.). The 15 minute average for both batches was 67° F. (19.44° C.). At 20 minutes, the average temperature was 82° F. (27.78° C.). At 25 minutes, it was 98° F. (36.67° C.). At 30 minutes, the average was 113° F. (44.99° C.). At 35 minutes, the average temperature was 121° F. (49.44° C.). At 40 minutes, the average was 129° F. (53.89° C.). At 45 minutes, the average temperature was 134° F. (56.67° C.).

The target temperature at the center of the eggs of 129.9° F. (54.4° C.) was achieved at a time between 40 and 45 minutes. The eggs held for this period of time showed no signs of occlusion of the white. Indeed, the white had thickened, making the egg appear fresher.

This phenomenon of the egg white thickening without occlusion continued until about 1.5 hours had elapsed at which time a very slight but noticeable occlusion of the white appeared. The appearance of the egg was very similar to that of a freshly laid egg, which has a somewhat lightly occluded white.

The bunch-up of the white around the yolk and the disappearance of thin running egg white continued up to 1.75 hours after which the egg became more noticeably occluded.

Eggs which had been held for 1.5 hours at 134.6° F. (57° C.) were equivalent to shell eggs held at 139° F. (59.4° C.) for 1.25 hours. The raw eggs were tested by a panel for appearance and were then prepared by frying, scrambling, and poaching and tested for taste against controls. No significant differences were detected.

EXAMPLE III

Shell eggs for this test were selected for obvious surface filth; i.e., fecal matter, blood streaks, smudges, feather adherence, and the like. Eighteen medium sized eggs selected from several thousand were rinsed in a 0.005% chlorine water solution. The eggs were immersed in a water bath preset to 139° F. (59.4° C.). Every 5 minutes, while still in the water bath, the shell of an egg was punctured and a thermometer inserted into the center of the yolk. The egg was then removed, the shell was broken, and the egg was dropped into a Petri dish for examination and preparation of culture samples.

The results after culturing for the indicated number of hours are shown in Table 3.

TABLE 3

	Condition	Temperature	Millipore Culture Results (microorganisms per cc)
5 mins	White clear	Yolk/38° F.	<50/48 hrs
10 mins	White clear	Yolk/39° F.	<100,000/48 hrs
15 mins	White clear	Yolk/51° F.	0/48 hrs
20 mins	White clear	Yolk/74° F.	<9,000/48 hrs
25 mins	White clear	Yolk/88° F.	<100/48 hrs
30 mins	White clear	Yolk/101° F.	<50,000/48 hrs
35 mins	White clear	Yolk/117° F.	<200,000/48 hrs
40 mins	White clear	Yolk/129° F.	<50/48 hrs
45 mins	Thicker	Yolk/135° F.	<10/48 hrs
50 mins	Thicker	Yolk/139° F.	<20/48 hrs
55 mins	Thicker	Yolk/139° F.	<40/48 hrs
60 mins	Thicker	Yolk/139° F.	<10/48 hrs
65 mins	Thicker	Yolk/139° F.	0/48 hrs
70 mins	Thicker	Yolk/139° F.	<10/48 hrs
75 mins	Thicker, very slight occlusion	Yolk/139° F.	0/48 hrs
80 mins	Thicker, slight occlusion	Yolk/139° F.	0/48 hrs
85 mins	Thicker, slight occlusion	Yolk/139° F.	0/48 hrs
90 mins	Thicker, occlusion	Yolk/139° F.	0/48 hrs.

EXAMPLE IV

Medium and large grade eggs stored either at room temperature (70° F.) or at 45° F. for 12 hours were inoculated with Salmonella typhimurium bacteria (10^6 gm) either between the shell and outer membranes (outer) or directly into the yolk (inner).

The inoculated eggs were placed in a water bath operated at different times at 134°, 136°, and 138° F. (±0.3° F.). Ten eggs representing each combination of variables (starting temperature, egg size, and pasteurization process temperature) were removed at two-minute intervals beginning after initial heating for 38 minutes and continuing through 50 minutes. This represented 38, 40, 42, 44, 46, 48, or 50 minutes of total heating (TPT). The sampled eggs were cooled to room temperature and analyzed.

For each combination of variables described above (egg size, egg storage temperature, heating time, and heating temperature), another 10 uninoculated eggs processed at the same temperatures and for the same TPT's were utilized for functionality evaluation. After heating/cooling, these eggs were cracked open; and yolk/white color, egg white whipability, and yolk emulsification capacity were evaluated. Eggs of the same size and at the same storage temperature served as controls.

The *Salmonella* kill results appear in Table 4 below.

TABLE 4

	Salmonella Reduction (percent)							
	Egg size:							
	Medium				Large			
	Initial egg temp, °F.:							
	70° F.		45° F.		70° F.		45° F.	
	Inoculation:							
	outer	inner	outer	inner	outer	inner	outer	inner
Pasteurization temp, 134° F.	—	—	—	—	—	—	—	—	—
Heating time, min:	38	43	35	29	18	40	33	25	15
	40	46	38	31	20	45	35	29	18
	42	52	43	34	21	50	40	31	20
	44	55	45	36	24	53	43	35	22
	46	64	52	39	27	60	50	37	25
	48	73	64	40	30	70	60	39	27
	50	87	72	43	31	85	70	41	30
Pasteurization temp, 136° F.	—	—	—	—		—	—	—	—
Heating time, min:	38	47	37	33	23	45	35	30	20
	40	50	40	35	25	47	37	33	23
	42	55	46	41	29	51	40	40	26
	44	58	49	46	31	55	45	44	29
	46	67	58	50	34	63	53	48	30
	48	81	72	54	36	77	68	50	35
	50	93	80	56	38	90	77	53	37
Pasteurization temp, 138° F.	—	—	—	—		—	—	—	—
Heating time, min:	38	67	48	65	61	65	45	63	42
	40	73	52	70	68	70	50	68	48
	42	91	81	87	85	89	80	85	77
	44	100	96	96	93	100	94	96	90
	46	100	100	100	100	100	100	100	100
	48	100	100	100	100	100	100	100	100
	50	100	100	100	100	100	100	100	100

Even in the worst case situation (large egg, 45° F. initial temperature, yolk inoculation), a 100 percent bacterial kill was obtained with 46 minutes TPT at 138° F.; and a satisfactory kill was obtained in all tests in which the eggs were processed to levels equivalent to or exceeding the minimum USDA standards for liquid whole eggs.

No egg white separation or coagulation were noted in any of the eggs evaluated in this study. Even the longest heating time (50 min) produced no adverse results. In addition, no changes in egg white and yolk color were observed. Likewise, egg white whipability and egg yolk emulsion stability were not significantly different than in the non-heat processed controls.

EXAMPLE V

For each test, 12 shell eggs at an initial center of yolk temperature of 50°±1.5° F. and varying in size from 54 to 67 gms were placed in the Blue M MAGNAWHIRL precision water bath. The eggs were monitored by a TYPE K, hypodermic probe thermocouple coupled to a Tegam K, J&T, single input TC thermometer. The results were as follows:

TABLE 5

Pasteurization Temperature	130° F.	134° F.	136° F.	138° F.
Number of Eggs Tested	260	200	180	180
Average size (gms)	53	60	64	57

TABLE 5-continued

Average Time Before EqT (min)	62	44	40	38.5
Range of Time (min)	±1	±1.5	±1.5	±1.5

The size and temperature of an egg entering a pasteurization medium are significant determinants of EqT and TPT. As a rule, for highest food safety, the lower the temperature at which an egg is held (down to about 38° F.), the better. At temperatures below about 45° F., the growth activity of shell egg infections is very low if not static. Any significant holding time before pasteurization at above 55° F. is undesirable since, from that point, the active growth of infectious organisms can be substantial. Virtually all shell eggs which are to be pasteurized should be at a temperature below 50° F. Less than 45° F. is preferred.

EXAMPLE VI

Breakage due to initial process temperature shock can be a significant factor. Usually, the lower the starting egg temperature, the more frequent breakage is. Breaking can be reduced by tempering shell eggs before they are heated to the pasteurization temperature. Tempering is accomplished by employing at least one intermediate, rapid incremental heat exposure step and is described in detail below.

Sixty-four (64) refrigerated fresh eggs (48 hrs old) were inoculated with 10^9 microorganisms per gram of *Salmonella*

typhimurium in distilled water by shell puncture with a Micropoint 0.3 cc syringe. Sixteen (16) medium and 16 large eggs were punctured and injected with 0.2 cc of the culture immediately beneath the shell and outer membranes. Sixteen medium and 16 large eggs were similarly inoculated by puncture through the vitelline membrane to the proximal center of the yolk as visually gauged while viewing the egg through the candling aperture. Each puncture hole was filled with a dab of hot resin, which was allowed to cool for 5 minutes. The eggs were then divided into two groups of 32, each comprised of 16 54±1 gram and 16 68±1 gram eggs with eight eggs of each size being shell inoculated and the other eight being yolk inoculated.

The eggs were placed in separate, precision temperature controlled, water baths, one set at 45° F. and the other at 65° F. After an elapsed time of 60 minutes four 54 gram and four 68 gram eggs from each water bath were punctured by a type K hypodermic thermal probe, and the temperature at the center of the yolk was taken. As measured at the yolk center, all eggs were at a temperature within 1° F. of the bath temperature; i.e., four eggs were at approximately 45° F. and 4 at approximately 70° F. Samples taken from puncture points at the inner shell and yolk center were cultured. The results were: average *Salmonella* for all eggs equalled 10^8 gm, the range being from 10^5 to 10^9 microorganisms per gram.

Inoculated eggs making up the two groups were respectively placed in water baths operating at 136°±0.5° F. and at 138°±0.5° F. After 35 minutes of residence time in the bath, a sample of four eggs was removed and cooled in a water bath set at 40° F. for 15 minutes. Each sample was composed of 54 gm eggs with initial temperatures of 45° and 65° F. and 68 gm eggs with the same initial temperatures.

This sampling procedure was repeated at 2 minute intervals; i.e., after 37, 39, 41, 43, 45, 47 and 49 minutes of TPT. All eggs were analyzed for *Salmonella*.

The remaining 8 eggs were withdrawn and cooled in a water bath at 40° F. These were tested against 8 untreated eggs of comparable age and size for visual appearance, whipability, yolk emulsification, and baking (standard sponge cake) equivalency test.

The results of these tests are presented in the following tables.

TABLE 6

Initial temperature = 45° F.
Process Temperature = 136 ± 0.5° F.

Egg Size	TPT	Reduction of Salmonella Population (Percent)	
(gm)	(min)	White	Yolk
54	35	28	17
54	37	32	20
54	39	34	26
54	41	60	30
54	43	75	65
54	45	83	72
54	47	90	82
54	49	92	84
68	35	29	12
68	37	33	22
68	39	41	24

TABLE 6-continued

Initial temperature = 45° F.
Process Temperature = 136 ± 0.5° F.

Egg Size	TPT	Reduction of Salmonella Population (Percent)	
(gm)	(min)	White	Yolk
68	41	59	28
68	43	63	46
68	45	79	69
68	47	85	71
68	49	90	82

TABLE 7

Initial Temperature = 65° F.
Process Temperature = 136 ± 0.5° F.

Egg Size	TPT	Reduction of Salmonella Population (Percent)	
(gm)	(min)	White	Yolk
54	35	28	17
54	37	34	23
54	39	35	25
54	41	40	29
54	43	73	61
54	45	81	76
54	47	95	85
54	49	100	92
68	35	27	12
68	37	31	19
68	39	33	24
68	41	59	28
68	43	71	51
68	45	79	71
68	47	93	80
68	49	98	88

TABLE 8

Initial Temperature = 45° F.
Process Temperature = 138 ± 0.5° F.

Egg Size	TPT	Reduction of Salmonella Population (Percent)	
(gm)	(min)	White	Yolk
54	35	38	22
54	37	45	26
54	39	51	44
54	41	71	67
54	43	96	89
54	45	100	95
54	47	100	100
54	49	100	100
68	35	31	17
68	37	41	23
68	39	48	38
68	41	57	50
68	43	89	88
68	45	99	97
68	47	100	100
68	49	100	100

TABLE 9

Initial Temperature = 65° F.
Process Temperature = 138 ± 0.5° F.

Egg Size	TPT	Reduction of Salmonella Population (Percent)	
(gm)	(min)	White	Yolk
54	35	54	25
54	37	63	31
54	39	88	41
54	41	97	54
54	43	100	90
54	45	100	100
54	47	100	100
54	49	100	100
68	35	31	29
68	37	47	35
68	39	56	48
68	41	80	74
68	43	94	91
68	45	100	100
68	47	100	100
68	49	100	100

Even in the worst case situation, (large egg, 45° F. initial temperature, yolk inoculation), a 100 percent kill was obtained with a TPT of 45 minutes at a pasteurization temperature of 138° F., and a satisfactory kill was obtained after a TPT of about 41 minutes.

Very minor cooking was noted in the whites of about 5 to 10 percent of the smaller eggs with an initial 65° F. temperature processed for 49 minutes at a temperature of 138°±0.5° F. No cooking was observed in any of the other eggs tested. No changes in egg white or yolk color were observed. Egg white whipability and egg yolk emulsion stability were not significantly different than in the unprocessed controls. Sponge cakes baked in accord with National Egg Board recommendations from treated eggs in all four egg size/initial temperature categories were equivalent to those baked from the controls.

The overall appearance of freshness was equivalent to that of freshly laid eggs. There was a noticeable enlargement of the yolks of the eggs in the 65° F. starting temperature group processed for more than 45 minutes but only when the processed eggs were closely compared to the controls. Yolks of eggs processed for TPT's exceeding 45 minutes seemed to rupture more readily than those of the controls when the eggs were cracked onto a hard surface. Additional tests in which treated eggs were chilled for longer periods of time (over 24 hrs at 42° F.) showed that this extended chilling restored the rupture resistance of the processed egg yolks to a breakage level about equal to that of normal yolks.

All treated eggs exhibited Haugh values (thickness of white; industry standard for measuring the freshness of a shell egg) equivalent and in some cases markedly superior to those of controls. Almost 50 percent of the eggs processed for 47 minutes (those weighing 54 and 68 gms whether processed from an initial temperature of 45° F. or 65° F.) exhibited some opacity in the whites. The observed type of opacity is visually indistinguishable from that of eggs which are very fresh or which have become partially occluded prior to significant coagulation or loss of SLP (soluble liquid protein). SLP is a measure of coagulation (see the above-cited Swartzel et al. U.S. Pat. No. 4,957,759).

Vibration of the eggs being processed by shaking or with ultrasonic energy or cavitation is another optional technique that can often be employed to advantage in the processing of eggs according to the principles of the present invention. Vibration promotes the transfer of heat to the inner parts of the egg, making the pasteurization process more efficient and ensuring an optional kill of any infections that may be present, irrespective of that part of the egg in which the infection may be located.

The advantages of employing vibration were demonstrated in the tests described in the following examples.

EXAMPLE VII

Control: 120 medium sized, 52 gm shell eggs at 70° F. were pasteurized at 138° F. in the Blue M water bath. Temperatures were taken at yolk center with the type K hypodermic thermal probe at intervals during a TPT of 37 minutes.

A Treated: same as control except that the eggs were placed on a reciprocating shaker platform located at the bottom of the 138° F. water bath. The platform was reciprocated at a ½ in pitch and at a frequency of 60 to 75 cycles per minute.

B Treated: 120 medium size eggs at an initial temperature of 70° F. were processed in batches of 12 per test (10 tests) in a Branson Type D, Ultrasonic Precision Water Bath set at power level 4 with the water at a temperature of 138° F.

The yolk center temperatures of the eggs at the indicated sampling intervals are presented in the following table.

TABLE 10

	Average Temperature (°F.) Control	Average Temperature (°F.) Test A	Average Temperature (°F.) Test B
5 minutes	100.0	101.0	101.0
10 minutes	122.4	124.5	123.7
15 minutes	125.0	126.6	127.0
20 minutes	128.6	130.5	131.3
25 minutes	133.0	135.0	135.0
27 minutes	134.0	135.5	136.3
29 minutes	135.0	136.6	137.0
31 minutes	135.5	137.2	137.5
33 minutes	135.7	137.9	137.7
35 minutes	136.2	138.0	138.0
37 minutes	137.0	—	—

The tabulated results clearly show that the rate of heating of a shell egg can be significantly increased by subjecting the egg to vibration. This translates into a quicker reaching of EqT, with a consequent shortening of TPT and a concomitant reduction in processing costs.

Comparing the EqT of eggs subjected to ultrasonic vibration with controls processed identically (except for ultrasonic vibration) at 136° F. for 44 minutes showed that an average five-to-eight percent increase in heat transfer efficiency was obtained at medium power settings of the Branson Ultrasonic Cleaner. The range of improvement in heat transfer efficiency ranged from three percent to as high as 15 percent.

Tests of eggs from the same batch and inoculated with *Salmonella typhimurium* at a concentration of 10^8 microorganisms per gram showed an increased reduction of the infection compared to eggs pasteurized under the same conditions for the same time; i.e., 138° F. for 41 minutes, both when ultrasonic energy generated at the same settings and mechanical vibration were employed. The average was an approximately 14 percent greater reduction in the TPT required for destruction of the infection at a given pasteur-

ization process temperature (which can also be translated into a lower temperature for a given TPT). The increase in infection reduction ranged from about 5 percent to 20 percent for the same TPT's at the same process temperatures.

EXAMPLE VIII

One significant discovery arising from the time-at-temperature pasteurization of shell eggs with mechanical vibration is that shell eggs can be scrambled inside the shell by application of the vibratory technique. Tests employed an adjustable, reciprocating flask shaker; an adjustable, orbital test tube mixing pad; and the Branson ultrasonic apparatus. The ultrasonic energy did not produce in-shell-scrambled eggs; the outer membranes of those eggs remained intact. In all tests utilizing mechanical vibration, it was found that shell eggs can be scrambled in the shell over a wide range of frequencies, amplitudes, and process times. Heating the eggs markedly reduced the time need for mechanical vibration to scramble the eggs in-shell.

The foregoing findings were confirmed by tests in which three dozen shell eggs were pasteurized at 139° F. for 50 minutes in a water bath in the Blue M apparatus.

After removal from the bath and while still very warm to the touch, the eggs were loaded into an orbital shaker and affixed by elastic retainers to the shaker arms as shown diagrammatically in FIG. **11**. The shaker is identified by reference character **60**, the four arms by reference characters ***62a–d***, the eggs by reference characters ***64a–d***, and the elastic retainers by reference characters ***66a–d***. The shaker arms oscillated over an adjustable throw or amplitude identified by arc **68** about an axis **70**. The amplitude was varied over a range of 1/32 in to 5/8 in and the frequency over a range of 50 and 500 cps.

Upon opening, about 60 percent of the eggs which had been vibrated for 7 to 10 minutes at amplitudes between about ¼ in and 7/16 in were prescrambled in the shell. The prescrambled eggs could be broken directly into a pan and perfectly scrambled.

Heating eggs subjected to vibration facilitated the transfer of heat to internal egg particles by producing contact of the heated shell with all particles inside the egg. This translates into improved pasteurization efficiencies.

Cold eggs were also scrambled, using the orbital shaker and the operating conditions described above. There was less uniformity of scrambling, and there appeared to be some shell membrane tearing. Warming the eggs to a temperature above 130° F. (54.44° C.) alleviated those problems.

Eggs processed with ultrasound were not scrambled.

EXAMPLE IX

Several eggs were tested at much higher frequencies and shorter amplitudes, i.e., between about 700 and 800 cps at a 1/64 in to 1/32 in throw for a total time of about 15 minutes. A very unusual phenomenon occurred. Upon opening the shell, it was found that the egg had become almost entirely one large yolk, there being little or no distinct egg white inside the shell. After a few minutes on a flat surface, however, egg white began to slowly reappear from the yolk. Apparently, the white was worked through pores in the vitelline membrane by the vibrations. The membrane expanded without breaking to compensate for the much greater encompassed volume attributable to the migrated egg white.

EXAMPLE X

It was pointed out above that it is often advantageous in the practice of the present invention to overshoot the selected pasteurization process temperature in the initial heating of the egg(s) being processed and then allow the temperature to drift down to the selected level. This approach has the advantage of increasing the rate of heat transfer through the egg to the yolk which, in effect, shortens EqT and, consequently, TPT. High temperature overshooting may require the use of a heat transfer medium at a temperature which will result in cooking of the white before the RPT required for the wanted pasteurization throughout the mass of the egg including the yolk center is reached.

Up to a point, the higher the overshoot temperature, the greater the rate of heat transfer through the egg. In effect, this results in a desirably reduced EqT. If the egg is placed in water at 145° F., the outer layers will show visible signs of cooking in about 5 to 10 minutes, depending on the size of the egg and its original temperature. However, if the egg is removed from the heat transfer media after a few minutes and before coagulation, the temperature will drop below critical levels at the surface; and the heat imparted by the initial immersion will dissipate rapidly into the egg. If the egg is then immersed in a pasteurization bath (gas, fluid, or liquid) with a temperature lower than the critical temperature producing virtually instant coagulation (about 140° F.), the time required for RPT at the selected pasteurization temperature may be shortened and the egg pasteurization processed without additional risk of coagulating the yolk. This results in a shorter EqT time and a longer RPT for a given TPT and, as a result, more effective destruction of infective organisms than is otherwise possible.

A typical overshoot temperature ranges from 139°–150° F. The overshoot temperature is used for about 2 to 3 minutes and is followed by a decrease to a process temperature in the 130° to 139+° F. range (but below 140° F.). The time employed will vary with the size or load of the eggs and the starting temperature of the eggs. The lower the pasteurization temperature selected, the higher the overshoot temperature which can be conveniently used. Higher pasteurization temperatures require closer controls and reduced time to prevent visible coagulation.

The advantages of employing overshoot (or intermittent pasteurization were demonstrated by a representative test in which 12 medium sized eggs at a preprocessing temperature of 55° F. were tempered in water at 132° F. for 3 minutes, removed from the water bath, allowed to dwell for 3 minutes in room temperature air, and then introduced into a 138° F. water batch in the Blue M apparatus. The following temperatures were measured: non-yolk portion of the tempered egg next to its shell, 131° F.; the middle portion of the white, 112° F.; the white adjacent the yolk, 77° F.; the outer edge of the yolk, 58° F.; the center of the yolk, 56° F.

Thus tempered eggs were also placed in a water bath at a temperature of 143° F. (above the coagulation point of egg white albumin), and the water bath temperature controller was at that time reset to 138° F.

Results

The time required to reach EqT of the eggs started at 143° F. was shortened by an average of 10 percent with no noticeable diminution in egg quality. This permits processing at preferred pasteurization temperatures while reducing TPT by about 5 to 8 percent.

By the time heat transferred through the shells into the outermost layers of the egg albumin (about 4 to 5 minutes), the temperature of the pasteurization medium dropped to a baseline temperature of 138° F. In this short period of time, not enough heat can transfer through the shell and outer membrane to coagulate the outer layers of albumin. At the same time and as discussed above, the faster rate of heat transfer obtained by employing the higher, initial, overshoot temperature decreases EqT and, consequently, TPT.

Much higher temperatures can be used to reduce EqT; but requirements for closer process parameter controls to prevent increased thermal shock breakage and risks of coagulation will be limiting factors. These limiting factors depend upon the quantity of the product pasteurized and the particular conditions employed for pasteurization.

While the preferred "overshoot" temperature will typically be between 139° F. and 150° F., this temperature can range up to about 170° F. The process parameter tolerances at this point, however, are so close that these higher overshoot temperatures, for all practical purposes, become more or less the same as those required the flash tempering technique described hereinafter.

EXAMPLE XI

Another technique that can be employed to advantage in the practice of the present invention is to pulse the pasteurization process temperature; i.e., cycle that temperature between low and high levels. This is beneficial because pasteurization temperatures high enough to otherwise cause coagulation can be employed if alternated periodically with less critical and lower but effective pasteurization temperatures. This approach enhances heat transfer to the egg center without coagulation of the white. This reduces TPT as a result of a reduced EqT time.

Preferred intermittent/periodic temperatures of the pasteurization medium are between about 130° and 138° F. on the low side and about 139.5° and 145° F. on the high side. These temperatures are within a practical range for pulsing. Eggs being pasteurized can effectively be alternatively treated at a baseline pasteurization temperature of 130° F. or higher and a pulse temperature of 139° F. to 145° F. or even higher, provided that the time of exposure at the higher temperature is limited to a time shorter than that which will cause coagulation of the white at the selected high side or pulse temperature. However, closer control over the process parameters must be exercised when using higher pulse temperatures.

As an alternative to pulsing in the same media, eggs may be transferred between baseline temperature heat transfer media and higher pulse temperature transfer media. Also possible are combinations of techniques which employ one or more high side pulse and baseline temperatures and one or more pasteurization media to effect optimal pasteurization while working below critical coagulation times and temperatures and providing the most efficient EqT.

To demonstrate the efficacy of the just-described pulsing techniques, 60 gram eggs were heated at 145° F. for 2 minutes. The eggs were then held at ambient temperature for a dwell time of 2 minutes. This was followed by heating the eggs at 140° F. for 2 minutes and then heating them at 130° F. for 38 minutes.

EqT was reached after 35 minutes. This was 4 minutes faster than controls heated at 138° F. This represents an 11 percent decrease in EqT.

EXAMPLE XII

The percentage of eggs damaged by cracking increases as the differential between the initial and pasteurization process temperatures increases. That is, the more severe the temperature differential, the more eggs that will crack. This number can become substantial when shell eggs are subjected to the temperatures at the upper end of the useful pasteurization temperature range. To overcome this serious problem, the shell eggs are preferably raised to process temperatures in at least one and preferably two or more steps. This process of heating eggs from their initial temperature to the pasteurization temperature in stages to reduce breakage and for other purposes is referred to herein as tempering.

Tempering is typically accomplished by holding the eggs in air, preferably in a sanitary enclosure at one or more intermediate temperatures in the range of 65° to 131° F. for a total period of 10 minutes to 24 hours with the particular time(s) and temperature(s) depending on such factors as: the temperature conditions under which the eggs were heretofore held; the size of the eggs; the baseline pasteurization temperature to be used; and whether or not basic process aids such as turbulence, vibration, and/or heat transfer promoting pulsing treatments are to be used.

While not preferred, the minimum tempering temperature can be substantially lower than 130° F. Particularly when tempering temperatures below 130° F. are used, the tempering time should be no more than is required to reduce breakage when the egg is subsequently subjected to primary pasteurization because <130° F. temperatures promote the growth of *Salmonella* and other dangerous microorganisms.

Tempering quickly to prevent any significant growth of infections including those superficially present at the inner shell surface or those at the center of the yolk can be accomplished by flash tempering, which consists of first exposing the shell egg for a brief period of time to a higher temperature than could be employed if the eggs were exposed to it for an appreciable length of time.

The temperature for flash tempering can be considerably higher than 212° F.; and such temperatures can be reached by exposing the eggs to steam or an open flame, for example. Unless care is exercised, however, the use of these super high flash tempering temperatures can result in scorched or "off" odors and/or flavors in the egg. Consequently, the time of exposure for the temperature selected should be no more than is absolutely necessary to reduce breakage during processing to avoid imparting any "off" odor or flavor to the egg.

In all cases where tempering is utilized, the dwell or post-tempering time before entry into primary pasteurization should be of the minimum duration required for the tempering heat imparted to the egg to function to reduce subsequent breakage. This breakage reducing function may occur during tempering and also subsequently during the dwell or post-tempering period and during pasteurization. The total of tempering and post-tempering or dwell times is preferably from about 0.5 minutes at the highest temperatures (ca. 212° F. to steam and open flame temperatures) to 40 minutes.

Tempering at more modest temperatures (134.5° to 138.5° F.) is preferably accomplished by heating the eggs being processed in one or more stages with the eggs being treated in the last stage at a maximum temperature of 138.5° F. for about 1 minute with a minimum dwell time afterwards of about 3 minutes. The total time (heating and dwell) is in the range of 1 to 15 minutes. Most generally preferred for a wide

variety of processing applications are tempering temperatures in the range of 130° to 131° F. for total times of 5 to 50 minutes with 5 to 10 minutes being preferred.

The following table gives preferred pasteurization process parameters (times at temperatures for eggs flash tempered by heating them at a representative 146° F. for 2 minutes, this being followed by a dwell at room temperature of 5 minutes).

TABLE 11

	Shell Eggs at 73° F.	
Weight	Temperature (°F.)	TPT (min)
40–60	138.5 ± 0.7	35–43
60–80	138.0 ± 0.5	36–45

Preferred process conditions for eggs representatively tempered at 125° F. for 2–3 minutes with a 3–5 minute dwell appear in Table 12.

TABLE 12

	Shell Eggs at 68° F.	
Weight	Temperature (°F.)	TPT (min)
40–60	138.5 ± 0.7	37–45
60–80	138.0 ± 0.5	38–47

Tempering as usually accomplished in 5 to 10 minute steps may typically add about 1 to 5 minutes to TPT. Tempering and/or prepackaging and/or coating steps employed to overcome cracking may significantly increase the overall process time, especially in applications employing more severe treatment regimes in the range of from about 135° F. to about 140° F.

If accomplished within the specified parameters, tempering does not necessarily cause any significant increase in TPT or increase in infections but can significantly reduce EqT and cracking of shells and otherwise contribute to the overall effectiveness of the pasteurization process.

Tempering times will in general be inversely proportional to the tempering temperatures that are employed. That is, the higher tempering temperatures will be employed for the shorter indicated periods of time and vice versa. This avoids coagulation, thermal shock induced cracking of egg shells, and other problems which might otherwise occur.

The following representative tests employed tempering in pasteurizing eggs in accord with the principles of the present invention.

Control: 36 medium sized eggs at an initial temperature of 65° F. were divided into four batches of nine each. The batches were processed separately and introduced directly into a water pasteurization bath temperature regulated with a controller preset at 138° F. The eggs were held in the pasteurization bath for 20 minutes TPT.

The eggs were removed from the bath at the end of the 20 minute period and examined for cracks.

Results:

Batch 1: Broken eggs=2

Batch 2: Broken eggs=0

Batch 3: Broken eggs=1

Batch 4: Broken eggs=1

A Tempered eggs: 36 medium sized eggs at an initial temperature of 65° F. were divided into four batches of nine each. The batches were processed separately in a water bath regulated by a temperature controller set at 130° F. for 5 minutes and then transferred to a water pasteurization bath at 138° F. for 15 minutes TPT.

Results:

Batch 1: Broken eggs=0

Batch 2: Broken eggs=1

Batch 3: Broken eggs=0

Batch 4: Broken eggs=0

B Tempered Eggs: 36 medium sized eggs at an initial temperature of 65° F. were divided into batches of nine eggs, and the four batches were processed separately in an air box 12 in×10 in×24 in. Air preheated to 80° F. was circulated through the box at a rate of 15 cfm for 15 minutes to temper the eggs. Each batch of eggs was then removed from the box and transferred to the 138° F. water pasteurization bath for 15 minutes TPT.

Results:

Batch 1: Broken eggs=0

Batch 2: Broken eggs=0

Batch 3: Broken eggs=0

Batch 4: Broken eggs=0

The reduction in thermal shock cracking afforded by tempering as well as an increased thermal tolerance can be obtained by wrapping, bagging, coating, or otherwise encapsulating the eggs being treated before they are introduced into the pasteurization medium.

The application of these techniques to time-at-temperature egg pasteurization as disclosed herein is illustrated in the following examples.

EXAMPLE XIII

Thirty-six (36) medium sized eggs at an initial temperature of 65° F. were individually tightly wrapped in a Saran® wrap film commonly used for wrapping meat and divided into four batches. The four batches of wrapped eggs were pasteurization processed separately in the 138° F. water pasteurization bath for 20 minutes TPT.

Results:

Batch 1: Broken eggs=0

Batch 2: Broken eggs=0

Batch 3: Broken eggs=0

Batch 4: Broken eggs=1

EXAMPLE XIV

Thirty-six (36) medium sized eggs at an initial temperature of 65° F. were divided into four batches of nine and individually sealed in resealable 5 in×6 in Zip Loc® sandwich bags. The four batches of bagged eggs were separately processed in the 138° F. water pasteurization bath for 20 minutes TPT.

Results:

Batch 1: Broken eggs=0

Batch 2: Broken eggs=1

Batch 3: Broken eggs=0

Batch 4: Broken eggs=0

EXAMPLE XV

Thirty-six (36) medium sized eggs at an initial temperature of 65° F. were divided into four nine-egg batches and individually sealed by spraying the shells with a clear acrylic spray (Krylon® 12 ounce spray-on acrylic coating) The coatings were air dried at 70° F., and the coated eggs were

then immersed in the 138° F. water pasteurization bath for 20 minutes TPT.

Results:

Batch 1: Broken eggs=0

Batch 2: Broken eggs=1

Batch 3: Broken eggs=0

Batch 4: Broken eggs=1

Of considerable importance in the practice of the present invention is the handling and packaging or treatment of the processed egg(s) in a manner which will keep the eggs from being recontaminated with harmful organisms. Recontamination can be avoided by packaging the eggs immediately before pasteurization or immediately after pasteurization and before cooling or exposure to eliminate potential contamination by handling or contact with the ambient environment or non-sterile surfaces.

A preferred technique which can be employed involves: (a) individually prepackaging the eggs in a polymeric film formed separately around each egg, (b) sealing the packages, and then (c) pasteurizing the eggs in accord with the principles of the present invention.

This approach has the advantages of: reductions in handling and the above-described thermal shock breakage, elimination of recontamination, and easier control over the process since eggs may be pasteurized continuously on a packed belt line and the individual egg packages then cut apart or otherwise separated. Once sealed in film, the egg does not need to be pasteurized or handled in an aseptic environment. Also, this keeps processing aids such as shell treatment agents from coming off during processing.

Alternative techniques that can be utilized include sealed packaging in Cry-O-Vac® polymers and processing before or after sealing (preferably before).

Spoilage preventing inert gases such as carbon dioxide and nitrogen may be substituted for the air in the packages or added to the eggs by infusion or the use of negative and/or positive pressures as described in above-cited parent application Ser. No. 746,940. The packaging may be sterilized before use to eliminate any harmful microorganisms present on the packaging.

The following examples describe in detail representative applications of a packaging technique as just described in the pasteurization of eggs by the principles elucidated herein.

EXAMPLE XVI

Eight (8) 60 gm eggs tempered at 140° F. for 5 minutes in circulating air were removed from the tempering unit and immediately placed in a 500 ml beaker filled with CO_2 at 32° F. for 2 minutes. The eggs were removed from the beaker and placed in 4 in×4 in Seal-A-Meal® bags, which were immediately sealed. The eggs were in-bag pasteurized at 138° F. in a water bath and examined after 40 minutes at 5 minute intervals. The eggs showed no significant occlusion after pasteurization for 75 minutes.

Controls were all occluded after 68 minutes. This indicates that the CO_2 taken up in the eggs produced an at least 10% increase in heat tolerance. This is important in circumstances requiring that the egg be heated at a maximum or near maximum permissible temperature for the maximum length of time—for example, if heavy or widespread contamination throughout the mass of the egg with an infection is suspected.

The test was repeated at an otherwise unacceptably high 140° F. pasteurization temperature with the eggs being cracked every 2 minutes after 6 minutes pasteurization elapsed. CO_2 treated eggs showed little or no occlusion until after 18–20 minutes of pasteurization. Controls showed signs of occlusion after 12–14 minutes.

EXAMPLE XVII

Thirty-six (36) eggs inoculated through the shell with *Salmonella typhimurium* (10^9 gm) were divided into four nine-egg batches and placed individually in 4 in×4 in Seal-A-Meal® bags to which 6 gms each of dry ice (frozen CO_2) had just been added. The bags were sealed; and each batch of bagged eggs was separately processed in the 138° F. water pasteurization bath for 40 minutes TPT. Four eggs were then removed from the pasteurization bath in each run and analyzed.

Results:

	Average Reduction in Bacteria (percent)
Batch 1:	~70
Batch 2:	~80
Batch 3:	~60
Batch 4:	~70

The remaining eggs in each bath were processed an additional 2 minutes, removed from the bath, and analyzed.

Results:

	Average Reduction in Bacteria (percent)
Batch 1:	~100
Batch 2:	~80
Batch 3:	~90
Batch 4:	~90

As a consequence of adding CO_2 to the bags, it was possible to pasteurize the eggs for longer periods or at slightly higher temperatures with delayed occlusion (cooking). Both approaches permit better kills of infections.

EXAMPLE XVIII

Mild, safely consumable acids can also be used to increase the resistance of eggs to occlusion or coagulation of the whites, to reduce the loss of functionality, and to reduce other forms of degradation during time at temperature pasteurization.

This aspect of the invention is illustrated by the following tests:

Control

Thirty-six (36) medium sized eggs were each inoculated through the shell with 0.05 mls distilled water carrying a *Salmonella typhimurium* culture at a rate of 10^9 gm and divided into four batches of nine eggs each. The four batches were separately processed in a 138° F. water pasteurization bath for 40 minutes. Four eggs of each batch were removed from the bath and analyzed.

Results:

	Average Reduction in Bacteria (percent)
Batch 1:	~60
Batch 2:	~60
Batch 3:	~60
Batch 4:	~70

The remaining eggs were processed an additional 2 minutes, and the bacteria kill was measured in the manner just described:

Results:

	Average Reduction in Bacteria (percent)
Batch 1:	~70
Batch 2:	~70
Batch 3:	~80
Batch 4:	~70

Acid processed: The eggs in four nine-egg batches were inoculated through the shell with *Salmonella typhimurium* (10^9 microorganisms per gram) in the same manner as the controls. The four batches of inoculated eggs were separately pasteurization processed in the 138° F. water bath to which 0.2% volume percent of citric acid had been added for 40 minutes. Four eggs were removed from each batch, and the bacteria kill was measured.

Results:

	Average Reduction in Bacteria (percent)
Batch 1:	~60
Batch 2:	~80
Batch 3:	~70
Batch 4:	~70

The remaining eggs of each batch were processed an additional 2 minutes and the bacteria kill measured.

Results:

	Average Reduction in Bacteria (percent)
Batch 1:	~90
Batch 2:	~80
Batch 3:	~90
Batch 4:	~70

The increased level of bacterial kill is significant, especially in the case of the eggs pasteurized for the additional 2 minutes.

Citric acid may be used for the purposes just described in concentrations ranging from 0.05 to 0.5 percent based on the volume of the bath. Other acids which can be employed for the purposes just described include the above-mentioned ascorbic, benzoic, and lactic.

As discussed in detail in the working examples and elsewhere above, processes employing the principles of the present invention are designed to make shell poultry eggs safer to eat by destroying harmful organisms superficially resident on the outer surface of the shell and throughout the shell and interior of the egg without impairing the functionality of the egg or altering its organoleptic properties by holding the shell eggs under time/temperature conditions which will destroy harmful bacteria on and inside the egg shells.

One system in which a process of this character can be carried out is illustrated in FIG. **12** and identified by reference character **71**. That system includes a holding vessel or pasteurization tank **72**, an optionally employed pore sealing unit **74**, a heat exchanger **76**, and a packaging unit **78**.

As is discussed elsewhere in this specification, the initial step in treating whole eggs in a system like that identified by reference character **71** is to clean and, typically, disinfect the outer surfaces of the shell eggs.

The cleaned eggs are transferred to tank **72** where they are held in water or another pasteurization medium at the temperature and for the time selected to reduce any infection located anywhere in the mass of the eggs to a level at least equivalent to that obtained by pasteurizing liquid whole eggs to USDA minimum or protracted standards.

Thereafter, the treated shell eggs can be transferred to heat exchanger **76** to rapidly reduce their temperature to a level which is below that at which growth of any remaining viable bacteria might be a problem and appropriate for packaging. Then, the now cooler eggs are transferred to packaging unit **78** where they are placed in cartons or other containers.

Optionally, the pores and the shells of the treated eggs can be treated with palm stearine or other sealing agent before they are packaged in unit **78**. This keeps infectious microorganisms as well as oxygen-containing and other unwanted gases from contaminating the pasteurized egg by penetrating through the pores in the egg shells to the interior of the egg, thereby reducing degradation, preserving food safety, and improving the keeping quality of the treated egg.

It was also pointed out above that the keeping quality and food safety of eggs treated in the manner just described can often be even further improved by evacuating indigenous gases from the interior of the egg shell and replacing the evacuated gases with inert gases before the pores of the egg shell are sealed. A system for carrying out this process is illustrated in FIG. **13** and identified by reference character **80**.

That system includes pasteurization vessel **72**; vacuum vessel **82**; packaging unit of **85**; pressure vessel **84**; sources **86**, **88**, and **90** of carbon dioxide, sterile air, and nitrogen; pore sealing unit **74** (optional); heat exchanger **76**; and packaging unit **78**.

Cleaned and treated eggs are transferred from the tank **72** in which they are pasteurized to vacuum tank **82**. Here, they are held under negative pressure for a period long enough to draw unwanted, indigenous gases from the interior of the egg through the pores in its shell. Of concern are those gases such as oxygen that might cause unwanted chemical reactions; e.g., those that produce spoilage.

From vacuum unit **82**, the shell eggs are transferred, still under a negative pressure, to pressure vessel **84**. Sterile gas is introduced into the vessel from one or more of the sources **86** . . . **90** under pressure; and the eggs are held in this pressurized environment for a period long enough for the selected gas or mixture of gases to infuse through the pores in the egg shell and fill the interstices in those parts of the egg within the shell.

Thereafter, the treated shell eggs may be cooled in heat exchanger **76** and packaged in unit **78**. Alternatively, the pores in the egg shells may first be sealed in unit **74** to

prevent unwanted exchanges between gas infused into the eggs through the pores in their shells and gases in the surrounding environs.

Also, in using system **80**, the pasteurized eggs may be packaged before they are cooled in order to decrease the chances of recontamination before the eggs are cooled. In this case packaging unit **85** is employed, and unit **74** is deactivated. The package may be filled with an atmosphere-modifying gas of the character and for the purposes discussed above in pressure vessel **84**.

Referring still to the drawing, FIG. **14** discloses another "basic" system **94** for processing whole shell eggs which includes pasteurization unit **72** and cooling unit **78** and, in addition: a shell egg cleaning unit **96**, a packaging unit **98**, and a storage unit **100** for the packaged eggs. Cleaning unit **96** is conventional and is employed to superficially clean the exteriors of the eggs being processed before they are introduced into pasteurization unit **72**.

Packaging unit **98** is also conventional. Here, the eggs are placed in cartons or other packages including those designed to hold only a single egg.

The term storage unit is employed generically. This may be, at various times, and even for the same eggs, a refrigerated warehouse or truck or the cooler at a retail outlet.

The whole shell egg processing system **104** depicted in FIG. **15** differs from the processing system **94** just described primarily by the addition of a tempering unit **106**; a post-pasteurization unit **108**; and, optionally, a source **110** of an inert gas such as carbon dioxide, nitrogen, or a mixture of the foregoing.

Tempering unit **106** is used vide EXAMPLE XII above and elsewhere in this specification to reduce breakage of the eggs being processed, a technique which is particularly useful when the differential between the initial egg temperature and the pasteurization process temperature is large and the risk of breakage is accordingly high. Post-pasteurization unit **108** is employed to treat the eggs to prevent recontamination by sealing the pores of the egg shells as discussed above or by packaging the eggs. If the latter technique is adopted, unit **110** may optionally be employed to fill the packages with an atmosphere modifying gas of the character and for the purposes discussed above.

Depicted in FIG. **16** is a shell egg processing system **112** which differs from the FIG. **14** system **94** primarily by the addition of an egg packaging unit **114**, an optional inert gas source **116**, and a package filling and sealing unit **118**.

Packaging unit **114** is employed vide examples XIII–XVII and for the purposes described in those examples and elsewhere in the specification to package the eggs cleaned in unit **96** before they are pasteurized. An inert gas from source **116** may optionally be employed to fill the packages before they are sealed and transferred to pasteurization unit **72**. Alternatively, as indicated by reference character **118**, the packaged eggs may be optionally filled with a sterile inert gas and sealed immediately after they are pasteurized and before they are transferred to cooling unit **78**.

As discussed above, it is possible to significantly shorten the time required to reach EqT in processing eggs for improved safety in accord with the principles of the present invention by: first heating the eggs to a temperature above that at which they can be heated for a time equivalent or exceeding the minimum mandated by the USDA for liquid whole eggs, then holding the eggs for a dwell period in which the heat soaks into the eggs, and then pasteurizing the eggs at the selected temperature in the range specified above. A unit for processing whole shell eggs in the manner just described is depicted in FIG. **17** and identified by reference character **122**. That system differs from the basic system illustrated in FIG. **14** primarily by the interposition of an overshoot unit **124** between shell egg cleaning unit **96** and pasteurization unit **72**. The medium in which the eggs are heated in overshoot unit **124** may be any of those indicated above to be suitable for use in pasteurization unit **72**.

The invention may be embodied in many forms without departing from the spirit or essential characteristics of the invention. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description; and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed is:

1. A method of making a poultry shell egg safer to eat, said method comprising the steps of:

promoting the transfer of heat to the egg by first heating said egg at a temperature above that at which the white of the egg will coagulate but not higher than about 170° F. but for a sufficiently short period of time to preclude significant coagulation of said white; and then

heating said egg at a second, lower, pasteurization temperature in the range of 130° F. to <140° F. and below the coagulation temperature of the egg white for a time sufficient to destroy infectious microorganisms throughout the mass of the egg.

2. A method of improving the food safety quality of a poultry shell egg, said method comprising the steps of:

promoting the transfer of heat to the egg by heating the egg at a first, higher temperature above that at which the white of the egg will coagulate and in the range of 139° to about 170° F. but for a sufficiently short period of time to preclude significant coagulation of said white; and then

heating said egg at a second, lower pasteurization temperature of at least 130° F. and below the coagulation temperature of the egg white for a time sufficient to destroy infectious microorganisms throughout the mass of the egg.

3. A method as defined in claim **2** in which the egg is first heated at a temperature in the range of 139° to 150° F. for a period of 2 to 3 minutes and is then heated at a pasteurization temperature in the range of 130° to less than 140° F.

* * * * *

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United States Patent [19]

Davidson

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[45] Date of Patent: Dec. 1, 1998

[54] METHOD FOR PRODUCTION OF PASTEURIZED IN-SHELL CHICKEN EGGS

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[21] Appl. No.: 962,766

[22] Filed: Nov. 3, 1997

Related U.S. Application Data

[63] Continuation of Ser. No. 519,184, Aug. 25, 1995, abandoned.

[51] Int. Cl.[6] A23B 5/00; A23L 1/32; A23L 3/16

[52] U.S. Cl. 426/298; 426/614; 426/521

[58] Field of Search 426/614, 521, 426/298

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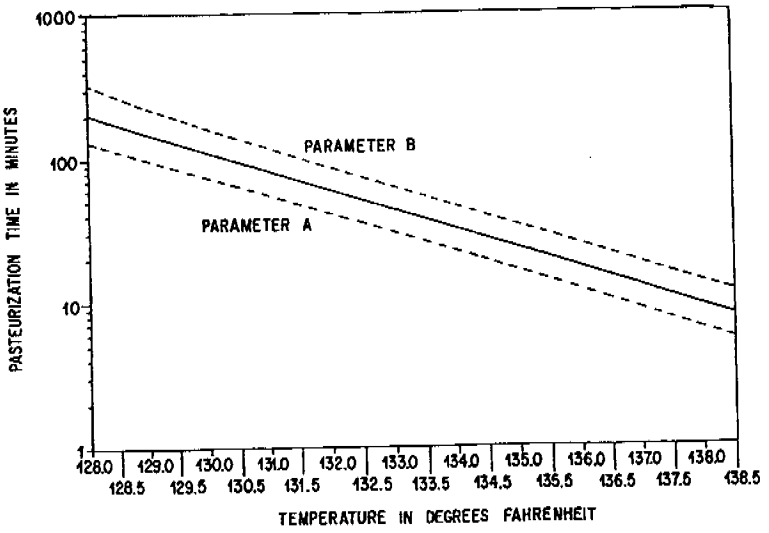
[57] ABSTRACT

A method of pasteurizing in-shell chicken eggs by heating eggs until a central portion of the yolks of the eggs is at a temperature between 128° F. to 138.5° F. That temperature is maintained and controlled for times within parameter line A and parameter line B of FIG. 1 and sufficient that any Salmonella species present in the yolk is reduced by at least 5 logs but insufficient that an albumen functionality of the egg measured in Haugh units is substantially less than the albumen functionality of a corresponding unpasteurized in-shell egg.

18 Claims, 1 Drawing Sheet



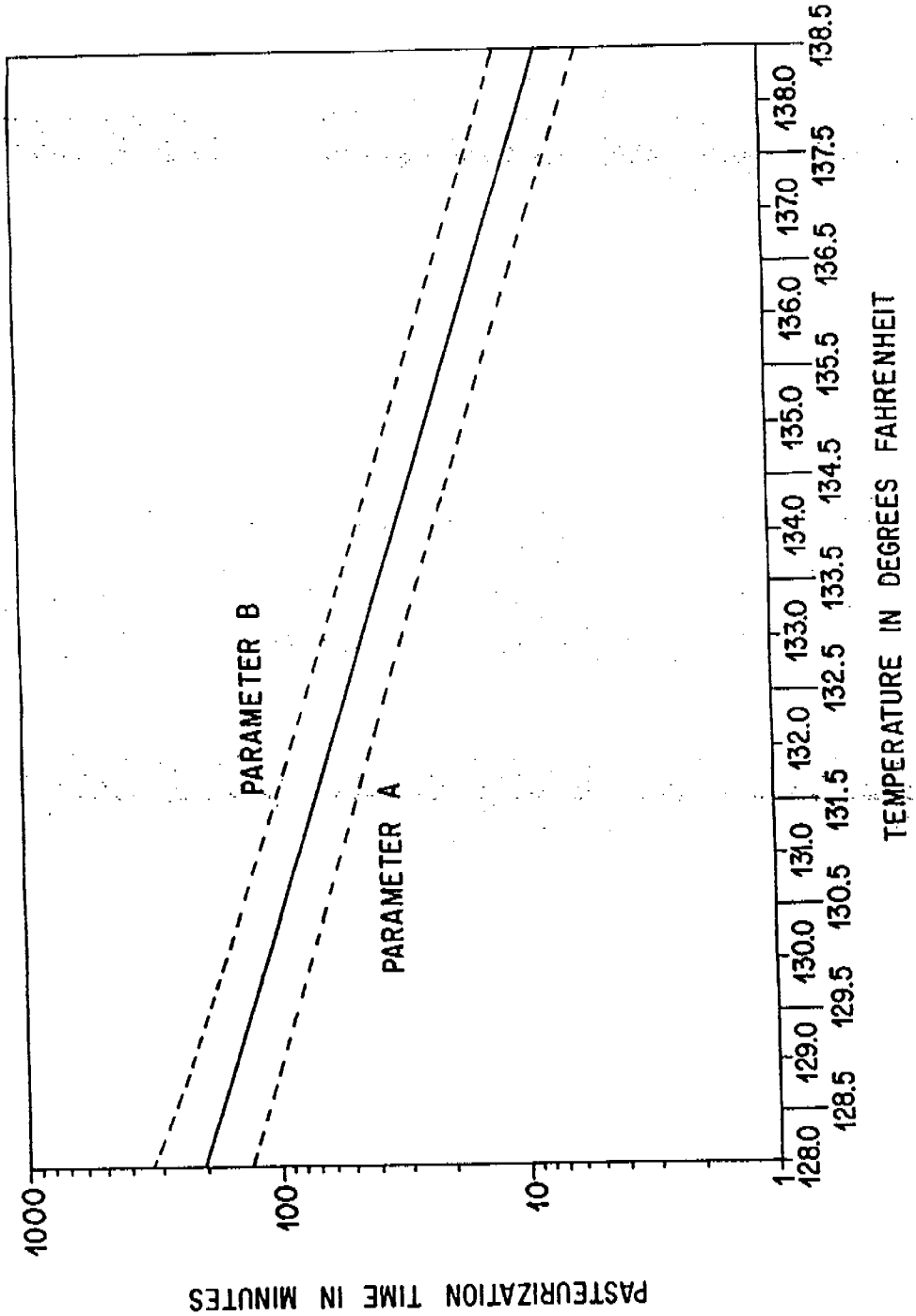

PARAMETER B
PARAMETER A
1000
100
10
1
PASTEURIZATION TIME IN MINUTES
128.0
128.5
129.0
129.5
130.0
130.5
131.0
131.5
132.0
132.5
133.0
133.5
134.0
134.5
135.0
135.5
136.0
136.5
137.0
137.5
138.0
138.5
TEMPERATURE IN DEGREES FAHRENHEIT

FIG. 1

METHOD FOR PRODUCTION OF PASTEURIZED IN-SHELL CHICKEN EGGS

This application is a continuation of Ser. No. 08/519,184, filed Aug. 25, 1995, now abandoned.

The present invention relates to pasteurized in-shell chicken eggs and to a method for production thereof, and, more particularly, to such eggs and method where certain pathogens whenever present in the eggs are reduced in quantity to a level safe for human consumption while at the same time the functionality of the eggs is preserved, particularly the albumen functionality, such that the pasteurized eggs are substitutable for fresh, unpasteurized eggs in most consumption uses.

BACKGROUND OF THE INVENTION

The term pasteurization is used herein in connection with the present invention in the general sense that the term is applied to other food products, e.g. pasteurized milk, in that the present pasteurized eggs are partially sterilized at temperatures which destroy objectionable microorganisms, without major changes in the functionality of the eggs. In this regard, food products are conventionally heated at temperatures and for times so as to sufficiently destroy pathogenic microorganisms, which may be contained in the food, so that the pasteurized food is safe for human consumption. In order to provide a pasteurized food safe for human consumption, it is not necessary that all pathogenic microorganisms in the food be destroyed, but it is necessary that those pathogenic microorganisms be reduced to such a low level that the organisms cannot produce illness in humans of usual health and condition. For example, fresh whole milk may contain virulent pathogenic microorganisms, most notably microorganisms which cause tuberculosis in humans, and during pasteurization of the milk, those pathogenic microorganisms are reduced to such low levels that the milk is safe for consumption by humans of ordinary health and condition. In the case of some microorganisms, however, usual pasteurization temperatures and times can completely destroy those microorganisms. Milk so pasteurized does not have major changes in the functionality thereof. The taste and texture of pasteurized milk are slightly changed, but those changes are not of practical significance to most consumers thereof.

Heat destruction of microorganisms in eggs has long been known in that the eggs were cooked sufficiently to effect destruction thereof. For example, when frying an egg, fried to a reasonable hardness, microorganism destruction will occur. Likewise, when boiling an egg to a hard-boiled state, heat destruction of microorganisms in the egg will occur. However, with these cooking processes, major changes in the functionality of the egg occurs, e.g. coagulation of the yolk and white, and, thus, this is not pasteurization in the usual sense, as explained above.

Recently, pasteurization of liquid chicken eggs (eggs out of the shell) has been commercially practiced. The process, very basically, involves heating liquid chicken eggs for short times at higher temperatures to reduce any pathogenic microorganisms therein such that the pasteurized liquid chicken eggs are safe for human consumption, while, at the same time, major changes in functionality do not occur. See, for example, U.S. Pat. No. 4,808,425.

However, the art has long since struggled with pasteurizing in-shell chicken eggs. While in-shell eggs may be heated sufficiently to destroy microorganisms, the art has not, at the same time, been able to substantially retain the functionality of the eggs. The functionality is determined by various tests, but a more basic test is that of the albumen functionality, which test measures the whipped volume, under standard conditions, of whipped liquid albumen, as measured in Haugh units.

In the case of liquid chicken eggs (not in the shell), by careful control of the time and temperature of heating the liquid eggs, usually with a short time, high temperature (HTST) apparatus, pasteurization can be achieved while retaining, at least substantially, the functionality of the eggs. This is particularly true when the liquid eggs are heated for pasteurization purposes in a very thin film, where the temperature and time of heating of the liquid eggs can be very carefully controlled.

In liquid eggs, the yolk may or may not be mixed with the albumen. As can be appreciated, however, with in-shell chicken eggs (also referred to as "shell eggs"), not only is the mass of the egg substantially different from the mass of a unit of thin film of liquid eggs, but the yolk is essentially centrally positioned in the shell. Accordingly, while the art has struggled for some time to carefully control temperatures and times for pasteurizing in-shell eggs, none of those efforts in the art have been successful in terms of both reducing pathogenic microorganisms found in chicken eggs to a level safe for human consumption while maintaining essentially the same functionality of the eggs as unpasteurized eggs. As a result, no commercial process for pasteurizing in-shell eggs and no commercial pasteurized in-shell eggs have been available.

The art has taken many different approaches in attempts to pasteurize in-shell eggs. See, for example, U.S. Pat. Nos. 1,163,873; 2,423,233; 2,673,160; and 3,658,558. The more prevalent approaches involve heating the in-shell eggs, usually in a water bath, for various times and at various temperatures, as specified by the various investigators in the art. These times and temperatures specified by the various investigators vary widely, and this is because all of those approaches involve a compromise either in the degree of safety achieved or in the quality of the functionality retained.

In this latter regard, if the in-shell egg is heated in a water bath, where the water bath temperature and time of heating are specified by the investigator, one of two results have generally occurred. The first result is that, when higher temperatures and longer times are specified, while the egg may be acceptably reduced in microorganism content, the functionality of the egg is also considerably reduced, such that the egg is no longer substitutable for unpasteurized eggs in either usual home cooking, e.g. frying, or in conventional baking recipes. The other result, when using lower temperatures of the water bath and shorter times, while the functionality of the egg is substantially maintained, the decrease in pathogenic microorganisms, which may be present in the eggs, is severely compromised, and the egg may be safer but not be safe for human consumption. While eggs processed according to this latter approach can be said to be safer to eat, in that there is some reduction of pathogenic microorganisms in the eggs, the eggs are not pasteurized in the sense as set forth above, i.e. that they are safe for consumption by humans of ordinary health and condition.

Faced with the above difficulties, that art searched for intermediate water bath temperatures and dwell times where functionality of the egg is preserved and microorganisms are substantially reduced. Unfortunately, these searches have generally resulted in the worst of both of the results noted above, i.e. both reduced functionality of the egg and still insufficient reduction in microorganisms, which result is less desirable than either of the two above-noted general results.

Accordingly, therefore, the art has been on the horns of a dilemma, i.e. if the times of dwell and temperatures of the water bath are high enough to substantially reduce the microorganism content of in-shell eggs, then the functionality of the eggs is substantially reduced, while if the times of dwell and temperatures of the water bath are sufficiently low as to substantially maintain the functionality of the eggs, the eggs are not sufficiently reduced in microorganism content so as to be pasteurized.

Pathogenic microorganisms are introduced into chicken eggs by two principal routes. Firstly, pathogens are introduced into the in-shell eggs from environmental contamination. This environmental contamination may occur through a variety of causes, but typically, infected chickens or mice in commercial egg-laying chicken houses deposit feces which contact the shell of a laid egg. Certain microorganisms, especially Salmonella, when in contact with the shell of the egg, can penetrate that shell, especially through small fissures or pores in the shell. That contamination is, therefore, from the outside of the shell into the egg, and the contamination remains, largely, in the albumen near the shell. This contamination can be very substantially reduced by the above-noted approaches of the prior art, since, when the egg is placed in a water bath heated to the temperatures suggested by the art, this is sufficient to heat the albumen near the shell and substantially destroy pathogens which may have penetrated the shell from environmental contamination. In this sense, the egg is, indeed, safer to eat.

The second route of contamination in the eggs is systemic, and this poses a far more difficult problem. Typically, feces of infected chickens or mice are ingested by the chicken during feeding, and that infection becomes systemic in the chicken. Certain organisms, very notably *Salmonella enteritidis*, enter the bloodstream of the chicken and pass, trans-ovarially, into the interior of the egg itself. Most especially, that systemic contamination occurs in the yolk of the egg, although that contamination can also easily extend into the albumen. In this type of contamination, the prior art approaches, as noted above, are ineffective toward substantially reducing microorganisms in the eggs, including the yolk, while at the same time maintaining the functionality of the eggs.

While many suggestions have been made in the prior art, principally, a water bath is heated to specified temperatures (although air, oil and the like heat transfer media have been suggested), and the in-shell eggs are then placed in that heated water bath and dwell therein for a specified length of time. It is generally assumed that the yolk temperature will come to equilibrium with the water bath temperature after a sufficiently long dwell time of the eggs. Unfortunately, specifying the temperature of the water bath and the time of dwell of the eggs therein does not necessarily specify temperatures within the eggs, and especially the yolks. This is because eggs can vary in one or more of weight, size, shape, composition (e.g. relative size of yolk and air sack) and density, all of which affects the heat transfer properties of a particular egg in the water bath at the specified temperatures. Thus, when operating in water baths at specified temperatures within specified time ranges, the temperature within a particular egg, and especially the yolk, is entirely problematic, and, hence, the control of the prior art approaches toward pasteurizing eggs, especially in regard to yolk contamination, has been completely inadequate and more or less is a matter of chance—see, for example, WO 95/14388.

The specified temperatures of the water baths in the prior art vary considerably, with some investigators taking the approach of relatively low temperature baths, e.g. as low as about 100° F., with long dwell periods of the eggs, while other investigators took the approach of high temperature baths, e.g. up to 160° F., with relatively short dwell periods of the eggs, and others took an intermediate approach, e.g. 130° F. to 140° F., with intermediate dwell periods, e.g. 50 minutes. However, no matter which of these approaches is adopted, as explained above, the art simply has not found combinations of temperatures of water baths and times of dwell which will ensure eggs safe for human consumption, i.e. pasteurized eggs, including pasteurization of the yolks, while at the same time maintaining the functionality of the eggs. Accordingly, it would be a very substantial benefit to the art to provide a method for pasteurizing eggs where the eggs are not only pasteurized, i.e. safe for consumption by humans of ordinary health and condition, but which also assures that the functionality of the eggs is substantially retained.

BRIEF SUMMARY OF THE INVENTION

Very briefly, the present invention provides pasteurization of an in-shell chicken egg, i.e. safe to eat by humans of ordinary health and condition, by achieving a 5 log reduction of Salmonella species which may be present in the egg by controlling the yolk temperature within relatively narrow limits so that both the pasteurization is achieved and the functionality of the egg is not substantially decreased. In these regards, the present invention is based on several primary discoveries and several subsidiary discoveries.

As a primary discovery, it was found that, if the temperature and dwell time of the yolk is at a certain correlation of temperature and time or within a 95% confidence level deviation, Salmonella species which may be present in the egg yolk, as well as the albumen, can be reduced by at least 5 logs, which reduction is sufficient for true pasteurization, i.e. safe for consumption by humans of ordinary health and condition, while at the same time there is a retention of functionality of the eggs.

As a subsidiary discovery in this regard, it was found that, if Salmonella species are reduced by that at least 5 logs, other microorganisms found in the egg are also reduced, such that the egg is pasteurized in respect to those other microorganisms.

As a second primary discovery, it was found that, if the egg is pasteurized according to that certain correlation, or within the limits of deviations noted above, the albumen functionality of the egg, measured in Haugh units, is not substantially deteriorated, as compared with a corresponding unpasteurized in-shell egg.

As a third primary discovery, it was found that, in order to effectively pasteurize an egg, the yolk temperature of that egg must be controlled within relatively narrow temperature limits.

As a subsidiary discovery in this regard, it was found that the temperature of the yolk must be controlled in a range of from 128° F. to 138.5° F. At temperatures of the yolk below 128° F., adequate pasteurization will not occur. On the other hand, at temperatures of the yolk above 138.5° F., the functionality of the egg substantially decreases.

As a fourth primary discovery, it was found that, within this range of yolk temperatures, the dwell time of the yolk at a selected temperature must be relatively closely correlated to that temperature. If the dwell time is significantly below that correlation, pasteurization will not occur. On the other hand, if the dwell time is significantly above that correlation, then the functionality of the egg is substantially deteriorated.

As a subsidiary discovery in this regard, it was found that the limits of deviation from that correlation which are permissible to achieve both pasteurization and retention of functionality are relatively small. Deviations should be no greater than that which will provide a 95% statistical confidence level of pasteurization. Thus, the limits of deviation from that specific correlation must be carefully observed.

Thus, broadly stated, the present invention provides a method of pasteurizing an in-shell chicken egg comprising heating the egg until a central portion of the yolk of the egg is controlled within the range of 128° F. to 138.5° F., and maintaining that controlled yolk temperature for times within parameter line A and parameter line B of FIG. 1 annexed hereto and sufficient that a Salmonella species that may be present in the egg is reduced in amount by at least 5 logs but insufficient that an albumen functionality of the egg measured in Haugh units is substantially less than the albumen functionality of a corresponding unpasteurized in-shell egg.

The invention also provides a pasteurized in-shell chicken egg comprising a pasteurized central portion of a yolk of the egg having at least a 5 log reduction of a Salmonella species that may be present in the yolk in its unpasteurized form. The so-pasteurized egg will have an albumen functionality measured in Haugh units not substantially less that the albumen functionality of a corresponding unpasteurized in-shell egg.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a graph showing the required correlation between the temperatures of a central portion of the yolk of an egg during the pasteurization process and the log (base 10) of time at which that central portion of the yolk of the egg dwells at such temperatures. That graph also shows permissible limits of deviation from that correlation, indicated by parameter lines A and B.

DESCRIPTION OF PREFERRED EMBODIMENTS

The present invention is directed to in-shell chicken eggs, and it cannot be extrapolated to other in-shell poultry eggs. In-shell poultry eggs from different birds vary considerably in the mass, propensity for coagulation of the albumen and yolk, temperatures and dwell times for adequate pasteurization, heat transfer properties, and usual functionalities. For example, it has been found that an in-shell duck egg, which is probably the closest poultry egg to a chicken egg, cannot be pasteurized to a 5 log cycle reduction of a Salmonella species found in chicken eggs and maintain functionality with the method of the present invention. In attempts to pasteurize in-shell duck eggs by this method, it was found that the time and temperature correlations found for in-shell chicken eggs were inappropriate for in-shell duck eggs. Therefore, it is emphasized that the invention relates only to in-shell chicken eggs, and the method of the invention cannot be considered workable to any other in-shell poultry egg. See Dutch Patent No. 72,454.

As opposed to the prior art, briefly summarized above, which relied upon the temperature of the medium for heating the egg, e.g. usually water, the present invention relies upon the temperatures of the yolk of the egg, along with the correlated dwell times of the yolk at those temperatures, and for this reason, the particular medium in which the egg is heated is not critical, as opposed to that of the prior art. Thus, in the prior art, since, generally speaking, the temperature of the heating medium was controlled and the temperature of the yolk was essentially uncontrolled, the choice of heating medium was a critical choice because the heat transfer properties of a particular medium greatly influenced the results of the process. For that reason, most of the approaches in the prior art chose water as the heating medium, since the temperature of the water in a heating bath could be carefully controlled, and heat transfer from the water bath to the egg is accelerated. The present invention does not rely on controlling the temperature of the heating medium to effect pasteurization. Conversely, the present invention relies on controlling the temperature of the yolk. Thus, the heating medium of the present invention can vary widely. The egg can be heated with any fluid heat transfer medium or it can be heated by direct heat from heat sources, such as radiant heaters, infrared heaters, or radiation, such as microwaves. However, since all of those direct heating means require special care in ensuring that the direct heat uniformly heats all surfaces of the egg, it is preferred that the heating medium is a fluid heat transfer medium, since the fluid can be caused to flow around the egg and ensure uniform heating along all surfaces of the shell of the egg. The fluid medium may be any gas, e.g. air, nitrogen, carbon dioxide, etc., but it is preferred that the fluid medium be an aqueous medium, since heat transfer from aqueous mediums is easy to control. Thus, the aqueous medium may be in the form of water vapor, but, more preferably, the aqueous medium is liquid water. Mixtures or sequences of heating medium may also be used, e.g. water and then air.

However, liquid water does have a disadvantage in that, as is well known, during heating in liquid water, gases nucleate on the shell of the egg. This can be observed by anyone boiling an egg in a pot. The nucleated gases decrease the heat transfer between the liquid water and the shell of the egg and, hence, into the interior of the egg. Since this decrease in heat transfer may not be uniform throughout the area of nucleated gases on the shell of the egg, it is most preferable to avoid or displace those nucleated gases to the extent possible. This may be done by adding a surface active agent to the water, e.g. a food-grade ionic, anionic or non-ionic surface active agent, many of which are known in the art, for example, the Tweens. Usually only a fraction of a percent of surface active agent is necessary, e.g. one half of one percent based on the weight of the water, although the surface active agent can be as low as one hundredth of a percent and as high as three or four percent.

Alternatively, the nucleated gases may be displaced from the shell of the egg when at least one of the water and the egg is in motion relative to the other. Thus, the water may be sprayed onto the egg, which keeps the water in motion relative to the egg, or the egg may pass through a substantially continuous curtain of flowing water, or in a water bath, the water may be fully circulated over the egg. In addition, in any of the above cases, the egg may be rotated on a support, and supports for rotating eggs are well known in the art. Alternatively, both motion of the water and the egg can be used, along with a surfactant (non-foaming surfactant) to minimize or avoid inconsistent heat transfers due to nucleated gases.

As noted above, the present invention relies on controlling the temperature and dwell time of the yolk of the egg. However, within the entire yolk, the temperatures thereof may vary, depending upon the proximity of a particular portion of the yolk to the shell and the proximity of the particular portion of the yolk to the center of the yolk. As will be explained hereinafter in detail, the present method is carried out by controlling the temperature of the yolk at a central portion thereof. The center of the yolk, of course, is

a theoretical point and modern temperature-measuring devices are not capable of measuring temperatures at a theoretical point. However, such devices are capable of measuring temperatures in a central portion of the yolk, consistent with the width of a modern temperature-measuring probe, e.g. thermocouple. Thus, in the present specification and claims, the central portion of the yolk is defined to mean that portion of the yolk substantially surrounding the center of the yolk which has sufficient volume to accommodate and receive a conventional temperature-measuring probe.

As noted above, it has been found that the temperature of the yolk must be in the range of 128° F. to 138.5° F. While pasteurization can be achieved with yolk temperatures as low as 126° F., this temperature is near the minimum temperature to kill Salmonella and variables, such as particular egg histories and sizes/grades, etc., as explained below, very significantly affect results. Thus, at 126° F., the results are so variable as to be unreliable, and to avoid the same, the yolk temperature must be at a higher value, i.e. at 128° F. or higher.

In this regard, experiments which attempted to establish the correlation line of FIG. 1 at between 128° F. and 126° F. showed the data for that correlation line to be so scattered that parameter lines A and B could not be established with any certainty. This reflects that at temperatures below 128° F. the above-mentioned variables become so significant that pasteurization while retaining functionality cannot be accurately predicted. Thus, for practical application of the invention, the central portion of the yolk must be at a temperature of 128° F. or higher.

This means, of course, that when a heat transfer medium as described above is used, that medium must be at a temperature of at least 128° F., since, otherwise, that heating medium would not be capable of heating the central portion of the yolk to at least 128° F. On the other hand, while the central portion of the yolk should not reach a temperature greater than about 138.5° F., the temperature of the heating medium can be higher than that temperature, since there will be a temperature differential between the temperature of the heating medium and the central portion of the yolk until an equilibrium temperature is established. However, it has also been found that a higher temperature of the heating medium should not be substantially greater than 138.5° F., since, otherwise, the chances of decreasing the functionality of the albumen before pasteurization occurs, especially near the shell, increases. For this reason, it is preferable that the medium is heated to temperatures no greater than 142° F.

The medium may be heated to more than one temperature during the pasteurization process. For example, the medium may be heated to a higher temperature of no greater than 142° F. for part of the pasteurization dwell time of the yolk, and then cooled to lower temperatures no less than 128° F. for the remainder of the portion of the dwell time of the yolk. There are certain advantages to heating to such higher temperatures and then cooling to such lower temperatures during the pasteurization process, in that the total time required for pasteurization is decreased. At the higher yolk temperatures, within parameter lines A and B of FIG. 1, the chances of decreased albumen functionality are increased. Therefore, in order to decrease processing time and the chances of decreased functionality, the heating medium may be heated to higher temperatures for part of the pasteurization and then heated to a lower temperature for the remaining part of the pasteurization, consistent, of course, with the yolk temperature being within the range specified above and within the dwell times of parameter lines A and B. If such different temperatures of the heating medium are used, it is preferable that the higher temperatures are between about 136° F. and 139° F. and the lower temperatures are between about 131° F. and 135° F.

The most preferred method in the foregoing regard is that of using one or more higher heating medium temperatures, e.g. 138° F., until the yolk temperature reaches a target value, e.g. 134° F., and then decreasing the temperature of the medium to that target temperature, e.g. 134° F., and maintaining that reduced medium temperature until the dwell time specified by FIG. 1 is reached. Several or more different medium temperatures may be used, so long as the resulting temperatures and dwell times of the yolk fall within parameter lines A and B of FIG. 1. This provides some latitude in fine adjustment of the process for optimum pasteurization and retention of functionality of the egg even with varying egg input and input egg conditions.

In this latter regard, a difficult problem in the prior art, where the eggs were processed by temperature control of the heating medium alone, e.g. a water bath, for specified time ranges, is that the particular input eggs and the prior handling conditions thereof could very substantially affect the results. For example, freshly laid eggs are normally stored in controlled temperature refrigerators until handling, processing, packaging and distribution are achieved, with the possible exception of grading. However, such conditions are not uniform, and the conditions vary from processor to processor. Thus, if eggs to be processed according to the prior art were stored at 41° F. and then placed in a heated water bath maintained at the prescribed temperatures and allowed to dwell therein for the prescribed time, the actual results that would be achieved thereby in terms of decrease in microorganisms and preserved functionality would vary significantly from that which would be achieved if the eggs had been stored at, for example, 44° F. Those results would vary most considerably if the eggs to be processed were brought to room temperature before processing. This is because the amount of heat required to be transferred into the egg to achieve reduction in microorganisms depends upon the temperature of the egg entering the process, e.g. entering the temperature-controlled hot water bath.

Likewise, the effects of specific dwell times in a water bath controlled at a specific temperatures will vary with the age of the egg. In addition, it will vary with the size, particular configuration, weight and density of the particular egg, which can vary somewhat. At least to some extent, the effects will vary with the particular breed of poultry used to produce the eggs.

All of these problems are obviated by the present method, where the control for pasteurization and retention of functionality is not in connection, specifically, with the temperature of the heat transfer medium, but is the result of the control of the temperature of the central portion of the yolk of the egg.

However, changes in functionality, especially of the albumen, can occur when the time required to reach the target yolk temperature within parameter lines A and B is overly long. This is referred to as the "come-up" time. The "come-up" time can be minimized by prewarming the eggs, e.g. to room temperature or up to about 120° F., prior to processing for pasteurization. It should be noted that any time during which the yolks of the eggs are within parameter lines A and B in reaching such target yolk temperature should be subtracted from the dwell time required by FIG. 1.

In regard to the "come-up" time, it was found that at yolk temperatures below 120° F., the growth rate of Salmonella

is very low. Further, it was found that at yolk temperatures at 120° F. or below, protein denaturing (loss of functionality) also proceeds at a very low rate. With these two discoveries, it was found that eggs could be prewarmed to yolk temperatures up to 120° F. over relative long times without any significant increase in Salmonella or decrease in functionality. While the longer the prewarming time the greater the chance for loss of functionality and increase in Salmonella, prewarming periods of up to two hours, especially one hour and more especially up to 30 minutes are quite satisfactory. Such prewarming can considerably reduce the "come-up" time.

As noted above, the present method ensures that a Salmonella species, which may be present in the egg yolk, is reduced by at least 5 logs (base 10 log) while the albumen functionality of the egg, measured in Haugh units, is not substantially less than the albumen functionality of a corresponding unpasteurized in-shell egg. In this regard, it has been found that if a Salmonella species present in the egg is reduced in an amount by at least 5 logs, then any other pathogenic microorganism which may be expected to be in the egg will also be reduced by at least 5 logs, particularly, when the reduction of 5 logs is in connection with the species *Salmonella enteritidis*. *Salmonella enteritidis* is a particularly troublesome pathogenic species of Salmonella in that it is a more common species of infection in the yolk of the egg, for the reasons explained above, and is a particularly virulent pathogenic species. In addition, that species is more difficult to destroy because of its predominant yolk location and the corresponding difficulty to destroy while maintaining functionality. Therefore, if the process is designed and carried out so as to reduce *Salmonella enteritidis* by at least 5 logs, as essentially the worst case scenario, then it can be assured that other pathogens in the egg have been reduced sufficiently that the egg is safe for consumption by humans of ordinary health and condition.

In this regard, FIG. 1 is a graph of the temperature of the central portion of the yolk of an egg being pasteurized versus the log of the dwell time of the yolk at that temperature. That correlation is a straight line on log scale, and parameter lines A and B show permissible deviation from that correlation line, while still substantially ensuring a 5 log reduction in a Salmonella species, as well as a substantial retention of the albumen functionality. For optimum results, the dwell time at a specific temperature or dwell times at different temperatures, as explained above, should fall near that correlation line. However, as noted above, for some fine tuning of processes in connection with the particular egg input, the technical ability to control temperatures, and for shortening the process time, the time-temperature correlation can be within parameter lines A and B and satisfactory results will be obtained. However, it is much preferred that deviations from the correlation line be at longer dwell times, rather than at shorter dwell times, from the correlation line. This will ensure a 5 log reduction of Salmonella while still ensuring good functionality. Thus, the dwell times are within a 95% statistical confidence level for the straight line graph of temperature and log of dwell time (indicated in minutes), where one terminus of the line is at 128° F. for 215 minutes and the other terminus of the line is at 138.5° F. for 8.0 minutes. The 95% confidence level is calculated by standard statistical methods which are well known to the art and need not be described herein.

Thus, by carrying out the process so that the yolk is pasteurized in the above manner, this also ensures that the entire mass of the egg is likewise pasteurized such that there is at least a 5 log reduction of Salmonella species throughout the yolk, albumen and entire mass of the egg.

Newly proposed standards of the United States Food and Drug Administration (USFDA) require at least a 5 log reduction in Salmonella species for in-shell eggs to qualify as pasteurized. Acceptably retained functionality must also be achieved for practical commercial application. Heretofore, the art has not been able to meet that proposed standard. For example, only a 3 or 3.5 log reduction of a Salmonella species could be achieved by prior art processes, while reliably retaining the functionality of the in-shell eggs. As a result, some of the prior processes, instead, purported to use the USDA standard for liquid eggs (out-of-shell eggs). Those in-shell eggs are, nevertheless, not pasteurized eggs in that, while they may be safer to eat, they are not safe to eat.

As noted above, while the functionality of an egg can be determined by several or more tests, it has been found that the most sensitive and reliable test for determining retained functionality of eggs pasteurized by the present invention is that of the albumen functionality test. Since the yolk temperature is controlled according to the present invention, i.e. controlled at a temperature between 128° F. and 138.5° F., this, inherently, means that the albumen reaches a temperature of at least 128° F., but could for a portion of the time of the pasteurization process reach temperatures up to 138.5° F. or slightly higher when the temperature of the heat transfer medium is higher than 138.5° F., e.g. up to 142° F., as explained above. Therefore, these higher temperatures of the albumen, as opposed to the temperatures of the yolk, can cause loss of functionality of the albumen before there is a substantial loss of functionality of the yolk. By, therefore, controlling the yolk temperature, the functionality of the albumen is safeguarded so as to not be substantially reduced from that of an unpasteurized egg. Therefore, it can be ensured that the functionality of the whole egg including the yolk will not be substantially reduced in functionality.

As a very surprising and unexpected occurrence in connection with the present invention, when pasteurization is carried out very close to the correlation line of FIG. 1, not only is the albumen functionality not decreased but, in fact, quite surprisingly, is increased in some regards. The data actually shows that while a corresponding unpasteurized egg of Grade A quality may have an albumen functionality rating of between 60 and 72 Haugh units, when an egg is pasteurized close to the present correlation line of FIG. 1, the albumen functionality rises by up to 10 units, e.g. somewhere in the 70 or 80 units. It is noticed that there is a slight enlargement of the air sac and an enlargement of the yolk in such eggs, which enlargements are usually found in slightly older eggs. Even when operating the process close to either parameter line A or parameter line B, the albumen functionality of pasteurized Grade A eggs will still exceed 60 Haugh units.

In this latter regard, the term "corresponding unpasteurized in-shell egg" is defined to mean an egg of corresponding shape, weight, age, flock and processing history as that of the pasteurized egg, since, as explained above, these variables can effect the results of the process and, correspondingly, the results of the Haugh unit test. Therefore, in connection with the corresponding unpasteurized egg, the pasteurized egg is not substantially reduced in the albumen functionality test.

As is well known in the art, any substantial heating of egg protein causes some denaturization of that protein. In the prior art processes, while reduction of microorganisms in the eggs could easily be achieved, reduction of higher log cycles resulted in denaturing of the egg protein and a decrease in the functionality of the eggs to the extent that the eggs were not commercially useful for all purposes. In addition, that

denaturing of the protein causes very substantial changes in the functionality of the eggs with storage. Thus, in those prior art processes, while freshly heat-treated eggs might not have acceptable functionality for all uses, they might have acceptable functionality for limited uses, e.g. producing a soft-boiled egg. However, with storage of the eggs, which is normal in the industry, even that functionality would substantially further decrease such that long time stored eggs would become unacceptable for almost all uses. Therefore, it is not only necessary to achieve pasteurization, while retaining functionality, as described above, but it is also necessary to retain that functionality over a significant period of time of storage of the eggs. Otherwise, without preservation of functionality during storage, the pasteurized eggs are simply not acceptable from a commercial point of view.

Storage affects both unpasteurized and pasteurized eggs (e.g. stored at 41° F.). There is some weight loss during storage, the yolk height and width tend to change, yielding a changed yolk index and the whipped albumen height, in Haugh units, also tends to change in both types. These are, however, usually not practically significant. Generally speaking, eggs should not be stored (e.g. at 41° F.) for longer than about 75 days prior to use. In the prior art approaches, the processed eggs stored for up to 75 days showed unacceptable changes in egg functionality. For example, depending upon the prior art approach, the eggs could not make an acceptable sunny-side up fried egg, acceptable homogeneous scrambled eggs, or acceptable over-easy fried eggs. Neither could those eggs be used for making food products, such as salad dressings, e.g. Caesars salad dressing, mayonnaise, sponge cakes, cookies and other baking applications.

While the following example details the data of test results, that example shows that the present process not only destroys the Salmonella species so as to pasteurize the egg, i.e. at least a 5 log reduction, but does so without substantially adversely affecting the egg quality, e.g. functionality, even when stored up to 75 days at 41° F. Those eggs can be used for preparing sunny-side up, scrambled and over-easy cooked eggs, as well as in preparing salad dressings, mayonnaise, sponge cakes, cookies and other baking applications.

Thus, the present method and pasteurized eggs are further different from prior art methods and treated eggs in that the present pasteurized eggs have an egg weight substantially the same as a corresponding unpasteurized egg, a yolk index and yolk strength substantially the same as a corresponding unpasteurized egg, and an angel cake test and a sponge cake test substantially the same as a corresponding unpasteurized egg. Further, the present pasteurized eggs have frying, scrambling and boiling characteristics substantially the same as a corresponding unpasteurized egg, and, just as importantly, those characteristics are maintained in the present pasteurized eggs for up to 75-days storage at 41° F.

The egg produced by the method of the invention, as noted above, is a pasteurized in-shell chicken egg which comprises a pasteurized central portion of the yolk of the egg having at least a 5 log reduction of a Salmonella species which may be present in the egg in its unpasteurized form. The egg has an albumen functionality, measured in Haugh units, not substantially less than a corresponding unpasteurized in-shell egg. In this regard, "not substantially less" means that any differences are not of practical significance. The present pasteurized egg also has the reduction in Salmonella species throughout the yolk and albumen of the egg. Also, the egg weight, the yolk index, the yolk strength, the angel cake test, the sponge cake test, and frying, scrambling and boiling characteristics of the present pasteurized egg are not substantially less than a corresponding unpasteurized in-shell egg. Likewise, the present pasteurized egg can substantially maintain those characteristics for up to 75-days storage at 41° F.

It will be appreciated by those skilled in the art that a reduction in Salmonella species of at least 5 logs, while not substantially decreasing the albumen functionality, is a very substantial improvement in the art. Prior art approaches, such as those described above, under ideal conditions, could produce, perhaps, as much as a 3.5 log reduction in *Salmonella enteritidis* without substantially decreasing the albumen functionality. However, while up to a 3.5 log reduction will make the egg safer to eat, that egg is not pasteurized according to the proposed USFDA standard, discussed above, and, hence, cannot be said to be safely consumable by a human of normal health and condition. Unless at least a 5 log reduction is obtained, under the proposed USFDA standard, it cannot be assured that the egg can be safely consumed by such human. The present process is able to achieve that 5 log reduction, while maintaining the functionality of the egg, and, in this sense, has solved the dilemma which has plagued the art for some time. Indeed, by following closely the correlation line of FIG. 1, log reductions greater than 5 can be achieved, while substantially maintaining the functionality, e.g. 6 log reductions and even 7 log reductions, and this is a very substantial advance in the art.

While, as stated above, the method may be carried out by heating the eggs with any desired means, as also stated above, the preferred method is that of heating the eggs in an aqueous medium, preferably in a water bath, for the reasons set forth above, and this particular means of heating the eggs will be specifically discussed, for conciseness purposes, but it is to be understood that the invention is not limited thereto. It should be further understood that the specific method illustrated below is merely a preferred method when using a water bath as the heating medium, but that other methods may be used in connection with the use of a water bath as the heating medium, or in connection with other heat transfer media, so long as the yolk temperature/dwell time of the invention is observed.

In carrying out the method, it is necessary to control the yolk temperature of the egg. However, it is first greatly preferred to appropriately calibrate a particular apparatus and particular process conditions of that apparatus to ensure that the particular apparatus and conditions calibration results in the required yolk temperature/dwell time to pasteurize the eggs and retain functionality, according to FIG. 1. Thereafter, subsequent processing and pasteurization of eggs can be achieved by repeating those calibration process conditions without measuring the yolk temperature/dwell time of the eggs. For example, in such calibration, it may be established by temperature measurement of the yolk that when eggs stored at 41° F. are placed in a water bath at 137° F. for a particular apparatus with a particular agitation for 14 minutes and then removed and cooled in 41° F. storage, the yolk temperature/dwell time required by FIG. 1 is achieved. Thereafter, to effect pasteurization of succeeding lots of eggs, including the required yolk temperature/dwell time and retained functionality, it is only necessary to maintain that calibration agitation, water temperature, 14-minute dwell time, egg storage temperature and cooling temperature, to ensure that the yolk temperature/dwell time is that required by FIG. 1, without having to measure that yolk temperature/dwell time or functionality of succeeding

lots of eggs. However, it is preferable that the calibration be periodically rechecked during processing of succeeding lots of eggs by checking the calibration with a lot of eggs from time to time by measuring the temperature of the yolk and measuring functionality.

To these ends, for a chosen lot of eggs being pasteurized, a statistical number of the eggs being processed will have a temperature probe inserted into that central portion of the yolk, and these eggs may be referred to as "control eggs". The temperature probe, e.g. thermocouple, is inserted into the egg, in a manner well known in the art, and sealed thereagainst by conventional manners, e.g. glues, waxes, putties, and the like, to prevent water from entering the egg during processing. The temperature of the central portion of the control egg yolks is monitored by the temperature probe, and the yolk temperature/dwell time is determined and controlled to ensure that the values fall within parameter lines A and B of FIG. 1. If so, the calibration has been obtained or maintained; if not, adjustment of operating conditions and recalibration are required.

Whether in regard to such calibration or in regard to production pasteurization of eggs, normally, eggs of essentially the same size range will be processed as a lot. Otherwise, with eggs of greatly different sizes, the calibration or production processing could not ensure pasteurization. The sizes may be determined by weight, and, for example, eggs of a target weight plus or minus 10% are processed as a lot.

In the method of the invention, a lot of eggs is placed in a conventional pasteurization apparatus, which may be any conventional pasteurization apparatus, such as a cheese vat, and heated water is introduced into that vat with the water being heated to at least 128° F. and up to 142° F., but preferably less than 138.5° F. The temperature of the central portion of the egg yolk of a statistical number of eggs is monitored by a temperature probe present in "control" eggs as a periodic or continual recheck of calibration, as explained above, or as the primary means of control of egg yolk temperature, e.g. in an apparatus which has not been calibrated as described above. Preferably, however, the apparatus has been calibrated, and such control eggs are not required or are used only periodically to recheck calibration. When the desired target temperature of the yolk, e.g. 134° F. is reached, the temperature of the water is controlled to maintain that target temperature by adding cold or hot water as required, and that yolk temperature is controlled for the time set by the correlation line of FIG. 1 or at least within parameter lines A and B.

After the eggs have reached that temperature and been controlled at that temperature for the time of the correlation line, the eggs are removed from the pasteurizer and cooled to at least below 126° F., and more preferably below 115° F., and yet more preferably below 100° F. This cooling should be as rapid as possible such that residual temperatures in the eggs do not substantially further denature protein beyond that achieved at the correlation temperature. Usual cooling procedure, e.g. air, is sufficient for this purpose, but it is preferable to cool the eggs in cool water or in normal storage, e.g 41° F., after removal from the pasteurizer. It should be noted that any time during which the yolks of the eggs remain within parameter lines A and B during cooling should be subtracted from the dwell time required by FIG. 1. After the eggs have been so cooled, the eggs are then dried, e.g. air drying, packaged and transferred to a cold storage, maintained at an acceptable temperature of between 38° F. and 45° F., e.g. 41° F., and are then ready for distribution.

In addition, for calibration, recheck of calibration or primary control of the pasteurization, a statistical number of "control" eggs may be analyzed for functionality. While the functionality will be largely known by the albumen functionality test, in Haugh units, to ensure that the functionality of the pasteurized egg is substantially the same as a corresponding unpasteurized egg, in addition to the albumen functionality, "control" eggs may be examined for egg weight, yolk index and yolk strength, angel cake test and sponge cake test, as well as the characteristics of frying, scrambling and boiling, as described above.

All of the control eggs, i.e. yolk temperature and functionality control eggs, are essentially part of calibration for a particular pasteurizing apparatus operated at particular conditions with particular eggs. This is because particular pasteurizing apparatuses can vary in their performance of pasteurization, and any particular apparatus must be calibrated to ensure that the yolk temperature/dwell time reaches the desired results required by FIG. 1. However, as noted above, once calibrated, for successive pasteurizations of substantially the same eggs, then it is no longer necessary to use the temperature probed "control" eggs or to perform the functionality tests mentioned above, since by repeating the calibration process, the same results will be achieved. This is, of course, based on the assumption that all succeeding lots of eggs processed in that same manner have essentially the same histories and conditions, as described above. If the histories or conditions change markedly, then the apparatus must be recalibrated, as discussed above.

Optionally, the pasteurized eggs may be protected from environmental recontamination by wrapping the eggs or cartons of eggs in a protective barrier, such as a plastic film. Heat shrinkable plastic film is particularly well suited to this purpose, such as the heat shrinkable films made by the Cryovac Division of W. R. Grace & Co. These films are co-extruded polyolefin films, some of which are cross-linked. These films are generally referred to as "industrial food source films" and particularly useful are those films designed as D-955 and MPD 2055. It is to be understood, however, that pasteurization of eggs, similar to pasteurization of milk, does not extend the shelf life of the eggs nor does it lessen the necessity for proper handling and cooling of the eggs, in the same manner as pasteurized milk. Accordingly, simply wrapping each individual egg or package of eggs will not extend the shelf life of the eggs.

The invention will now be illustrated by the following example, where all percentages and parts are by weight, unless otherwise indicated.

EXAMPLE

This example illustrates two different protocols for pasteurizing eggs.

In a manner described above in connection with the method of calibrating a particular apparatus/process conditions, the graph of FIG. 1 was experimentally determined by inoculating a statistical number of eggs with *Salmonella enteritidis*. The inoculated eggs were sealed in the same manner as sealing the temperature probe of the "control" eggs. These "control" inoculated eggs were processed in the same manner. The "control" inoculated eggs were examined for *Salmonella enteritidis* log reduction by standard microbiological techniques. The graph of FIG. 1 was then constructed on the basis of yolk temperature/dwell time which would achieve at least a 5 log reduction in *Salmonella enteritidis*. Parameter lines A and B show a 95% confidence level. Retained functionality was confirmed by the same procedure described below.

Thus, it was known by this experimental data that by processing eggs within parameter lines A and B of FIG. 1, a 5 log reduction in a Salmonella species resulted while maintaining functionality. This Example, therefore, illustrates that retained functionality and further illustrates that retained functionality during long-term storage, i.e. at 41° F. for up to 75-days storage.

The pasteurizer used in this example was a Kusel (Kusel Equipment Co., Watertown, Wis.). It has a 100 gallon capacity and is usually used as a cheese vat. The vat is filled with water and heated to the target temperature with a steam jacket. The vat is equipped with a Nonox steam/water mixer and that target temperature is maintained by flowing temperature controlled water into the vat with a corresponding outflow of water. For temperature control, the vat is equipped with mountings for separate temperature probes to monitor the water temperature. In this example, the water temperature was monitored using three Type T 24 gauge (copper-constantant Teflon-coated) thermocouples connected to a Cole-Palmer (Niles, Ill.) Dual Input Thermocouple Thermometers (Model No. 08112-20). The thermocouples were placed at three different locations and at three different water levels throughout the vat to monitor the evenness of water temperature.

Thirty-six eggs were used in each test and were placed in conventional filler flats at 12 inches below the water level. Each batch of test eggs also contained three eggs that were probed with a thermocouple. The thermocouple was inserted 1¾ inches into the large end of the eggs to the central portion of the yolks. The eggs were sealed with a gel-based glue and allowed to dry. Temperatures of the eggs and water vat were monitored at one minute intervals with an accuracy of ±0.2° F. Mild agitation was carried out in the vat and was regulated using a rotary stainless steel impeller pump with a 1½ inch inlet and a 1½ inch outlet.

Approximately 4-day old eggs were used for each of the tests, and the eggs were large Grade A quality eggs from the same flock. The eggs had been stored at 41° F. until processed. The eggs were removed from the storage cooler and placed into the plastic filler flats. The three eggs with the thermocouples mounted therein were also included in each flat. The filler flat was then placed in the preheated vat, and the temperatures of the water and the egg yolk temperatures were recorded at one minute intervals.

In one protocol, when the average internal yolk temperature of the three eggs reached 134° F., cool water was added to the vat and mixed, as needed, to maintain that internal yolk temperature. In the other protocol, the cool water was added when the average internal temperature of the yolk reached 133° F. Both of the protocol fall within parameter lines A and B of FIG. 1.

After processing, the eggs were removed from the water vat and placed directly into a 41° F. cooler, by which they were rapidly cooled.

No pasteurized eggs were removed from the cooler until after the average internal yolk temperature reached 41° F. The various batches for each treatment were combined and randomly assigned to Day 0, 10, 20, 30, 60 or 75 days storage.

Treatment of the eggs were assigned treatment numbers as follows:

1. Treatment No. 1—a control group of unpasteurized eggs;
2. Treatment No. 2—a control group of unpasteurized eggs which were placed in a Cryovac package (film);
3. Treatment No. 3—pasteurized eggs, initial water bath temperature of 137° F. and average internal yolk temperature of 133° F.;
4. Treatment No. 4—pasteurized eggs, initial water bath temperature of 137° F. and average internal yolk temperature of 133° F., packaged within a Cryovac package;
5. Treatment No. 5—pasteurized eggs, initial water bath temperature of 138° F. and average internal yolk temperature of 134° F.; and
6. Treatment No. 6—pasteurized eggs, initial water bath temperature of 138° F. and average internal yolk temperature of 134° F., packaged within a Cryovac package.

Treatment Nos. 2, 4 and 6 were packaged in groups of six in cardboard or plastic filler flats. The packaging was provided by Cryovac and consisted of a plastic sleeve into which the eggs were placed and then sealed using a bar sealer. The plastic sleeve was made of Cryovac D-955 film.

A description of the tests of the various treatments at day intervals is set forth in Table 1 below.

TABLE 1

Day	Treatment	Tests
0	#1, #3, #5	Egg Quality -
		Weight
		Yolk Index
		Haugh Units
		Yolk Strength
		Foam Stability
		Angel Cake Volume
		Sponge Cake Volume
		Whip Test
		Lysozyme Activity
10 & 20	#1, #2, #3,	Egg Quality -
	#4, #5, #6	Weight
		Yolk Index
		Haugh Units
		Yolk Strength
30, 60 & 75	#1, #2, #3,	Egg Quality -
	#4, #5, #6	Weight
		Yolk Index
		Haugh Units
		Yolk Strength
		Foam Stability
		Angel Cake Volume
		Sponge Cake Volume
		Whip Test
		Lysozyme Activity

A. Egg Quality Tests:

1. Egg Weight—Initial and final egg weights (to one hundredth of a gram) were recorded to determine if a weight gain or loss occurred during processing or storage.

2. Yolk Index—Yolk index is a measure of yolk quality. A decreasing yolk index indicates a lower yolk quality.

Yolk index=Yolk height (mm)/Yolk width (mm)

3. Haugh Units (Albumen Functionality Test)—The Haugh units measure albumen (egg white) quality. As the egg ages, the thick white thins. The Haugh units are calculated using both the egg weight and the height of the thick albumen. Standard Haugh unit values for different grades of eggs are as follows:

Grade AA>72 Haugh units

Grade A 60–72 Haugh units

Grade B<60 Haugh units

4. Yolk Strength—Yolk strength is a measure of how easily the yolk will break when dropped from a distance of 6 inches onto a flat surface.

B. Properties Tests:

1. Angel Cake Volume—Angel cake volume is a sensitive test of egg white protein damage. Generally, heat damage will greatly increase whipping time and decrease the cake volume.

2. Sponge Cake Volume—Measures both foaming volume and emulsification properties. The yolk proteins are less heat sensitive than egg white proteins. Sponge cake volume provides a measure of the effect of heat processing on yolk functionality.

3. Foaming Stability—Measures the foaming efficiency of egg whites. The foaming properties of egg whites are provided by certain egg white proteins. These proteins are particularly sensitive and may be damaged by heat processing. If proteins are damaged, then foam volume will decrease and the liquid drainage from the whipped foam will increase. The egg whites are whipped to a specific gravity of 0.1. Percent drainage was calculated by dividing the grams of drainage by the initial weight of the foam.

4. Whip Test—This is another measure of the foaming efficiency of egg whites. Egg whites are whipped for a specific time and speed and the height of the foam is then measured.

All functionality tests were performed in triplicate per treatment.

C. Other Tests:

1. Lysozyme Test—This test measures the enzyme activity. Lysozyme is one of the constituents in eggs which provides some antibacterial activity. It acts upon gram positive organisms. Rate of clearing was determined per minute at the most linear portion of the curve, i.e. between 0.5–3.0 minutes.

Results and Observations of Eggs at Day 0

Visual Observations

Observations were conducted on eggs from Treatment Nos. 1, 3 and 5. Treatment No. 1 (unpasteurized eggs) showed no signs of cloudiness, and the yolk shape was normal. Treatment No. 3, pasteurized with an initial water bath temperature of 137° F. and a yolk temperature of 133° F. (137°–133° F.) showed cloudiness in the thick and thin albumen. The yolk was slightly flatter than in Treatment No. 1. Treatment No. 5 (138°–134° F.) was very similar in appearance to Treatment No. 3, with the exception of a slight decrease in cloudiness in the thin albumen.

Egg Quality

Weight Loss—No statistically significant ($p>0.05$) differences in weight loss occurred between the control and pasteurized eggs at Day 0. A statistically significant ($p<0.05$) difference was found between the pasteurized eggs, with the eggs from Treatment No. 3 (137°–133° F.) losing the least amount of weight.

Yolk Index—No statistically significant ($p>0.05$) differences in yolk index occurred between Treatment Nos. 1, 3 and 5.

Yolk Strength—Pasteurization did not statistically significantly ($p>0.05$) affect yolk strength.

Haugh Units—No statistically significant ($p>0.05$) differences in Haugh units occurred between Treatment Nos. 1, 3 and 5.

Properties Test

Angel Cake Volume—Differences in angel cake volume between all three treatments were not statistically significant ($p>0.05$). However, whipping time to achieve a medium peak was increased in the pasteurized eggs compared to the control eggs.

Sponge Cake Volume—Significant ($p<0.05$) differences were found in sponge cake volume between Treatment Nos. 3 and 5, with Treatment No. 3 having greater cake volume. There was not a statistically significant ($p>0.05$) difference in sponge cake volume between the control and pasteurized eggs.

Whip Test—Whip test results indicated a statistically significant ($p<0.05$) difference between the control and pasteurized eggs with the control eggs having the least amount of drainage and the greatest foam volume. There was no statistically significant ($p>0.05$) difference between Treatment Nos. 3 and 5. To achieve a specific gravity of 0.1 in the control eggs, the whipping time was 30 seconds compared to 3 minutes for the pasteurized eggs.

Other Tests

Lysozyme—A statistically significant ($p<0.05$) difference in lysozyme activity was found between the control and pasteurized eggs. Differences in enzyme activity between Treatment Nos. 3 and 5 were not statistically significant ($p>0.05$).

Conclusion

At Day 0, the pasteurized eggs exhibited some cloudiness in the thick albumen (white) as compared to unpasteurized eggs. The degree of cloudiness is not practically significant.

A small amount of weight was lost during the pasteurization process but was comparable to average weight loss in the unpasteurized eggs. No weight gain occurred during pasteurization. The pasteurization process did not practically significantly adversely affect the yolk index, Haugh units, or yolk strength. After pasteurization, the eggs remained large Grade A quality eggs.

Pasteurization did not practically significantly affect angel and sponge cake volume when comparing to the unpasteurized egg. However, Treatment No. 3 (137°–133° F.) had a greater sponge cake volume than Treatment No. 5 (138°–134° F.), which was found to be significant.

Unpasteurized eggs were slightly superior in foam volume and foam stability as compared to the pasteurized eggs, but this superiority is not practically significant.

Lysozyme activity decreased in the pasteurized eggs as compared to the unpasteurized eggs. However, the loss in activity is of little practical significance.

Results and Observations of Eggs at Day 10

At Day 10, the results were similar to Day 0 in regard to the common tests. Cloudiness was apparent in the pasteurized eggs compared to the unpasteurized eggs. The degree of cloudiness is not practically significant. No visual differences were observed between the packaged and unpackaged eggs.

Some degree of weight loss occurred in all treatments during the 10-day storage period. Packaging did not significantly affect the amount of weight loss.

A statistically significant difference was found in yolk index between the pasteurized and unpasteurized eggs and the packaged and unpackaged eggs. Haugh units were not affected by the pasteurization process. Unpackaged eggs had higher Haugh units as well as eggs from Treatment Nos. 5 and 6. The differences in the yolk index and Haugh units are not practically significant and do not affect the quality of the eggs. The eggs were still large Grade A quality eggs.

Results and Observations of Eggs at Day 20

At Day 20, the results were similar to Day 10 in regard to the common tests. The pasteurized eggs at Day 20 were still cloudy in appearance as compared to the unpasteurized eggs. Some cloudiness also appeared in the thin albumen. The degree of cloudiness is not practically significant. Packaging did not affect the visual appearance of the eggs.

All treatments lost weight at Day 20 of storage. Packaging did decrease the amount of weight loss as compared to the unpackaged eggs. The unpasteurized eggs lost less weight compared to the pasteurized eggs. The amount of weight loss is not practically significant and would not change the grade designation.

The unpasteurized eggs had a slightly higher yolk index. Packaging did not affect yolk index. No practical significant differences in Haugh units or yolk strength were apparent between all treatments. At the end of 20-days storage, all eggs were still large Grade A quality eggs.

Results and Observations of Eggs at Day 30

At Day 30, the results were similar to Day 20 in regard to the common tests. Cloudiness in the thick albumen and slight cloudiness in the thin albumen were present in the pasteurized eggs. The pasteurized eggs were also slightly more runny in the outer thin albumen than unpasteurized eggs. No differences between the packaged and unpackaged eggs were apparent. The degree of cloudiness and runniness is not practically significant.

Weight loss occurred in all treatments, with the unpasteurized eggs losing the least amount of weight. Packaging did not have a significant effect on weight loss. Unpackaged eggs had a higher yolk index than those that were packaged. Packaging and pasteurization did not have a significant effect on yolk strength or Haugh units. The eggs still remained large Grade A quality eggs after 30 days of storage.

Angel cake and sponge cake volume was not affected in all treatments at Day 30. Longer whipping times were necessary for the pasteurized eggs. Packaged and pasteurized eggs had a greater sponge cake volume but were not practically superior to the other treatments..

Foam stability and volume were greatest in the unpasteurized eggs. Longer whipping times were necessary in the pasteurized eggs. Loss of lysozyme activity occurred in all treatments; however, the loss in activity is of little practical significance. None of these differences were of practical significance.

Results and Observations of Eggs at Day 60

At Day 60, the results were similar to Day 30. The cloudiness of the thick albumen and slight cloudiness in the thin albumen of the pasteurized eggs were observed. Packaging did not play a significant role in appearance. The outer thin albumen of pasteurized eggs was slightly more runny than the unpasteurized eggs. The degree of cloudiness and runniness of the pasteurized eggs is not practically significant.

Weight loss occurred in all treatments but was not significantly affected by packaging or heat treatments. Weight loss was not significant enough to change the classification of the eggs.

Yolk strength and yolk index were not affected by pasteurization or packaging. Haugh units were greater in pasteurized eggs than unpasteurized eggs. At the end of 60-days storage, all treated eggs were still large Grade A quality eggs.

Unpasteurized eggs had greater angel and sponge cake volume. Packaging did not play a significant role in cake volume. Foam stability and volume were greater in the unpasteurized eggs. Longer whipping times were needed for the pasteurized eggs. None of these differences were practically significant.

Lysozyme activity was lost in all treatments but was not practically significant.

Results and Observations of Eggs at Day 75

At Day 75, the results were similar to Day 60. The pasteurized egg albumen was more cloudy than that of unpasteurized eggs. The degree of cloudiness is not practically significant. Runniness was more apparent in the outer thin albumen. Packaging did not appear to make a significant difference in egg quality.

Weight loss occurred in all treatments, with the packaged eggs losing the least amount of weight. Yolk index was better in the unpasteurized eggs. Yolk strength was not significantly affected by pasteurization or packaging. Haugh units were greater in the pasteurized eggs than in the unpasteurized eggs. However, at the end of Day 75, all treatments were still large Grade A quality.

Angel cake volume was not significantly affected by pasteurization or packaging. Unpasteurized and unpackaged eggs had the greater sponge cake volume. None of these differences are of practical significance.

Foam stability and volume were superior in the unpasteurized eggs compared to pasteurized eggs. Longer whipping times were required for the pasteurized eggs. None of these differences were of practical significance.

Lysozyme activity decreased in all treatments after 75 days of storage, but not enough to cause a practical significant effect.

Overall Conclusion

Cloudiness of the thick albumen occurs in pasteurized eggs that is not apparent in the unpasteurized eggs. However, the degree of cloudiness is not practically significant. Cloudiness remained essentially constant during the 75-day test period and is similar to the natural cloudiness of two-day old eggs.

Weight loss statistically significantly ($p<0.05$) increased during storage for all treatments. Packaging statistically significantly ($p<0.05$) reduced weight loss of all three treatment groups. Pasteurized eggs were noted to have statistically significantly ($p<0.05$) more weight loss as compared to unpasteurized eggs. None of these differences, however, are of practical significance.

Yolk index of the control eggs was found to be statistically significantly ($p<0.05$) better than the pasteurized eggs for most of the storage periods. Yolk index statistically significantly ($p<0.05$) declined in all groups up to 60 days. All treatments exhibited an increase in yolk index at 75 days, which resulted in a statistically significant ($p<0.05$) day by treatment interaction. This increase is, however, not practically significant.

The yolk breakage test indicated that yolk breakage was satisfactory in all groups throughout the storage study.

Haugh units of pasteurized eggs were observed to be statistically significantly ($p<0.05$) higher than the control eggs. This was particularly true at longer storage periods (beyond 30 days). Packaging statistically significantly ($p<0.05$) improved the Haugh units of all treatment groups.

Angel cake volume was found to be variable. Control eggs were found to have a statistically significantly ($p<0.05$) better angel cake volume. Whip foam volume and foam stability were statistically significantly ($p<0.05$) superior in control eggs as compared to pasteurized eggs. None of these differences are, however, practically significant.

Sponge cake volume was statistically significantly ($p<0.05$) better in pasteurized eggs up to 30 days as compared to control eggs. After 30 days, the control group eggs

were noted to have statistically significantly ($p<0.05$) better sponge cake volume. The 137° F. treatment groups eggs were found to have a statistically significantly ($p<0.05$) better sponge cake volume as compared to the 138° F. treatment group. Although sponge cake volume was variable and declined through storage, the sponge cake volume was acceptable in all tests, and the differences are not practically significant.

Lysozyme activity statistically significantly ($p<0.05$) declined in all treatment groups throughout storage. Pasteurization also statistically significantly ($p<0.05$) reduced lysozyme activity. Previous research has shown that lysozyme activity in shell eggs will decrease during storage. Although lysozyme activity was lower in pasteurized eggs, this difference is not practically significant.

The pasteurized eggs are suitable for all forms of food preparation. They can be prepared sunny-side up, scrambled and over-easy. The pasteurized eggs can also be utilized in salad dressings (e.g. Caesars salad), mayonnaise, sponge cakes, cookies and other baking applications.

Thus, overall, there was no practical significant difference in functionality of the pasteurized eggs as compared with corresponding unpasteurized eggs for the entire storage period.

Test Details

Sponge Cake Test

Ingredients:

50.0 g cake flour

46.25 g sucrose

19.30 g dextrose

5.0 g nonfat dry milk

1.25 g salt

2.50 g baking powder

29.49 g whole egg

18.90 g water (first addition)

10.26 g water (second addition)

Procedure:

1. Preheat oven to 375° F.

2. Allow all ingredients to come to room temperature.

3. Sift all dry ingredients.

4. Blend all dry ingredients for one minute on the stir speed of a Kitchen Aid Mixer (Model K4-B).

5. Add egg to mixture.

6. Mix for 1 minute at speed 2 while slowly adding the first water.

7. Scrape down sides of bowl.

8. Mix for 2 minutes at speed 8.

9. Mix for 2 minutes at speed 4, while slowly adding the second water.

10. Scrape down sides of bowl.

11. Mix 2 minutes at speed 8.

12. Measure out 150 g into a tared 5.5"×3.5"×2.75" baking pan. (Two 1" strips of wax paper placed lengthwise along the bottom of the pan, extended over the ends to facilitate removal of the cake from the pan.)

13. Bake in reel-oven for 30 minutes.

14. After baking, allow to cool for 10 minutes, and remove from pan.

15. Volume determinations are made with a rape seed displacement method. Record initial volume of rape seeds. Turn mechanism over and add cake. Invert mechanism to allow rape seeds to surround cake and record final volume.

16. Report results as cm^3.

Angel Cake Test

Ingredients:

90.0 ml blended egg white

1.8 g salt-cream of tartar mixture (0.45 g salt, 1.35 g cream of tartar)

69.0 g super-fine sugar

56.0 g flour-sugar mixture (23.0 g sugar, 33.0 g flour)

Procedure:

1. Preheat oven to 390° F.

2. Warm Kitchen Aid Mixer (Model K4-B) by letting it run at speed 10 for 15 minutes.

3. Sift twice, separately:

56.0 g flour-sugar mixture

69.0 g sugar

1.8 g salt-cream of tartar mixture

4. Place 90.0 ml blended egg white in a bowl, sift salt-cream of tartar mixture over egg white.

5. With mixer set on speed 10, white to a medium peak.

6. Sift 69.0 g super-fine sugar over foam in three increasingly larger portions and whip at speed 6 for 4 seconds after each addition.

7. Sift 56.0 g of flour-sugar mixture onto foam in 3 portions, folding after each addition. Use a wire whip and about 20 strokes.

8. Weight out 120 g of the batter into a tared 5.5"×3.5"×2.75" pan (two 1" strips of wax paper placed lengthwise along the bottom of the pan, extended over the ends to facilitate removal of the cake from the pan) with perpendicular sides. Place in reel oven for 20 minutes.

9. Remove from the oven and place in an inverted position on a cooling rack.

10. After 24 hours, measure and record cake volume, using the rape seed displacement method. Record initial volume of rape seeds. Turn mechanism over and add cake. Invert mechanism to allow rape seeds to surround cake and record final volume.

11. Report results as cm^3.

Foaming Stability Test

Procedure:

1. Weigh out 50 gram sample of room temperature egg white. Place in mixing bowl (Kitchen Aid Mixer, Model K4-B). Add 10 ml of distilled water.

2. Begin timing and whip at high speed (speed 10) until the foam has a specific gravity of approximately 0.1. Specific gravity determination: density determination is substituted, tare a container of known volume, fill, level and weigh. Density is determined by:

Weight in grams/Volume in ml=Density

The whipping time for this stage to be reached is noted.

3. Transfer the foam to a tared glass funnel and immediately record weight of the foam.

4. Cover the funnel with a large petri plate and allow to drain into a graduated cylinder tared on a scale.

5. Record weight of drainage at 15 minute intervals for 1 hour.

Calculation: Calculate grams of drainage per 100 grams of foam from the total weight of foam and the weight of drainage by:

Grams of Drainage/Grams of foam×100=% Drainage

Whipping Test

Procedure:

1. Weigh out 50 gram sample of room temperature egg white. Place into mixing bowl (Kitchen Aid Mixer, Model K4-B).

2. Mix for 90 seconds on speed 2.
3. Mix for 90 seconds on speed 10.
4. Transfer foam from bowl into 600 ml beaker. Level foam and measure depth of foam.
5. Record results in cm.

Lysozyme Assay

Reagents:

0.0667M Sodium Phosphate Monobasic: Dissolve 9.218 g $NaH_2(PO_4)$ H_2O and bring to 1 L final volume.

0.0667M Sodium Phosphate Dibasic: Dissolve 9.48 g Na_2HPO_4 and bring to 1 L final volume.

M/15 Phosphate Buffer pH 6.2: Mix portions of 0.0667M Sodium Phosphate Mono and Dibasic solutions together until a pH 6.2 is reached. About 300 ml of dibasic to 1 L monobasic.

50 mg % Suspension of U.V. Killed and Lyophilized Micrococcus Lysodeikticus: Dissolve 0.5 g in M/15 phosphate buffer pH 6.2 and bring to 1 L final volume. Keep refrigerated at 4° C.

Procedure:

Allow preblended egg white samples and cell suspension to come to room temperature. Use plastic as lysozyme adheres to glass.

Dilute egg white samples to give a moderate clearing rate. Add 0.02 ml of egg white to 0.98 ml buffer, gives a theoretical lysozyme concentration of 70 ug/ml, the limits of this assay are 0.1 to 10 ug (per 2.9 ml substrate) of active lysozyme.

Using the kinetics software package on a Beckman Spectrophotometer, edit program to the following:

Wavelength=450 nm

Tabulate=1.0 (yes)

Int Time=3.00 sec

Total Time=8.00 min

Plot=1.0

Span=0

Slope=1

Results=1

Factor=1.000

Calibrate using 2.9 ml of cell suspension.

Place cuvette containing 2.9 ml of 50 mg % cell suspension into cell holder in spectrophotometer. Add 0.1 ml of diluted egg white and immediately mix using a plastic pasteur pipet. Allow program to run.

Maximum velocity will be extrapolated from the most linear portion of the curve by the software package. Factors used are 2–8 min., 2–4 min., 3–8 min., and 0.5–3 minutes. Rate reported per minute by software.

Report as delta abs (at 450 nm)/min. per g sample/2.9 ml substrate at 22° C. (room temperature).

From the above example, it can be seen that the invention provides a method for, and a pasteurized egg resulting therefrom, reducing a Salmonella species that may be present in eggs by at least 5 logs, while at the same time does not substantially practically decrease the functionality of the pasteurized egg. This is a most significant advance in the art. From the foregoing, it will be understood that the term "pasteurized" in connection with the present invention means that a Salmonella species which may be present in a chicken egg is reduced by at least 5 logs, the pasteurized egg is safe for consumption by humans of ordinary health and condition, and the functionality of the egg, measured in Haugh units, is not substantially less than that of a corresponding unpasteurized chicken egg. In this latter regard, the term "substantially less" does not mean there is no statistically significant difference, but means that there is no practical difference in terms of usual uses of the eggs, e.g. in baking, cooking, frying, boiling, poaching, scrambling, etc. The specification and claims should thus be so construed.

It also should be understood that the invention is not limited to the foregoing embodiments, but extends to the spirit and scope of the annexed claims.

What is claimed is:

1. A method of pasteurizing an in-shell chicken egg, comprising heating the egg until a central portion of a yolk of the egg is controlled within a temperature range of 128° F. to 138.5° F. and maintaining that controlled yolk temperature range for times, (i) within parameter line A and parameter line B of FIG. **1** and (ii) sufficient that a Salmonella species present in the egg yolk is reduced in amount by at least 5 logs such that the egg is pasteurized but (iii) insufficient that an albumen functionality of the egg measured in Haugh units is substantially less than the albumen functionality of a corresponding unpasteurized in-shell chicken egg.

2. The method of claim **1**, wherein the egg is heated with a fluid heat transfer medium.

3. The method of claim **2**, wherein the medium is an aqueous medium.

4. The method of claim **3**, wherein the aqueous medium is liquid water.

5. The method of claim **4**, wherein the water contains a surface active agent.

6. The method of claim **4**, wherein at least one of the water and the egg is in motion relative to the other.

7. The method of claim **1**, wherein the heat transfer medium is heated to more than one temperature.

8. The method of claim **7**, wherein the medium is heated to a higher temperature of less than about 142° F. and then cooled to a lower temperature greater than 128° F.

9. The method of claim **8**, wherein the higher temperature is between about 136° F. and 138° F. and the lower temperature is between about 131° F. and 135° F.

10. The method of claim **1**, wherein said times are within a 95% confidence interval for a straight line graph of temperature and a log of dwell time in minutes where one terminus of the line is at 128° F. for 215 minutes and the other terminus of the line is at 138.5° F. for 8.0 minutes.

11. The method of claim **1**, wherein the Salmonella species is *Salmonella enteritidis*.

12. The method of claim **1**, wherein the albumen functionality is at least 60 Haugh units for Grade A eggs.

13. The method of claim **1**, wherein the Salmonella species is reduced throughout the yolk and albumen of the egg by at least 5 logs.

14. The method of claim **1**, wherein the pasteurized egg has an egg weight substantially the same as a corresponding unpasteurized egg.

15. The method of claim **14**, wherein the pasteurized egg has a yolk index and yolk strength substantially the same as a corresponding unpasteurized egg.

16. The method of claim **15**, wherein the pasteurized egg has an angel cake test result and sponge cake test result substantially the same as corresponding test results with an unpasteurized egg.

17. The method of claim **14**, wherein the pasteurized egg has frying, scrambling and boiling characteristics substantially the same as a corresponding unpasteurized egg.

18. The method of claim **17**, wherein said characteristics are maintained in the pasteurized egg for up to 75 days storage at 41° F.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 5,843,505
DATED : December 1, 1998
INVENTOR(S) : Leon John DAVIDSON

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 24, claim 1, in line numbered 11, after "egg", insert --in a heat transfer medium at a temperature between 128°F and 142°F--.

Column 24, claim 1, in line numbered 12, change "controlled" to --heated to--.

Column 24, claim 1, in line numbered 13, after 138.5°F.", insert --and wherein there is a temperature differential between the temperature of the heat transfer medium and said yolk temperature,--.

Column 24, claim 1, in line numbered 13, change "that controlled" to --said--.

Signed and Sealed this

Thirtieth Day of March, 1999

Attest:

Attesting Officer

Q. TODD DICKINSON

Acting Commissioner of Patents and Trademarks

United States Patent [19]
Vandepopuliere et al.

[11] Patent Number: 6,004,603
[45] Date of Patent: *Dec. 21, 1999

[54] METHOD OF CONTROLLING SALMONELLA IN SHELL EGGS

[75] Inventors: Joseph M. Vandepopuliere; Owen J. Cotterill, both of Columbia, Mo.

[73] Assignee: University of Missouri System at Columbia, Columbia, Mo.

[*] Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

[21] Appl. No.: 08/769,579

[22] Filed: Dec. 19, 1996

Related U.S. Application Data

[63] Continuation of application No. 08/178,734, Jan. 7, 1994, abandoned.

[51] Int. Cl.[6] A23B 5/00; A23L 1/32; A23C 1/00

[52] U.S. Cl. 426/298; 426/300; 426/614; 426/520; 426/521

[58] Field of Search 426/298, 300, 426/614, 520, 521

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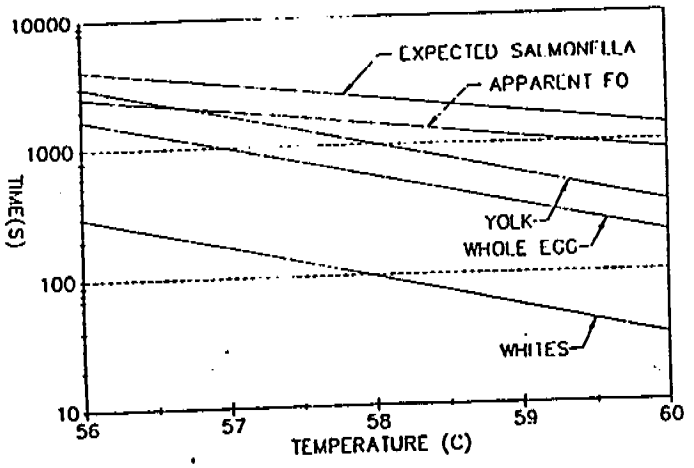
Primary Examiner—Anthony J. Weier
Attorney, Agent, or Firm—Myers Bigel Sibley & Sajovec

[57] ABSTRACT

The present invention relates to producing a safer shell egg through thermal treatment. The present invention provides methods of producing a shell egg wherein the albumen and the yolk of the shell egg receives a thermal treatment sufficient to pasteurize the shell egg and thereby combat the risk of salmonella. The present invention provides methods of providing thermal treatments to the shell egg through introduction of the shell egg into an aqueous solution of a predetermined temperature and maintaining the shell egg in the solution for a predetermined time sufficient to cause the required reduction in salmonella. The predetermined times and temperatures may be characterized by use of the equivalent point method of thermal evaluation, by use of the F_o line for shell egg or by other methods of determining the reduction in salmonella.

10 Claims, 2 Drawing Sheets



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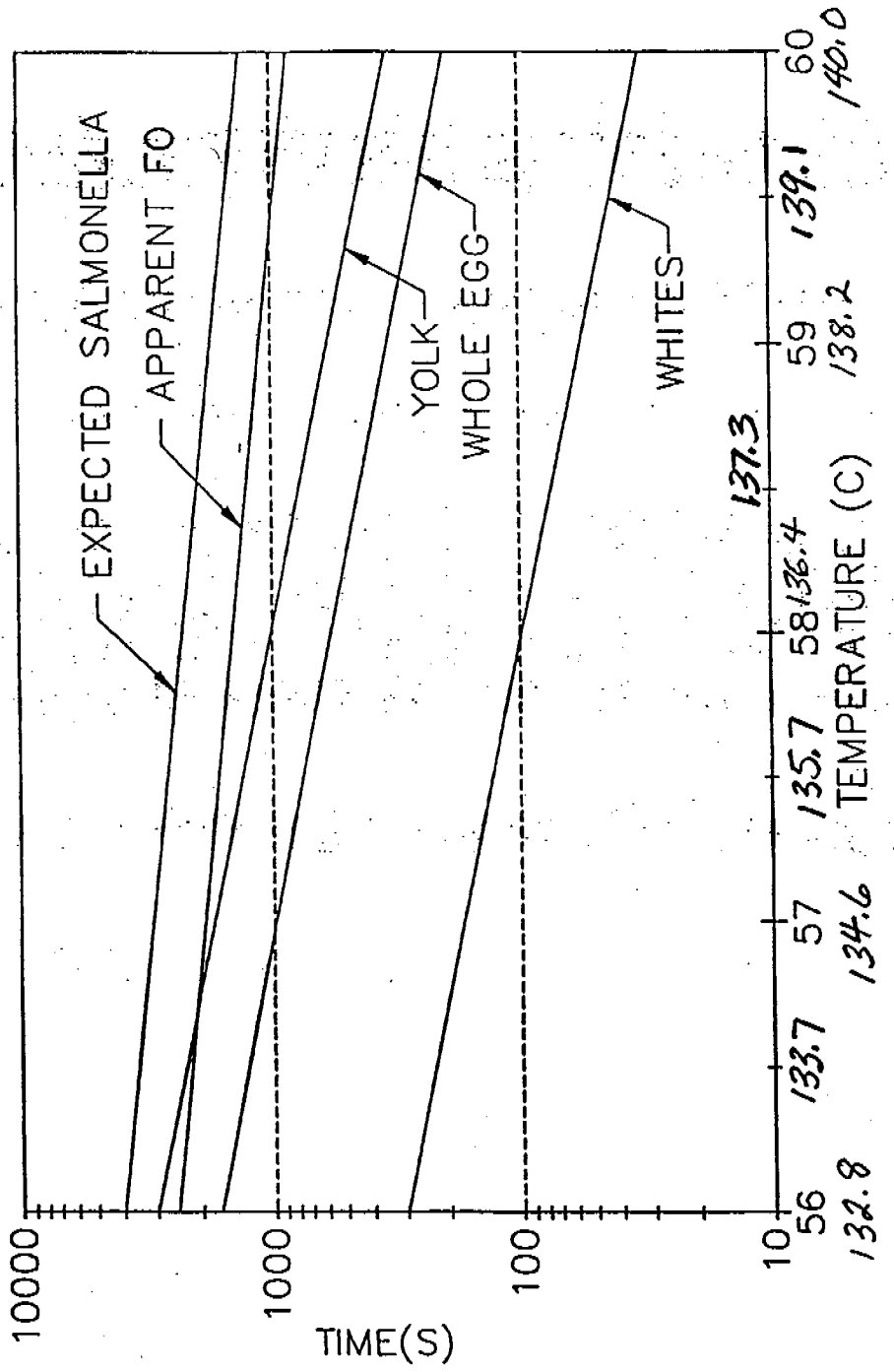
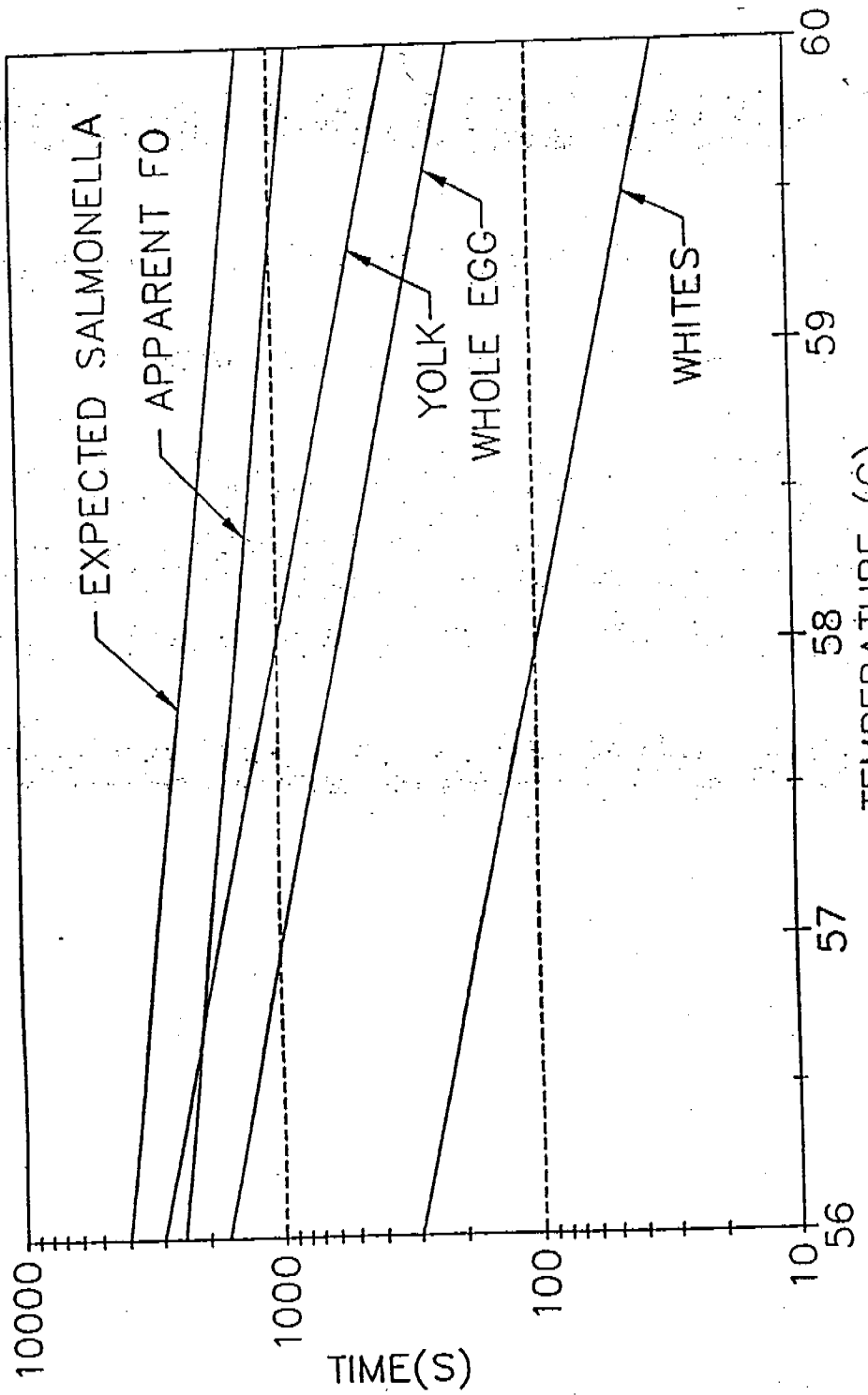

EXPECTED SALMONELLA
APPARENT FO
YOLK
WHOLE EGG
WHITES
10000
1000
100
10
TIME(S)
56
57
58
59
60
TEMPERATURE (C)
132.8
133.7
134.6
135.7
136.4
137.3
138.2
139.1
140.0

FIG. 1.


EXPECTED SALMONELLA
APPARENT FO
YOLK
WHOLE EGG
WHITES
TEMPERATURE (C)
60
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10000
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TIME(S)

FIG. 1.

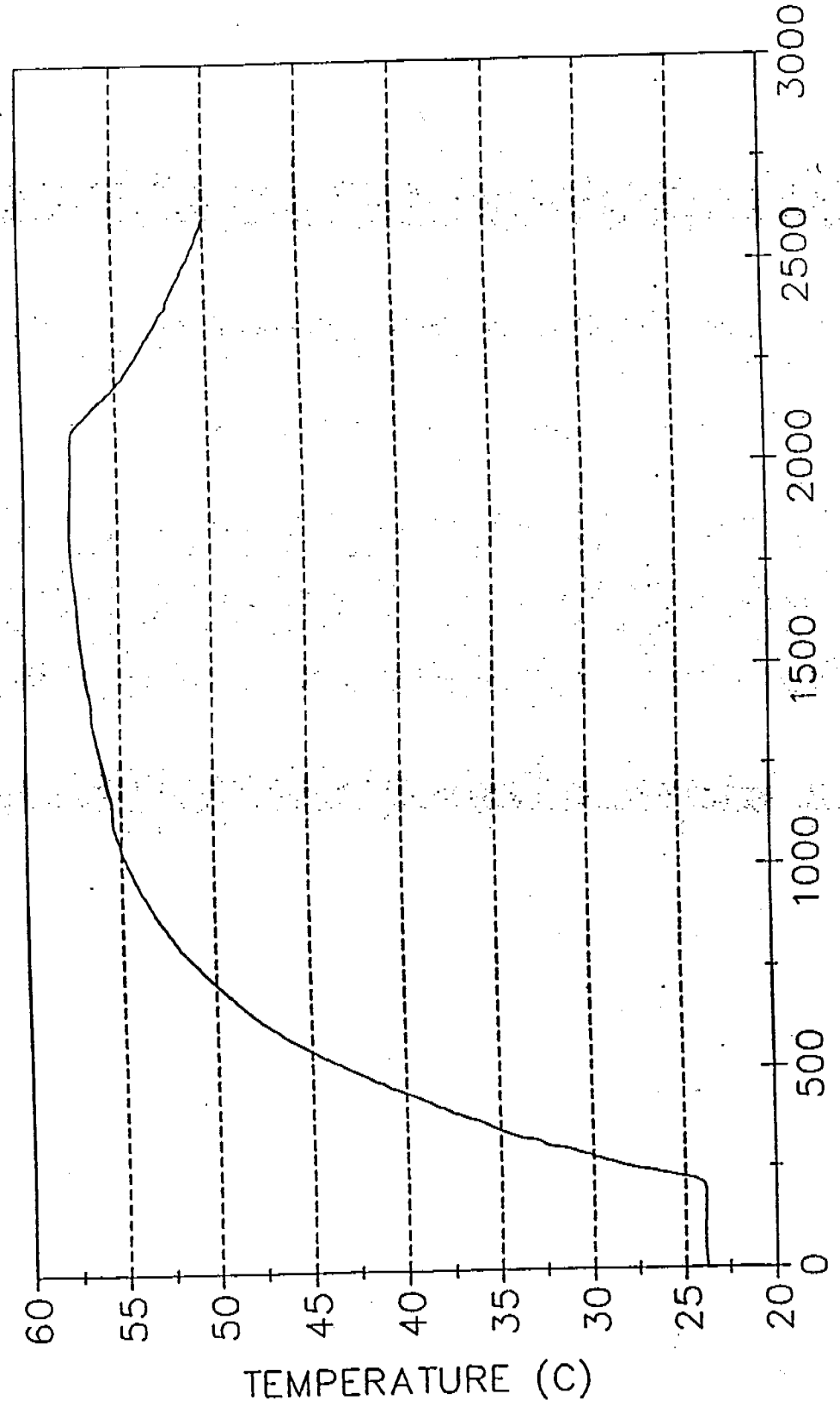
3000
2500
2000
1500
1000
500
0
TIME (S)
60
55
50
45
40
35
30
25
20
TEMPERATURE (C)

FIG. 2.

METHOD OF CONTROLLING SALMONELLA IN SHELL EGGS

This application is a continuation of application Ser. No. 08/178,734, filed Jan. 7, 1994, now abandoned.

FIELD OF THE INVENTION

The present invention relates to methods for pasteurizing shell eggs. More particularly the present invention relates to methods for reducing or eliminating Salmonella from shell eggs and for improving the storage capabilities of shell eggs.

BACKGROUND OF THE INVENTION

It is well known that Salmonella organisms have been associated with egg products. More recently, *Salmonella enteritidis* (SE) has been detected within shell eggs. Presently, the presence of Salmonella within the shell egg is a major concern. Some states have enacted legislation preventing the serving of unpasteurized egg products unless fully cooked. In fact, since as early as 1969, the USDA has overseen the processing of liquid egg removed from the shell to reduce the level of Salmonella contamination to acceptable levels. However, no commercially acceptable methods have been developed to combat Salmonella in shell eggs. Since shell eggs must be used in situations where a liquid egg product cannot, it is therefore desirable to develop a commercially acceptable process for the reduction of Salmonella within shell eggs to provide a safe and functionally acceptable shell egg to the consumer.

Thermal treatments of shell egg to prevent embryonic growth in fertile eggs, to reduce incidence of spoilage during long term storage, and maintain internal quality received considerable research attention from about 1943 to about 1953. This research resulted from the nature of the egg industry at that time in that most of the eggs were produced by small flocks and the majority of the eggs used by the food industry were collected as seasonal surpluses in the spring. As a result of the production practices the eggs were more likely to lose interior quality or become unfit for human consumption because of bacterial growth or embryonic development. Research into "thermostabilization" was directed at solving these problems, which were largely perceived as embryonic growth and the contamination of the egg from contaminants external to the shell. (See Egg Science, Chapter 4, 3d Ed., 1986).

U.S. Pat. No. 2,423,233 to Funk describes the thermostabilization of shell eggs. The '233 patent described a process of heating the shell egg to arrest embryonic development in the egg. As described in the '233 patent, when heating with water the preferred times and temperatures for the heat treatment were 138 degrees Fahrenheit for from five to ten minutes. However, the work of Dr. Funk was not concerned with the elimination of pathogenic organisms. In fact, the times and temperatures suggested by Dr. Funk for heating with water would not be sufficient to cause high enough levels of *Salmonella enteritidis* destruction to insure that a safe shell egg would result. Furthermore, because eggs available through modern production and distribution are fresher and have a lower pH they require a different thermal process than was used by Funk.

Accordingly, it is one object of the present invention to provide a safe shell egg product which is essentially free of Salmonella and more preferably free of *Salmonella enteritidis*.

It is another object of the present invention to provide a commercially acceptable process for reducing the levels of *Salmonella enteritidis* in shell eggs to acceptable levels.

It is still a further object of the present invention to provide a method of producing a Salmonella negative shell egg without requiring additional thermal treatments which could reduce the functionality of the shell egg.

SUMMARY OF THE INVENTION

The present invention provides methods for producing a pasteurized shell egg while retaining the normal appearance of the shell egg contents. The present invention, therefore, relates to a commercially viable method of producing a pasteurized shell egg. One particular embodiment of the present invention involves heating the shell egg in an aqueous solution of a predetermined temperature for a predetermined time. The heating at a predetermined time for a predetermined temperature provide to the albumen of the shell egg a total thermal treatment which can be described by an equivalent time and an equivalent temperature which define a point above the "whites" line of FIG. 1 but is insufficient to cause coagulation of either the albumen or the yolk of the shell egg.

In another aspect of the present invention the equivalent time and equivalent temperature define a point above the "yolk" line of FIG. 1, but again insufficient to cause coagulation of either the albumen or the yolk of the shell egg.

Another aspect of the present invention involves heating the shell egg in an aqueous solution of a predetermined temperature and maintaining the shell in the aqueous solution for a predetermined time, wherein the predetermined time and the predetermined temperature provide to the albumen of the shell egg a thermal treatment sufficient to cause a 9D reduction in *S. enteritidis* but insufficient to cause coagulation of the albumen or the yolk of the shell egg. A further aspect of this embodiment involves providing a thermal treatment sufficient to cause a 9D reduction in *S. enteritidis* from the yolk of the shell egg, but again insufficient to cause coagulation of the albumen or the yolk of the shell egg.

Yet another aspect of the present invention provides a method of producing a pasteurized shell egg by heating the shell egg in an aqueous solution of a predetermined temperature and maintaining the shell egg in the aqueous solution for a predetermined time, wherein the predetermined time and the predetermined temperature define a point above the Apparent F_o line of FIG. 1, and wherein the predetermined time and the predetermined temperature are insufficient to cause coagulation of the albumen or the yolk of the shell egg. A further aspect of the present invention provides a thermal treatment wherein the predetermined time and the predetermined temperature define a point below the Expected Salmonella line of FIG. 1.

The present invention is also directed to a pasteurized shell egg, wherein the albumen of said shell egg has received a thermal treatment sufficient to cause a 9D reduction in *Salmonella enteritidis* but insufficient to cause significant coagulation. In another aspect of the thermally treated shell egg, the yolk of the shell egg receives a thermal treatment sufficient to cause a 9D reduction in *Salmonella enteritidis* but insufficient to cause coagulation.

The foregoing and other objects and aspects of the present invention are explained in greater detail in the specification below and the drawings herein, wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a graph of the apparent F_o line superimposed on the thermal death time curves for Salmonella.

FIG. 2 is a graph of the thermal curve for a representative thermal treatment received by a shell egg according to the methods of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The term "shell egg" as used herein refers to poultry eggs, in the shell thereof with the shell essentially unbroken, wherein the egg yolk and the egg white are essentially liquid. Thus it is desired that shell eggs of the present invention contain yolks and whites which are substantially uncoagulated, in contrast to "soft boiled" (i.e., an egg placed in boiling water for three minutes) or "hard boiled" eggs (an egg cooked until both yolk and white are coagulated and solid). While any poultry egg may be used to carry out the present invention (including chicken, turkey, duck, goose, quail, and pheasant eggs), chicken eggs are particularly preferred.

One aspect of the present invention involves the heating of shell eggs in an aqueous solution of a specified temperature for a time sufficient to cause at least a reduction in *Salmonella enteritidis* (SE) of greater than 5 log cycles (5D). More preferably, the shell egg is placed in aqueous solution wherein the time in the solution and the temperature of the solution impart a treatment to the shell egg sufficient to cause a greater than 7D reduction in SE, and most preferably a reduction in SE of greater than 9D. It is preferred that the treatment of the shell egg be sufficient to cause the reduction in SE in the albumen of the shell egg and most preferable that the treatment be sufficient to cause the SE reduction in both the albumen and the yolk of the shell egg. These reductions in SE should be accomplished while retaining the functionality of the shell egg (e.g., maintaining the egg yolk and egg white in essentially liquid form).

For comparative purposes, it is noted that PCT Application No. WO 93/03622 to Cox describes a method of "hyperpasteurization" of shell eggs. As is described in FIG. 10 of Cox, relatively severe thermal treatments are expected to be required before Salmonella is destroyed. The data points shown in FIG. 10 of Cox may be used to construct a line which reflects what would be an expected Salmonella destruction line for shell eggs. This "Expected Salmonella" line is labelled as such and is shown in FIG. 1 herein ("Expected Salmonella") and has the equation $\log(t)=8.456-0.1183T$, where t is time in minutes and T is temperature in °C. However, these more severe thermal treatments could cause loss in functionality to the shell egg (e.g., partial or complete coagulation of the egg yolk or egg white).

Eggs contain air cells, and the liquid component of eggs have gases such as oxygen and carbon dioxide therein. Cox describes altering the natural proportion of indigenous gases in the eggs being treated by means such as infusing oxygen into the egg or withdrawing gases from the egg. In carrying out the present invention, it is preferred that no such treatment steps be carried out which alter the natural indigenous gases present in the shell egg. Thus, the heating, holding, and cooling steps may be carried out at atmospheric pressure.

In the present invention, the thermal treatment employed preferably defines a point below the "Expected Salmonella" line of FIG. 1. Furthermore, the treatment of the shell egg should be insufficient to cause coagulation of either the albumen or the yolk of the shell egg. The methods of the present invention result in a SE negative shell egg having essentially the natural proportion of indigenous gases.

The method of the present invention involves placing shell eggs in an aqueous solution of a predetermined temperature and then maintaining the shell egg in the aqueous solution for a predetermined time sufficient to cause the reductions in SE described above. Preferably the volume of the aqueous solution is sufficiently great to minimize the reduction in temperature of the solution by the addition of the lower temperature shell eggs. Optionally, the eggs may be agitated or the aqueous solution may be circulated about the eggs to facilitate the transfer of heat from the solution to the eggs. Any suitable aqueous solution may be employed, including tap water and water with salt such as NaCl added.

After maintaining the eggs in the aqueous solution for the required time, the eggs may be removed and allowed to cool at room temperature. Cooling may be carried out by other means, such as by direct refrigeration, as long as the treatment received by the shell egg is sufficient to achieve the desired reduction in SE. The heat treatment received by the shell egg after removal from the aqueous solution may be considered in determining the total thermal treatment received by the shell egg, as will be apparent from the discussion below.

As will be appreciated by those skilled in the art, after thermally treating the shell eggs the shell eggs may be oiled or waxed in accordance with known techniques with a suitable edible oil such as mineral oil to improve the keeping quality of the eggs.

In selecting the heating temperatures and times to use in carrying out the present invention, any number of methods may be used, including the equivalent point method of thermal evaluation to determine the total thermal treatment at various locations of the shell egg, including the albumen and the yolk, inoculation studies may be conducted to determine the treatment conditions which yield the desired reduction in SE, or a F_o value could be determined for the shell egg which results in the desired SE reduction. Furthermore, times and temperatures may be selected to give differing reductions in SE in different sections of the shell egg. For example, a time and temperature condition may be selected to provide a 9D reduction in SE in the albumen of the egg while imparting a 7D reduction in the yolk.

While lower temperatures may be used, in practice, aqueous solution temperatures of greater than about 134° F. (or about 56° C.) and less than about 140° F. (or about 60° C.) are preferred and, as discussed above, it is preferred that the temperature of the solution remain approximately constant for the time the shell eggs are heated. Times of from about 20 minutes to about 45 minutes or greater may be selected to achieve the desired reduction in Salmonella with shorter times being required for higher temperatures. The specific times and temperatures required may vary with size, age and pH of the shell egg and whether the shell egg has been oiled before or after thermal treatment.

If an equivalent point analysis of the thermal treatment received by a particular portion of the shell egg is utilized to determine the reduction of SE in the shell egg, then the resulting equivalent time and equivalent temperature should define a point above the desired Salmonella thermal death time curves such as those shown in FIG. 2 and Table 6 of the USDA Egg Pasteurization Manual, ARS 74-38, Agricultural Research Service, United States Department of Agriculture, Albany, Calif. (1969) which are labelled as such and reproduced in FIG. 1 herein and labelled as "Whites," "Yolk" and "Whole Egg".

If an F_o analysis is employed in carrying out the present invention, then to assure a sufficient reduction in Salmonella such that no shell eggs test positive for Salmonella utilizing

approved tests for Salmonella such as DPV approved by the USDA for use in liquid egg processing and discussed in the Egg Pasteurization Manual. then actual time and temperature combinations which define points at or above both the Apparent F_O line and the Salmonella thermal death time curve of FIG. 1 should be utilized. As will be understood by one of skill in the art. variations in shell egg physical characteristics. such as size. age. pH. etc., may cause the shell egg "Apparent F_O" line of FIG. 1 to shift.

Shell eggs produced by the methods of the present invention preferably receive a thermal treatment such that the shell eggs have a shelf life of 12, 24 or 36 weeks or more under refrigerated conditions. The term "refrigerated" as used herein means the eggs are stored at a temperature of 4° C.

For storage and shipping. shell eggs of the present invention may be packaged in a suitable container. such as egg cartons or egg flats. constructed of materials such as cardboard or plastic polymer.

Shell eggs of the present invention may be used for any purpose for which raw eggs are currently used. including the table-side preparation of Caesar salads. the preparation of fried eggs. the preparation of hard-boiled eggs. the preparation of other egg dishes. baking. etc.

The present invention is explained in greater detail in the following Examples. These Examples are intended to be illustrative of the present invention. and are not to be taken as limiting thereof.

EXAMPLE 1

Salmonella Thermal Resistance

Two experiments were conducted to determine the thermal resistance of SE (Phage type 8) in artificially infected shell eggs and the resulting changes in interior quality due to elevated processing temperatures. During the first experiment fresh shell eggs weighing approximately 62 grams each were obtained from the University research unit. The eggs were dipped in an iodoform solution. excess solution was removed with a cheese cloth and permitted to air dry on sterile plastic egg flats. Each egg was inoculated with 10^6 viable cells from a 24 hour Trypticase soy broth culture of SE (phage type 8). The shell was perforated with a sterile blunt 18 gauge needle. A sterile blunt glass needle on a 10µ pipet was used to inject the culture near the yolk surface and the hole in the shell was then sealed with a small piece of aluminum foil and Super Glue. Groups of 36 eggs were subjected to temperatures of 22.2 (unheated control). 56. 56.75 and 57.5° C. Eggs within a temperature-group were subjected to a range of heating time periods ranging from 15 to 45 minutes. The study was replicated in time. Heating was carried out in a shaking water bath equipped with polyethylene egg flats perforated with numerous 1 cm holes to increase water circulation around the eggs.

Immediately following the heat treatment. each egg was broken separately and the albumen plus yolk was mixed for 30 seconds in a sterile Stomacher bag containing 200 ml of lactose broth using a Stomacher Lab - Blender 400[1]. The mixed egg content was incubated in a sterile glass container for 24 hours at 39° C. A representative culture was then transferred to selenite-cysteine broth and incubated for 24 hours at 39° C. The incubated culture was streaked on brilliant green agar plates and incubated for 24 hours at 39° C. The suspect colonies were transferred to TSI slants. The second experiment was conducted to evaluate the effect of heating. oiling and storage on interior egg quality. Four storage treatments of two. three two and four weeks were used. each with oiled and non-oiled eggs. The eggs were heated in a water bath at 56.75° C. for 36 minutes and 57.5° C. for 23 minutes. Eggs were oiled following heat treatment. Thirty eggs from the control and each treatmeht were stored at room temperature (22.2° C. and 7.2° C.).

A group of 14 eggs from each variable was used to determine pH. foam volume. whipping time. foam depth. foam stability. grade and a second group of 14 eggs was used to evaluate Haugh units.

EXAMPLE 2

Microbiology

Table 1 presents the results of the thermal treatments on the survival of *S. enteritidis* inoculated into shell eggs. As temperature increased. the time required to obtain Salmonella negative eggs decreased. At 56° C., exposure time required to obtain no positive eggs was greater than 41 minutes. At 56.75 and 57.5° C., exposure times greater than 28 and 23 minutes. respectively. were required to obtain eggs negative for Salmonella. Standard USDA tests for Salmonella were utilized.

TABLE 1

Number of samples positive after heating at 56, 56.75 and 57.5° C.

	Temperature of Water		
Time in Waterbath min.	56° C. •No. – No. +	56.75° C. No. – No. +	57.5° C. No. – No. +
15			12–4
16		12–11	
19			12–2
20		12–8	
23			12–2
24		12–7	
27			12–0
28		12–2	
29	12–3		
31			12–0
32		12–0	
33	12–6		
37	12–4		
41	12–1		
45	12–0		

•No. – No. + · Number of samples heated – number positive

EXAMPLE 3

Thermal Evaluation

Times at temperatures where none of the twelve inoculated eggs were positive, were used in a regression equation to determine the thermal death time curve (TDTC) presented in FIG. 1. As the "Apparent F_O" line. The equation for the line is:

$$\log(t) = -0.1216 \times T + 8.4274$$

where t is the time in minutes and T is temperature in degrees Centigrade. The R^2=0.86.

The above equation may be consider a workable approximation or an "Apparent F_O" line for *S. enteritidis* in shell eggs. The temperature range and times used to obtain the data were selected with the intent of determining if commercially reasonable thermal treatments would have sufficient lethality for *Salmonella sp.* It is expected that increas-

ing the number of samples and extending the temperature range would result in some changes in the slope of the line, especially at lower temperatures (Cotterill et al., 1973). Based on concerns for the interior quality and their use in cooking, the practical upper temperature range would probably be less than 60° C.. At temperatures in the range of 55 to 65° C.. Cotterill et al. (1973) generally found linear TDTC for destruction of *S. oranienburg*. It is anticipated that the F_O line for other forms of Salmonella in shell egg are also linear over that temperature range.

It is established that different strains of Salmonella, the type of egg product, and other environmental conditions will effect the thermal inactivation of Salmonella. Shah et al. (1991) presented D values for 17 strains of *S. enteritidis* in whole egg ranging from 13.7 to 31.3 seconds at 60° C. The average D was 19.2±5.4 sec. and was reported to be similar to previous data. Cotterill et al. (1973) and USDA (1969) provide data showing the influence of egg product type, pH, salt, and sugar on the thermal resistance of *Salmonella sp.* When evaluating the thermal resistance of Salmonella in intact shell eggs, the location of the bacteria within the egg becomes important. The thermal resistance of Salmonella in different egg products is as follows: plain yolk>whole egg or pH 7 egg white>pH 9 egg white (USDA, 1969). Therefore, increased thermal treatments would be required for plain yolk over whole egg or pH 7 egg white or pH 9 egg white.

In this study, the culture was placed in the egg white near the surface of the yolk. The consensus of those actively studying *S. enteritidis* infection of shell eggs is that the bacteria is found in the egg white of naturally infected eggs produced by infected hens (Gast and Beard, *J. Food Prot.*, 55:152–156 (1991); Beard, *Egg Industry*, 92:3337 (1992)). The "Apparent F_O" line was plotted in FIG. 1, a redrawing of FIG. 6 from the Egg Pasteurization Manual (USDA, 1969). This allows a visual evaluation of the thermal processes applied to intact shell eggs relative to accepted minimal pasteurization processes for liquid egg products.

When comparing the "Apparent F_O" line and actual processes to the lines for pH 9 egg white and whole egg or pH 7 egg white, the shell egg processes seem to be more than adequate to achieve reductions of *S. enteritidis* sufficient for an accepted pasteurization process for protection of public health. The pH of the egg whites in this study ranged from 8.4 to 8.6 which is typical for shell eggs the age of those used in this study.

Although natural infections of the yolk are not expected at the time of ovulation, it is clear that under adverse handling conditions, *S. enteritidis* can be introduced into the egg and grow to very high numbers in the yolk (Hammack et al., *Poultry Science*, 72:373–377 (1993)). At 56° C. (134° F.), if the cells were in the yolk, the minimum holding time would be 36.42 minutes for an adequate pasteurization process. Since the apparent F_O line crosses the USDA yolk pasteurization line at about 134° F., it is therefore preferred that thermal treatments for shell eggs at temperatures above 134° F. be selected.

In addition to the F_O analysis described above, an equivalent point analysis of the time-temperature curve of the thermal treatment imparted to the shell egg may be utilized to determine the total thermal treatment imparted various locations in the shell egg. A temperature probe was inserted into shell eggs in the aqueous solution at various depths into the egg. Temperatures were taken in the albumen at the yolk/albumen interface and in the yolk. These temperatures were taken using a hypodermic needle probe model HYP4-16-1-½-100-EU-48-RP manufactured by BIOMEGA® of Stamford Conn. The probe was inserted into the egg through a cork which was glued to the egg and prevented water from entering the egg through the aperture created by the probe. A DAYTRONIC® System 10 data acquisition unit was connected through an RS-232 serial connection to a personal computer. Temperature measurements were taken every 5 seconds and recorded. A representative thermal curve for a thermal treatment to the shell eggs is shown in FIG. 2. To evaluate the equivalent point for the thermal curve shown in FIG. 2, the thermal reduction relationship (G_{Ea}) is calculated using the following equation:

$$G_{Ea} = \int_0^{t_{final}} e^{-\frac{Ea}{RT(t)}} dt$$

where Ea is the activation energy (J/mol), R is the Universal Gas Constant (8.314 J/mol.K), T(t) is temperature as a function of time (°K.) and t_{final} is the final processing time (s). This integration process is then repeated for a number of activation energies (Ea). Each G_{Ea} value defines a line of equivalent thermal treatments for that particular activation energy (Ea). The intersection of the lines defined by the G_{Ea}'s is the equivalent point of the thermal process. (Swartzel, 1986, *J. Agric. Food Chem.*, 34:397).

Performing such an equivalent point analysis for the SE negative tests described above results in the following equivalent times and temperatures:

TABLE 2

Equivalent Point Data

		Albumen		Yolk	
Bath Temp.	Bath Time	Eq. Temp.	Eq. Time	Eq. Temp.	Eq. Time
56° C.	45 min.	54.45° C.	51.14 min.	NA	NA
56.75° C.	32 min.	53.0° C.	39.58 min.	53.54° C.	38.41 min.
57.5° C.	31 min.	54.86° C.	38.49 min.	54.33° C.	37.47 min.

From these results an expected reduction in SE may be ascertained or additional thermal conditions predicted to achieve other reductions in SE.

Use of the time and temperature relationships discussed above should result in a shell egg which may be guaranteed to be Salmonella negative. As used herein Salmonella negative means a negative result indicating the absence of harmful Salmonella as determined by USDA approved methods of Salmonella testing. This insured Salmonella negative shell egg is referred to herein as a pasteurized shell egg.

EXAMPLE 4

Quality and Function

Quality and functional attributes of shell eggs heated at 56.75 and 57.5° C. with and without oiling are summarized in Table 2. The expected ability of oiling egg shells to maintain fresh egg pH and interior quality is evident. The egg white pH of the oiled eggs is clearly lower than for the unoiled eggs regardless of storage temperature. The thermal treatments did not seem to have an effect on egg white pH, but did seem to have an impact on interior quality as indicated by the Haugh unit values. For the non-thermally treated eggs, oiling held egg white pH and resulted in higher Haugh values at both storage temperatures. Oiling the thermally treated eggs appeared to help maintain interior quality if they were stored at room temperature (22.2° C.). The thermal treatments alone, provided good protection of inte-

rior quality. All thermally treated eggs regardless of oiling or storage temperature would be graded AA quality grades. There seemed to be less correlation of egg white pH with interior quality than might have been expected. This is particularly so when comparing the egg white pH and Haugh units of oiled and unoiled eggs. That result suggests the thermal treatments are stabilizing interior quality independently of deterioration mechanisms related to change in egg white pH. Funk U.S. Pat. No. 2,423,233 (1947) claimed that heating shell eggs for 5 to 40 minutes at temperatures of 60 to 43.4° C., respectively, would maintain interior quality without impairing the whipping qualities. However, he did not define quality or whipping qualities.

TABLE 3

Quality and Functional attributes of thermally treated shell eggs with and without oiling four weeks storage at 22.2 or 7.2° C.

	Egg White pH		Haugh Unit		Whip Volume[a]		Whip Time[b]	
	22/2 C.	7.2 C.	22.2 C	7.2 C.	22.2 C.	7.2 C.	22.2 C.	7.2 C.
No Oil								
No Heat	9.3	9.2	20	60	1,000	900	40	45
56.75 C., 36 min.	9.2	8.9	78	82	550	650	220	110
57.5 C., 23 min.	9.2	9.1	74	82	750	600	280	130
Oiled								
No Heat	8.0	8.1	58	70	950	800	45	45
56.75 C., 36 min.	7.9	8.2	80	80	550	650	190	200
57.5 C., 23 min.	8.0	8.1	81	82	600	700	200	210

[a]Whip Volume in ml.
[b]Whip Time in sec.

In this study, the whipping qualities as indicated by whip volume and whip time were adversely effected by the thermal treatments. This indicates that the thermal treatments were substantial and parallel damage that is expected when liquid egg white is pasteurized. Oiling or storage temperature did not seem to have an effect on function of the egg white.

Thermally treated eggs, when broken out onto a plate, appear quite similar to unheated eggs with the exception of some slight opaqueness of the albumen. The normal shape of the thick egg white is maintained and there appears to be the normal amount of outer thin albumen. The yolk membrane may exhibit some weakness. Although yolk indices were not determined, trained observers note some flattening of the yolk relative to unheated controls. The yolk membranes of heated shell eggs did not exhibit any additional fragility over the four week storage and seemed to withstand handling for Haugh unit determinations as expected for eggs of the same interior quality.

The foregoing examples are illustrative of the present invention, and are not to be construed as limiting thereof. The invention is defined by the following claims, with equivalents of the claims to be included therein.

That which is claimed is:

1. A method of producing a pasteurized chicken shell egg, comprising:

selecting a predetermined time and predetermined temperature so as to achieve at least a 5D reduction in Salmonella within the yolk of said chicken shell egg, and

heating the chicken shell egg in an aqueous solution for said predetermined temperature;

holding the chicken shell egg in the aqueous solution for said predetermined time; and

wherein said predetermined time and said predetermined temperature define a point above the "Apparent F_o" line of FIG. 1, and further wherein said predetermined time and said predetermined temperature are insufficient to cause more than insignificant coagulation of the albumen of the chicken shell egg and insufficient to cause more than insignificant coagulation of the yolk of the chicken shell egg.

2. The method of claim 1 wherein said predetermined time and said predetermined temperature also define a point above the "Yolk" line of FIG. 1.

3. The method of claim 1 wherein the chicken shell egg is oiled with an edible oil following said holding step.

4. The method according to claim 1 further comprising the step of cooling the chicken shell egg after said heating and holding step.

5. The method according to claim 4 wherein the pasteurized chicken shell egg has a refrigerated shelf life of at least 12 weeks.

6. A method of producing a pasteurized chicken shell egg, comprising:

heating the chicken shell egg in an aqueous solution of a predetermined temperature; and

holding the chicken shell egg in the aqueous solution for a predetermined time; and

cooling the chicken shell egg after said heating and holding steps;

wherein said predetermined time and said predetermined temperature provide to the albumen of the chicken shell egg a total thermal treatment described by an equivalent time and an equivalent temperature which define a point above the "Yolk" line of FIG. 1 but insufficient to cause coagulation of the albumen of the chicken shell egg and insufficient to cause coagulation of the yolk of the chicken shell egg, and wherein said equivalent time and said equivalent temperature also define a point below the "Expected Salmonella" line of FIG. 1, and further wherein the pasteurized chicken shell egg has a refrigerated shelf life of at least 12 weeks.

7. A method of producing a pasteurized chicken shell egg, comprising:

selecting a predetermined time and a predetermined temperature so as to provide to the albumen of the chicken shell egg a total thermal treatment described by an equivalent time and equivalent temperature which define a point above the "Yolk" line of FIG. 1 but

insufficient to cause more than insignificant coagulation of the albumen of the chicken shell egg and insufficient to cause more than insignificant coagulation of the yolk of the chicken shell egg, and wherein said equivalent time and said equivalent temperature also define a point below the "Expected Salmonella" line of FIG. 1, and further wherein said predetermined time and said predetermined temperature are sufficient to cause a 5D reduction in *Salmonella enteriditis* in the yolk of the chicken shell egg;

heating the chicken shell egg in an aqueous solution of said predetermined temperature of at least about 56° C.; and

holding the chicken shell egg in the aqueous solution for said predetermined time of at least about 20 minutes; and

cooling the chicken shell egg after said heating and holding steps.

8. A method of producing a pasteurized chicken shell egg, comprising:

selecting a predetermined time and a predetermined temperature so as to provide to the albumen of the chicken shell egg a total thermal treatment described by an equivalent time and equivalent temperature which define a point above the "Yolk" line of FIG. 1 but insufficient to cause more than insignificant coagulation of the albumen of the chicken shell egg and insufficient to cause more than insignificant coagulation of the yolk of the chicken shell egg, and wherein said equivalent time and said equivalent temperature also define a point below the "Expected Salmonella" line of FIG. 1, and further wherein said predetermined time and said predetermined temperature are sufficient to cause a 7D reduction in *Salmonella enteriditis* in the yolk of the chicken shell egg;

heating the chicken shell egg in an aqueous solution of said predetermined temperature of at least about 56° C.; and

holding the chicken shell egg in the aqueous solution for said predetermined time of at least about 20 minutes; and

cooling the chicken shell egg after said heating and holding steps.

9. A method of producing a pasteurized chicken shell egg, comprising:

selecting a predetermined time and a predetermined temperature so as to provide to the albumen of the chicken shell egg a total thermal treatment described by an equivalent time and equivalent temperature which define a point above the "Yolk" line of FIG. 1 but insufficient to cause more than insignificant coagulation of the albumen of the chicken shell egg and insufficient to cause more than insignificant coagulation of the yolk of the chicken shell egg, and wherein said equivalent time and said equivalent temperature also define a point below the "Expected Salmonella" line of FIG. 1, and further wherein said predetermined time and said predetermined temperature are sufficient to cause a 9D reduction in *Salmonella enteriditis* in the yolk of the chicken shell egg;

heating the chicken shell egg in an aqueous solution of said predetermined temperature of at least about 56° C.; and

holding the chicken shell egg in the aqueous solution for said predetermined time of at least about 20 minutes; and

cooling the chicken shell egg after said heating and holding steps.

10. A method of producing a pasteurized chicken shell egg, comprising:

selecting a predetermined time and a predetermined temperature so as to provide to the albumen of the chicken shell egg a total thermal treatment described by an equivalent time and equivalent temperature which define a point above the "Yolk" line of FIG. 1 but insufficient to cause more than insignificant coagulation of the albumen of the chicken shell egg and insufficient to cause more than insignificant coagulation of the yolk of the chicken shell egg, and wherein said equivalent time and said equivalent temperature also define a point below the "Expected Salmonella" line of FIG. 1;

heating the chicken shell egg in an aqueous solution of said predetermined temperature of at least about 56° C.; and

holding the chicken shell egg in the aqueous solution for said predetermined time of at least about 20 minutes; and

cooling the chicken shell egg after said heating and holding steps;

wherein the pasteurized chicken shell egg has a refrigerated shelf life of at least 12 weeks.

* * * * *

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Polster

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[54] PROCESS FOR HEAT TREATING FOOD PRODUCT

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[51] Int. Cl.[6] A23L 3/10; A23B 5/005

[52] U.S. Cl. 426/521; 426/520; 426/300; 426/407; 426/412

[58] Field of Search 426/407, 412, 426/520, 521, 298, 300

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[57] ABSTRACT

Proteinaceous food product is heated by immersing the product in a liquid bath and maintaining the bath at a controlled temperature within a range that treats the proteinaceous food product without substantial loss of functionality.

41 Claims, No Drawings

PROCESS FOR HEAT TREATING FOOD PRODUCT

This application is the national stage of International Application no. PCT/US94/12790, filed Nov. 7, 1994, and thus a continuation-in-part of U.S. patent application Ser. No. 08/148,915, filed Nov. 5, 1993 (now U.S. Pat. No. 5,494,687).

BACKGROUND OF THE INVENTION

This invention relates to a process for heat treating food product. The process is advantageously used for pasteurizing and/or tenderizing proteinaceous food product.

Pasteurizing of proteinaceous food product can be carried out by heating to destroy infectious organisms such as salmonella. Pasteurization may be defined as heat treatment for the purpose of killing or inactivating disease-causing organisms. For example for milk, a minimum exposure for pasteurization is 62° C. for 30 minutes or 72° C. for 15 seconds. The latter exposure is called flash pasteurization. Complete sterilization may require ultra-high pasteurization such as treatment at 94° C. for 3 seconds to 150° C. for 1 second to kill pathogenic bacteria and inactivate enzymes that cause deterioration and to provide for satisfactory storage life.

Minimum food safety processing standards for various commodities have been promulgated and are enforced by the United States Department of Agriculture (USDA). Pasteurization may be defined in accord with the standards mandated by the USDA. The Nutrition Action Health Letter published by the Center For Science In The Public Interest (July/August 1991 Edition, Vol. 18, No. 6, "Name Your (Food) Poison") describes concern with the growing number of cases of food poisoning due to food infections.

Many known processes for pasteurizing food are insufficient to assure safety of some foods from infections or cannot be applied to some food products. The "Name Your (Food) Poison" article reports that dairy products, eggs, poultry, red meat and seafood, in that order are the most common causes of food poisoning. Shell eggs are particularly difficult to pasteurize because of their structure. The article indicates that one of 10,000 eggs is contaminated with salmonella enteritis.

U.S. Pat. No. 4,808,425 to Swartzel et al. teaches a method of "ultrapasteurizing" a liquid whole egg product". The liquid whole egg product is passed as a continuous stream through a pasteurizing apparatus. The liquid whole egg product is heated to a predetermined real temperature by contacting the product with a heated surface. The total thermal treatment received by the whole egg product is prescribed by an equivalent temperature and an equivalent time that are defined to pasteurize the material but insufficient to cause coagulation (loss of functionality) of product.

U.S. Pat. No. 5,290,583 to Reznik et al. relates to an electroheating process for treating liquid egg. The process comprises the steps of electroheating the liquid egg with an AC electric current having a frequency effective to heat the liquid egg without electrolysis at a rate to avoid detrimental coagulation (loss of functionality). The liquid egg is held at a temperature sufficient to achieve pasteurization.

Functionality or functional properties of eggs relate to the volume, structure, texture and keeping quality of baked products produced by the eggs. Functionality is defined herein as the capability of a proteinaceous food product to provide the properties of the product that has not been treated by the process of the present invention. Loss of functionality is determined by observing the loss of quality of the food product. For example, spoilage or cooking is a loss of functionality of meat in a process designed for aging of meat without cooking. Coagulation is a loss of functionality of shell eggs during pasteurization. Cooking and/or loss of taste or texture is a loss of functionality of oysters that are to be eaten uncooked.

The extent to which functional properties of a proteinaceous food product are affected by heating may be determined by testing the performance of the product under conditions in which the damage is readily observed. For example, functionality of eggs can be established by determining the quality of food products that depend upon the quality of coagulation of the egg. Such food products may include custards and pie fillings and loaves or croquettes which depend upon the binding of food together that may be provided by the quality of egg coagulation. The functional properties may also include the elasticity of an egg protein film or the emulsifying ability to disperse oil in the making of mayonnaise and salad dressings. Functionality or functional properties of other food product are similarly established in terms of the capability of the food product to perform intended purposes after heat treatment including retaining a "natural" taste and texture.

While heat treatment may be effective in pasteurizing proteinaceous food product, heating at the same time may destroy some functionality or functional properties of the product. The present invention provides a process for heat treating proteinaceous food product that achieves a delicate balancing of effective heat treatment without destruction of functionality or functional properties.

The heat treating process of the present invention also provides a method of quick aging of meat by exposure to an elevated temperature without decomposition of the food product by cooking. Aging a meat can be carried out by storing pieces of meat in a refrigerated space for a time sufficient to permit natural enzymes to complete a tenderizing process. Enzymes in the meat continue to function post-mortem to catalyze the hydrolysis of collagen and other proteins. The enzymes break down connective tissue so that the meat becomes tender and flavorful. After aging, the texture of the meat is more acceptable to the consuming public.

During aging, the meat is generally refrigerated at a temperature of about 34° F. to suppress bacterial growth and at a relative humidity of about 80% to suppress mold growth. However at these conditions, the rate of enzymatic action is suppressed. An average of twenty-one days or more is often required to obtain satisfactory tenderizing. Substantial space in a refrigeration facility is required to store the meat for this period of time.

Increasing the temperature used in the aging process accelerates activity of the enzymes for tenderizing meat. However, bacterial activity is also increased. Slime growth, putrefaction and mold growth result in spoilage and can cause a substantial loss of usable meat. Maintaining low humidity in the refrigerated space to retard mold growth tends to desiccate and discolor meat. The desiccated and discolored parts must be trimmed. Additionally, low humidity causes shrinkage.

U.S. Pat. No. 2,713,002 to Williams proposes aging meat by storing a carcass in the presence of ultra-violet radiation. The carcass is wrapped in a combination of absorbent material with a moisture-vapor-permeable, pliable, extensile film. The meat is wrapped in the film and held under ultraviolet radiation for five, ten, fifteen or twenty days at

between 30° F. to 40° F.; for five or ten day periods at 47° F.; for two, three or five days at 60° F.; or for one or two days at 70° F. The covered meat is initially chilled in a cooler at a temperature of about 30° to 45° F. A period of twenty-four to seventy-two hours is required to bring the meat to an initial chill temperature for aging of about 30° F. to 35° F.

U.S. Pat. No. 3,445,240 to Bedrosian et al. discloses tenderizing meat by storage under specific controlled chilled conditions and for definite periods of time in an atmosphere containing controlled amounts of oxygen and carbon dioxide at a high humidity.

U.S. Pat. No. 3,552,297 to Williams relates to an apparatus for aging and flavoring meat at a temperature of around 65° F. to 75° F. The apparatus includes a germicidal lamp and a timer motor for setting the aging process for a period of one to four days. The aging process is conducted in the presence of Thamnidium, an anti-bacteria agent.

U.S. Pat. No. 3,663,233 to Keszler teaches a process of tenderizing and cooking meat products by pumping the beef with a liquid tenderizing agent. The beef is heated to a constant temperature and maintained at such temperature to allow tenderizing by the tenderizing agent. The temperature is then raised to cook the meat.

U.S. Pat. No. 3.961,090 to Weiner et al. teaches pumping an aqueous solution into a piece of uncooked beef, vacuum sealing the beef in a bag and cooking the beef "to attain a maximum internal temperature of 131° to 140° F."

U.S. Pat. No. 3,966,980 to McGuckian discloses a method of cooking foods in vacuum packages in a thermostatically controlled hot water bath followed by quick chilling and storage at 28° F. to 32° F. The bath is maintained in a range between 140° F. to 212° F. to cook the meat at least to a "rare" state. The cooked food is thereafter quick chilled for storage. A disclosed advantage of the process is that the meat may be enzymatically tenderized while it is being cooked.

U.S. Pat. No. 4,233,323 to Sway et al. discloses a tenderization process of exposing meat to ultraviolet rays of high intensity.

U.S. Pat. No. 4,346,650 to Zaitsu discloses a bath for sterilizing and cooking food. The process is a two-step process requiring sterilization at about 105° C. (221° F.) to about 140° C. (284° F.). The bath sterilizes and cooks packaged foods.

U.S. Pat. No. 4,983,411 to Tanaka et al. relates to an apparatus used for ultraviolet sterilization and shrink film packaging food. In the packaging step, the food is sprinkled with hot water.

A process of heat treating proteinaceous food product below a cooking temperature by exposure to an elevated temperature is desirable for pasteurizing, aging or both pasteurizing and aging the food product. However, elevated temperatures for periods required to pasteurize food material or to age food material can cause decomposition, i.e., loss of functionality or cooking. Elevated temperatures at shorter periods of time may not accomplish pasteurization or aging or may stimulate bacteria growth causing spoilage.

SUMMARY OF THE INVENTION

The present invention relates to a process of heat treating proteinaceous food product by immersing the product in a liquid bath and maintaining the entire volume of the bath at a controlled temperature within a range of ±2° F. The process heat treats the proteinaceous food product without substantial loss of functionality. The process can be used to effectively pasteurize or tenderize or otherwise treat proteinaceous food product.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The process of the invention permits heat treating food product within an abbreviated period of time to provide pasteurization, tenderizing or both pasteurizing and tenderizing. The process comprises immersing the food product in a liquid bath such as a water bath. The entire volume of the bath is maintained at a controlled temperature within a range that pasteurizes the food product without destroying functionality or that hastens enzymatic tenderizing of a food product but does not substantially cook the meat.

The heat treatment process of the present invention is particularly useful for pasteurizing food product such as seafood (e.g., fin fish and shellfish such as oysters, claims, scallops, mussels, crabs) and shell egg among many others. Shell egg may present a particular problem of infection. One source of infection may arise from the fact that egg shells have numerous pores that permit the egg to breathe. Pore holes vary in size. When the egg is laid, the holes come in contact with infections in the environment outside of the egg. Some of the infections may be in the form of microbes that are of a size that fit through the pores. Inside the egg, the microbes are not uniformly spread but are retained in small patches on the inner shell membrane that has pores that are smaller than the shell. Additionally, airborne microorganisms may invade an egg as a contaminant during gas and vapor exchange. Additionally, eggs can be contaminated by a transovarian infection.

Swartzel et al. describes USDA standards for pasteurizing liquid eggs. The minimum times for temperature processing required by USDA standards produces liquid eggs that are safe to eat while at the same time an acceptable degree of functionality is retained. However, standards for shell eggs are not available because no reliable temperature technique for treating shell eggs is known. Shell eggs present a particular problem of pasteurization because the shell egg is made up of diverse materials. An effective temperature treatment must expose all of the shell, the outer shell and egg membranes, the albumen layer or egg white, the chalaza, the vitelline membrane and the yolk to temperatures for times to adequately destroy the undesired organisms without destroying functionality.

To achieve these objectives, the shell egg may be exposed to a prepasteurization temperature of 45° F. or higher followed by exposure to temperatures from about 125° F. to near, but less than, 140° F. Another processing technique includes first processing at an elevated temperature near to 140° F. followed by a lowering of temperature to a processing temperature at the lower end of the effective pasteurization temperature range.

If temperatures are significantly above 139° F., the egg shell may crack and whites may begin to coagulate before the yolk has been pasteurized. At temperatures below the specified minimum, salmonella and other harmful microorganisms, including molds, bacteria and viruses, may not be effectively destroyed.

Processing times at these temperatures required for meeting minimum USDA requirements for liquid eggs range from a minimum processing time of about 20 minutes to a processing time of 345 minutes. Preferred temperatures include a range of 135° F. to 138 or 139° F. These time and temperature relationships are effective for pasteurization processing of whole shell eggs once an adequate prepasteurizing processing temperature is achieved within the center of the whole shell egg of between about 38° F. to about 60° F. The average first preprocessing temperature

should be lower than about 45° F. for whole shell eggs for consumer distribution.

The time and temperature relationships for pasteurizing shell eggs are determined in respect to the following factors: (1) temperatures attained by all material within the mass of the shell egg and the time for pasteurizing of the material at that temperature; and the average time that each material is heated to assure that each material is subjected to the least minimum condition to effectively pasteurize; and (2) the combination of processing parameters that will retain functionality by avoiding or minimizing adverse changes in appearance and performance while maximizing destruction of infections.

The following table provides temperature and real processing time (RPT) relationships for destruction of harmful microorganisms in shell eggs:

TABLE 1

Temperature		RPT (minutes)
130° F.	(54.4° C.)	= 65
131° F.	(55.0° C.)	= 49
132° F.	(55.6° C.)	= 38
133° F.	(56.1° C.)	= 28
134° F.	(56.7° C.)	= 20
135° F.	(57.2° C.)	= 16
136° F.	(57.8° C.)	= 11
137° F.	(57.8° C.)	= 8
138° F.	(58.9° C.)	= 4.75
140° F.	(60.0° C.)	= 3.5

These relationships describe processing of whole shell eggs after attaining required pasteurizing preprocessing temperature. The initial preprocessing temperature is applied until the shell egg reaches a temperature equilibrium with the heat transfer medium. The relationships of Table 1 are applicable after this point has been reached. The processing temperature is defined as an equilibrium temperature where heat has been transferred through external portions of the shell egg into the center of the yolk so that the temperature at the yolk center and at every other locus throughout the mass of the egg has reached an equilibrium with the process medium.

Treatment times include processing times (RPT) from Table 1 plus the time required for the egg to reach the preprocessing temperature. Certain factors may effect the time required for an egg to reach the effective process temperature,including egg size, the temperature of the egg before application of heating and the selected pasteurization process temperature. It is important that all of the egg be held at an appropriate temperature for an appropriate time to ensure pasteurization of entire egg and that this can be accomplished without simultaneous cooking or disruption of functionality of any portion of the egg.

In a preferred embodiment, the heat treatment is carried out in at least two steps. The process comprises a first heat treating at a temperature to provide an internal egg temperature to destroy infectous organisms without substantial loss of functionality. The first heat treating is followed by a second heat treating at a lower temperature to achieve pasteurization. The steps combine to advantageously pasteurize shell egg without loss of functionality.

Advantageously, the process of the invention permits aging (tenderizing) of meat within an abbreviated period of time in the absence of a chemical tenderizing agent and preferably also in the absence of an anti-bacteria agent. The process comprises immersing the meat in a liquid bath such as a water bath. The entire volume of the bath is maintained at a controlled temperature within a range that hastens the enzymatic tenderizing of the meat. The temperature is preferably below a minimum cooked temperature of the meat, preferably at a temperature that kills bacteria in at least the initial stages of the process. The meat is held at the bath temperature during tenderization. The process of this invention permits the tenderized meat to be chilled, stored, and/or distributed and later cooked for serving.

Cooking uses heat to substantially decompose and change fibers of meat. Cooking adds texture and flavor and prepares the meat for human consumption. The term minimum cooked temperature for a meat as used herein is a minimum temperature that a meat attains in preparation of the meat for human consumption as cooked meat.

The process of the invention can be applied to the aging of different types of meat, for example, beef, veal, pork, mutton, lamb or poultry, most preferably beef. Cooked temperatures for various meats are known. Typical minimum cooked temperatures for typical meats are as follows: rare beef-140° F.; veal-175° F.; lamb-160° F.; pork 175° F.; poultry 160° F. Thus suitable temperatures below the minimum cooked temperature of the meat for use in the present invention include temperatures less than or equal to 133° F., such as 130° F., 125° F. or 120° F. for beef. For other meats, the tenderizing temperature is kept under 160° F., preferably under 150° F. or 145° F., to avoid inactivation of enzymes.

Various sizes of meat can be tenderized by the process of the present invention. For example, very large sizes such as carcasses, primal cuts and whole muscle meat as well as various smaller sizes of meats can be tenderized by the process of the invention. Suitable periods of time for conducting the process of the invention to obtain tenderizing of meat will vary with the type of the meat once the meat has reached a uniform temperature. In general, the meat should be maintained in the bath long enough to reach a uniform temperature throughout its thickness, and long enough thereafter to reach the desired degree of tenderness. To expedite transfer of the bath temperature throughout larger cuts of meat, one can insert one or more heat conductors, for example aluminum spike(s), in the meat, taking care that they are inserted in a manner that will not cause perforation of any envelope around the meat.

According to a process of the invention, the entire volume of the bath is maintained at a controlled temperature within a range that hastens enzymatic tenderizing of the particular meat below a minimum cooked temperature of the meat. Thus in this preferred embodiment, the bath does not include even localized areas of liquid at or above the minimum cooked temperature. In embodiments, the process comprises immersing or spraying the meat in or with liquid or a liquid vapor such as steam at a first temperature within a range that quickly kills surface bacteria without substantially cooking the surface of the meat. The meat is then maintained in a liquid bath at a second temperature lower than the first temperature within a range that hastens enzymatic tenderizing of the meat.

According to a preferred process of the present invention, the entire volume of the bath is maintained at a controlled temperature within a range of ±2° F. The process of the invention preferably comprises immersing food product in a liquid bath and maintaining the bath within a very closely controlled temperature range, for example by heating laterally adjacent zones of the fluid and vertically perturbating the fluid, such as with a liquid jet or with bubbles. A suitable thermalizing apparatus for heat treating food product according to the present invention including maintaining the bath temperature by heating laterally adjacent zones of fluid and vertically perturbating the fluid with bubbles is dis-

closed in U.S. Pat. No. 5,445,062 to Polster entitled "Rethermalizer." The entire disclosure of this Patent is incorporated herein by reference.

The rethermalizer is a food heating vessel having sides and a bottom for retaining an aqueous bath, and including heat supply for heating the bath. A food locator rack is positioned in the vessel. The rack has a plurality of defined locations for supporting food product to be heated. Fluid outlets are positioned from the rack to the vessel beneath all of the locations to cause fluid to exit into the bath and agitate the bath over and past the food items. A connector connects the rack outlets to a pressurized source of fluid. The rethermalizer includes fluid conducting tubes with outlets on the locator rack and upwardly diagonally oriented conduits to conduct pressurized fluid to cause bath circulation. The heat supply is a heater element embedded in rubber-type material, for example silicone polymer, bonded to outside of the vessel. The heater element can be an electric resistance heater coil embedded between layers of the rubber-type material.

The rethermalizer includes water supply means for supplying additional water to the vessel to replace water lost by evaporation and removal with food product. Sensing elements are spaced at different vertical locations of the vessel with an upper one at the level desired for the bath and a lower one below that level for detecting the differential sensed by the elements. The sensing elements are operably associated with the water supply means for periodically actuating the water supply means to add supplemental water to the vessel when a predetermined differential is detected. The rethermalizer can include a graphic control panel with the panel having controls and indicators for each of food support locations.

The housing for the rethermalizer can define a heating chamber and a separate control chamber. The food heating vessel is in the heating chamber and electronic controls are located in the control chamber. Two walls between the chambers are spaced from each other and define a vertically elongated space. One of the walls is a wall of the heating chamber and the other wall is a wall of the control chamber. Air inlet openings at the bottom of the space provide for inlet air flow. Air outlet openings at the top of the space permit outlet air flow into the heating chamber. Heat from the heating chamber creates thermally-generated, upward air flow through the space to isolate and cool the control chamber wall.

Precise temperature control is critical to high quality results in cooking and rethermalizing vacuum package foods. Precise temperature control is also important to the process of heating food product for pasteurizing proteinaceous food product without destruction of functionality and/or for enzymatic tenderization of proteinaceous food product without substantial cooking according to the present invention.

Heating water or other liquid baths can result in localized too high or too low temperatures throughout the bath that impair food product quality. A stirred liquid bath does not flow evenly over all surfaces, but rather takes a path of least resistance. A liquid bath tends to stratify into thermal layers of different temperatures. Even if heat is applied throughout the surface of a vessel, loading of product into the vessel will cause sometimes widely varying temperature zones to occur. These conditions will prevent accurate temperature control in a hot liquid bath. Inaccurate temperature control within a bath can adversely affect the heat treating of proteinaceous food product. Localized hot spots can cause portions of a shell egg to lose functionality through coagulation or the like

and can cause portions of a tenderizing meat to cook. Low temperature zones can result in inadequate pasteurization or tenderization. Low temperature zones can prevent or reduce tenderizing and even enhance bacteria growth.

The present invention includes both batch and continuous heat treating processes. Temperature control in a liquid is more difficult in a continuous heat treating process. Liquid is lost from the bath not only by evaporation, but additionally by significant liquid transfer with product as pasteurized and/or tenderized proteinaceous food product is removed. Liquid is required to be added to a heated bath usually in a significant quantity by the time bath level decline is discovered by a food worker. Addition of liquid can cause temperature change in the bath whether heated or cooled liquid is added. This effect, if not controlled, can adversely influence a heat treating process. Control can be accomplished, however, as discussed below.

Another problem with heating in a liquid bath relates to temperature control techniques. The thermodynamics of a liquid bath create a lag time between the application of heat energy and the sensing of the same by a control system and the establishing of a uniform temperature throughout a bath in response to the setting. The thermodynamics of the liquid and the lag time may result in "overshoot" of temperature.

Liquid circulation can help to prevent temperature layer stratification and overshoot. However, circulation according to conventional bath heating methods is insufficient to provide the control necessary for pasteurization and/or tenderization. Additionally, circulation alone does not assure even flow over all surfaces of food product. The food product itself may disturb the circulation pattern of a bath. The bath liquid will take a path of least resistance and may create localized temperature zones or layer stratification.

Typical thermostatically controlled liquid baths used for cooking exhibit problems of heating and temperature control as described above. Thermostatically controlled liquid baths are characterized by overshoot and localized hot or cold spots. Most thermostatically controlled liquid baths cannot be used in the process of the present invention to maintain the entire volume of the liquid bath at a controlled temperature within a range of ±2° F., much less ±1° F. or less.

The Polster rethermalizer is provided with tubes to generate liquid flow. The tubes can inject bubbles, for example air bubbles, or liquid jets at various locations in the vessel to cause scrubbing of surfaces of meat. The resulting action provides excellent heat exchange at meat surfaces and eliminates temperature zoning and stratification. The vessel permits an accurate and efficient heat transfer to the meat to permit a uniform temperature within the meat without hot or cold spots. The bubbles or jets cause a vertical perturbation that permits utilizing the bath for a process of pasteurization and/or tenderizing without by cooking and without undesirable bacteria growth.

The Polster rethermalizer includes specially arranged and cooperative temperature sensors. The sensors are vertically displaced to provide temperature sensing. Temperature differentials are sensed between different vertical locations within the bath. The rethermalizer vessel is heated in laterally adjacent zones. A temperature sensor is located on the vessel for each zone near the heater to cooperate with sensors near the vessel bottom. The arrangement compensates for lag time, i.e., thermal momentum, and prevents overshoot of temperature above optimum tenderizing temperatures. A vertically displaced set of temperature sensors permits the addition of water in small regular quantities as needed to provide level control.

Adding bath liquid at different temperatures within the liquid bath is another technique that can be used to maintain

the liquid bath at a controlled temperature according to the invention. The process of the invention can be used for pasteurization, tenderizing or both pasteurization and tenderizing of proteinaceous food product. Any suitable thermal conveying liquid may be used as the bath liquid in the process of the invention for treating any type of proteinaceous food product. For example, the bath can comprise water or cooking oil. Preferably, the liquid is water. By means of the present process, the temperature of the bath can be maintained at a temperature ±2° F., preferably ±1° F. or ±0.75° F. or 0.5° F. Thus the bath can exclude even localized areas of liquid at or above a temperature that impairs functionality of or cooks the food product, and/or at or below a temperature at which pasteurization is incomplete. to maximize uniform quality of the tenderized meat precut.

The food product can be enveloped in a bag during treatment. If enveloped, the bag preferably is made of a relatively non-insulating material that is substantially impermeable to the liquid of the bath. The material should be impermeable to prevent food product from being permeated by the bath liquid. Additionally, the material must be relatively non-insulating to permit transfer of heat from the bath to the food product. Suitable materials are known to those of ordinary skill in the art, and can include materials such as those used in many cooking bags and wraps. Appropriate materials for enveloping the food product include polymeric laminates that can be comprised of an oxygen barrier layer and a moisture barrier layer. The oxygen barrier layer may comprise a hydrolyzed olefin\vinyl ester copolymer. The oxygen barrier layer may be a heat-sealable layer comprising high density polyethylene, alone or mixed with polyisobutylene; polypropylene; ethylene-propylene copolymers; ionomeric resins; polybutene-1 or blends of such polymers.

The laminate may include a substrate layer comprising a polyamide, which may be a homopolyamide such as polycaprolactam or polyhexamethyleneadipamide or a copolyamide; a polyester such as polyalkylene terephthalate or isophthalate; a polycarbonate; polypropylene; a polyallomer; poly(4-methyl-pentene-1); polybutene-1; polystyrene; polyvinyl chloride; medium or high density polyethylene; an acrylonitrile-butadiene-styrene resin; a methacryonitrile-butadiene-styrene resin or a blend of two or more such polymers. Examples of suitable materials are disclosed in U.S. Pat. Nos. 3,949,114 to Viola et al., 3,961, 086 to Turbak, 3,983,258 to Weaver, 3,988,499 to Reynolds, 4,132,048 to Day, 4,136,205 to Quattlebaum and 4,534,984 to Kuehne. The entire disclosures of these patents are incorporated herein by reference.

A process according to the present invention for heat treating meat, comprises encasing the food product in a plastic pouch, evacuating air from the pouch and sealing the pouch under vacuum. According to a preferred embodiment, the process of tenderizing meat in the absence of a tenderizing agent (or anti-bacteria agent), comprises vacuum packaging meat in a pouch, immersing the meat in a liquid bath, and maintaining the bath at a controlled temperature within a range below a minimum cooked temperature of the meat that hastens enzymatic tenderizing in the meat.

The tenderizing process of the invention is particularly advantageous for tenderizing meat either in advance of delivery to a serving area or at the serving area immediately prior to cooking. For example, individual steaks can be tenderized in a restaurant by the process. Additionally, the process of immersing a meat in a liquid bath can be conducted at higher temperatures to cook meat. Meat or fish can be subjected to an elevated temperature outside the immersing vessel and for a brief period of time to provide a grilled appearance or the like.

The pasteurization process of the invention is particularly advantageous for pasteurizing shell egg and "raw" shellfish because the process provides a means to precisely control treatment temperature to achieve pasteurization without destroying functionality of the food. The egg can be heated in the range of 134.5 to 139.5° F. for 20 to 345 minutes. Process time can be controlled in ranges from 34 to 52 minutes for a pasteurization temperature of 138.9±0.5° F. and up to 75 to 400 minutes for a pasteurization temperature of 130.3±0.4° F. The process can be used to treat shell egg at an initial temperature of 40 to 70° F. when the weight of the egg is 35 to 90 grams and to thereafter heat treat the egg at a temperature of 138±1.5° F. for a total time of 36 to 52 minutes. The process can heat treat the egg weighing 50 to 80 grams to an initial temperature in the range of 45 to 55° F. followed by a heat treatment at a temperature of 138±0.75° F. for 39 to 49 minutes.

Times and temperatures for heat treating other proteinaceous products can be the same as for shell eggs or can be determined by those skilled in the art according to the product treated and the objectives of the heat treatment. For example, pasteurization of seafood may be achieved at the same temperature and time relationships described above for shell egg.

While the invention has been described in connection with specific embodiments, it is to be understood that the embodiments are by way of illustration and are not intended to limit the invention. For example, while the invention is described in connection with the rethermalizer vessel disclosed by Polster in U.S. Pat. application Ser. No. 08/065, 627, various sizes of meat may require different size vessels or different types of vessels and various quantities of shell eggs may require different size vessels or different types of vessels. An enlarged vessel can be utilized to conduct the process of the invention with larger cuts of meat or an adapted Polster vessel with a separate heat source for tight control of temperature within the required range and/or an outside source of controlled temperature bath liquid can be utilized. An enlarged vessel can be utilized to conduct a process of the invention for a commercial scale processing of shell egg. While the invention is described in connection with the rethermalizer vessel disclosed by Polster and while the invention can be carried out in thermalizer vessels of varying size or Polster thermalizing vessels that may be modified, the process of the invention can be conducted by any suitable apparatus. Additionally, while the focus of the description of pasteurization has been on the shell egg example, the process applies to pasteurization of any proteinaceous food material including by way of example, meat and shellfish. In another example, the invention can be modified to raise the temperature of meat to a pasteurizing or tenderizing temperature and the process can be completed in a convention environment such as in a heated room. In another example, the process can include a spray bath type of immersion.

What is claimed is:

1. A process of heat treating a proteinaceous food product, comprising immersing the product in a bath liquid and maintaining the entire volume of the bath liquid at a controlled temperature within a range of ±2° F. to heat treat said proteinaceous food product without substantial loss of functionality.

2. The process of claim 1, comprising enveloping said proteinaceous food product in a relatively non-insulating material that is substantially impermeable to the liquid of said bath before immersing the proteinaceous food material in the bath.

3. The process of claim 1, comprising encasing the proteinaceous food product in a plastic pouch, evacuating air from the pouch and sealing the pouch before immersing the proteinaceous food material in the bath liquid.

4. The process of claim 1, wherein said liquid comprises a liquid selected from water and cooking oil.

5. The process of claim 1, wherein said liquid comprises water.

6. The process of claim 1, comprising separately heating laterally adjacent zones of said bath and vertically perturbating said bath liquid to maintain said bath liquid at said controlled temperature.

7. The process of claim 6, wherein said bath liquid is vertically perturbated with bubbles.

8. The process of claim 1, comprising adding liquid to said bath without causing greater than 2° F. variations within the entire volume of said bath liquid.

9. The process of claim 1, comprising maintaining said bath liquid at said temperature within a vessel having a plurality of spaced apart temperature sensors.

10. The process of claim 1, wherein at least one heat conductive member is inserted into said proteinaceous food product before immersing the proteinaceous food material in the bath liquid.

11. The process of claim 1, wherein said heat treating comprises tenderizing said proteinaceous food product at a controlled temperature below a minimum cooked temperature of the prozeinaceous food material for a sufficient time to carry out endogenous enzymatic tenderization of the proteinaceous food product.

12. The process of claim 11, wherein said proteinaceous food product is beef and said controlled temperature is maintained to be less than 135° F. and within a range of ±1° F.

13. The process of claim 11, wherein said proteinaceous food product is selected from the group consisting of veal, lamb, pork and poultry and said controlled temperature is maintained to be less than 160° F. and within a range of ±1° F.

14. The process of claim 1, wherein said heat treating process comprises pasteurizing said proteinaceous food product.

15. The process of claim 14, wherein said proteinaceous food product is a poultry shell egg.

16. The process of claim 15, comprising vertically perturbating said liquid to disrupt temperature stratification.

17. The process of claim 14, wherein said proteinaceous food product is a food product other than shell eggs.

18. The process of claim 17, wherein said proteinaceous food product is meat.

19. The process of claim 18, wherein said meat is poultry meat.

20. The process of claim 17, wherein said proteinaceous food product is seafood.

21. The process of claim 20, wherein said seafood is shellfish.

22. The process of claim 1, wherein said temperature is at least 130° F.

23. The process of claim 1, wherein said temperature is at least 135° F.

24. The process of claim 1, wherein said controlled temperature is maintained within a range of ±1° F.

25. The process of claim 1, wherein said controlled temperature is maintained within a range of ±0.75° F.

26. The process of claim 1, wherein said controlled temperature is maintained within a range of ±0.5° F.

27. The process of claim 26, wherein said food product is poultry shell eggs heat treated by said process on a commercial scale.

28. The process of claim 26, wherein said process is a continuous heat treating process.

29. A process for pasteurizing a shell egg, comprising immersing the shell egg in a bath liquid and separately heating laterally adjacent zones of said bath to maintain the entire volume of said bath at a controlled temperature.

30. The process of claim 29, further comprising vertically perturbating said bath liquid to disrupt temperature stratification.

31. The process of claim 29, comprising adding liquid to said bath without thereby causing greater than 2° F. variations within the entire volume of the bath liquid.

32. The process of claim 29, wherein said controlled temperature is maintained within a range of ±2° F.

33. The process of claim 29, comprising maintaining said bath liquid at said temperature within a vessel having a plurality of spaced apart temperature sensors.

34. A process of heat treating a proteinaceous food product, said process comprising:

immersing the product in a liquid bath containing a liquid; and

maintaining an entire volume of said bath liquid at a controlled temperature within a temperature variation of ±2° F. to heat treat said proteinaceous food product without cooking said food product.

35. The process of claim 34, wherein said bath includes laterally adjacent zones and further comprises:

separately heating said liquid in said laterally adjacent zones of said bath: and

vertically perturbating said liquid to maintain said entire volume of said liquid at said controlled temperature below a minimum cooked temperature of said food product without ever exceeding said minimum cooked temperature in said bath.

36. The process of claim 34, wherein temperature of said entire volume of said liquid of said bath is maintained below a minimum cooked temperature of said food product without ever exceeding said minimum cooked temperature in said bath.

37. The process of claim 34, wherein said maintaining step kills bacteria.

38. The process of claim 34, further comprising vertically perturbating said liquid of said bath to maintain said entire volume of said bath at said controlled temperature.

39. The process of claim 38, wherein bubbles are used to cause said vertical perturbation.

40. A process for pasteurizing a proteinaceous food product, comprising:

(A) immersing the food product in a bath liquid where the bath liquid contacting the immersed food product is at a predetermined temperature between 125° F. and 140° F.,

(B) heating the bath liquid to maintain the predetermined temperature, and

(C) vertically perturbating the bath liquid sufficient with a liquid jet or air bubbles that the bath liquid contacting the food product is maintained within ±2° F. of said predetermined temperature.

41. The process of claim 40, wherein said food product comprises shell eggs.

* * * * *

US005993886A

United States Patent [19]

Polster

[11] Patent Number: 5,993,886

[45] Date of Patent: Nov. 30, 1999

[54] METHOD AND CONTROL SYSTEM FOR CONTROLLING PASTEURIZATION OF IN-SHELL EGGS

[76] Inventor: Louis S. Polster, 2205 Marthas Rd., Alexandria, Va. 22307

[21] Appl. No.: 09/001,677

[22] Filed: Dec. 31, 1997

[51] Int. Cl.[6] A23B 5/00; A23L 1/32

[52] U.S. Cl. 426/614; 99/453; 99/468; 99/483; 426/521

[58] Field of Search 99/451, 452, 453, 99/467, 468, 516, 485, 486, 483; 422/21, 22, 24, 158, 33, 61, 307, 905–907, 117, 119; 426/521, 614; 116/206; 364/528.17; 219/497, 508, 492

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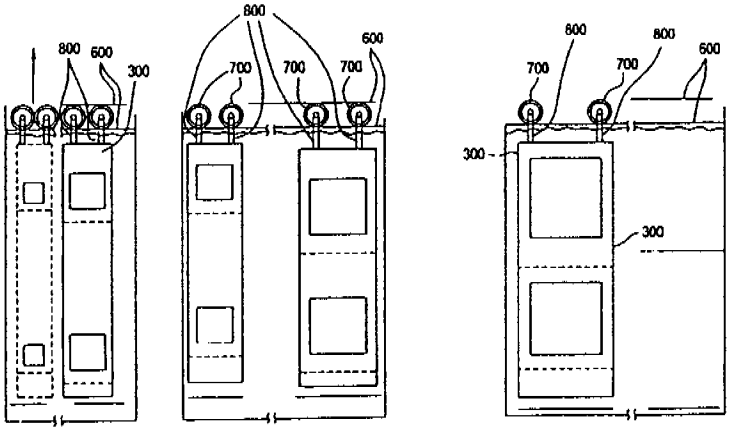
Primary Examiner—Timothy Simone
Attorney, Agent, or Firm—Oliff & Berridge, PLC

[57] ABSTRACT

In a method and control system for controlling pasteurization of in-shell eggs, the internal temperature of the eggs, at least one log kill rate of Salmonella based on the internal temperature of the eggs and a cumulative log kill of Salmonella as a function of the log kill rate and time are at least periodically determined. The cumulative log kill is at least periodically compared to at least one predetermined value, and a signal is generated when a predetermined relationship arises between the cumulative log kill and the predetermined value(s).

36 Claims, 8 Drawing Sheets



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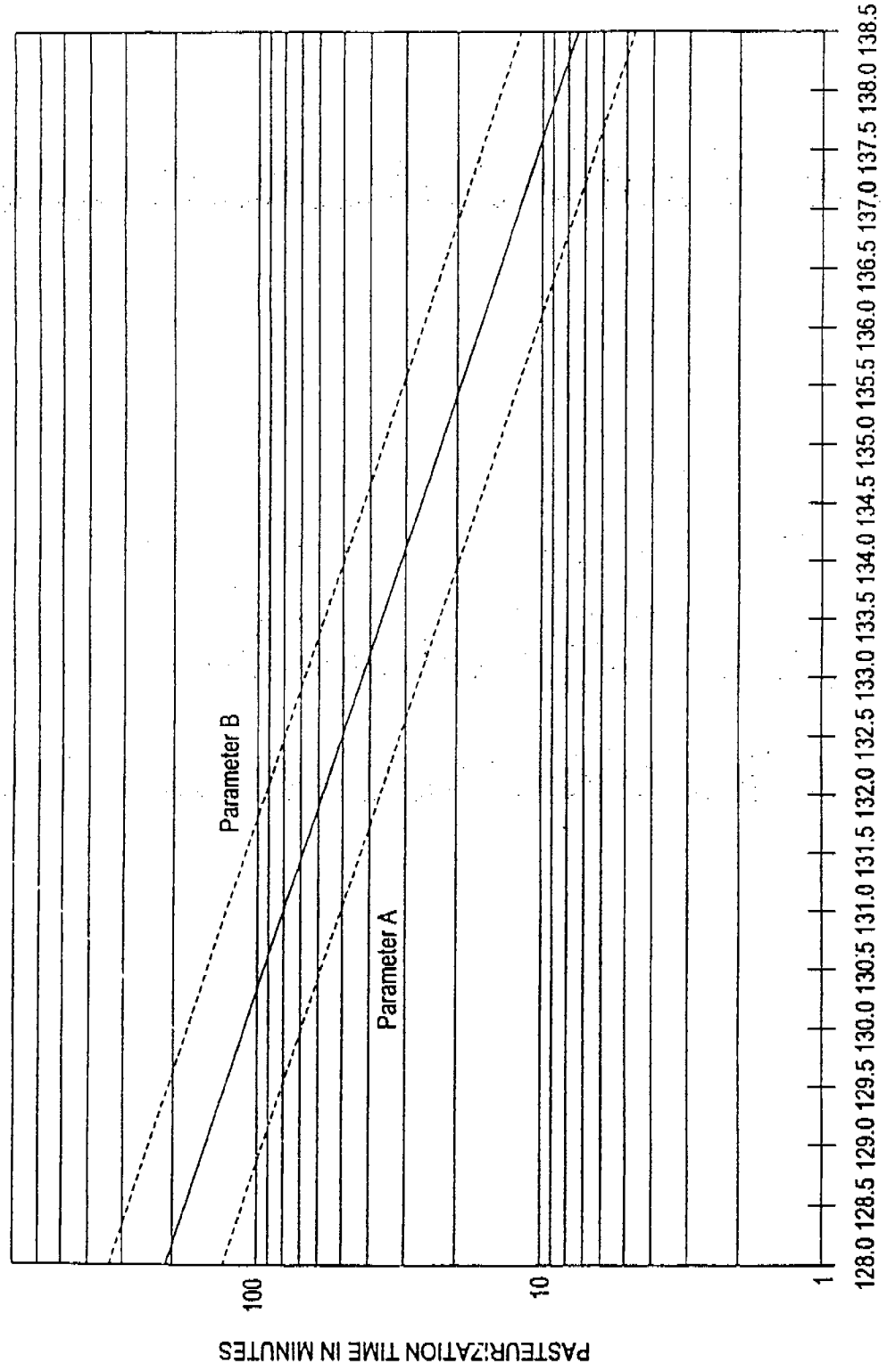
Parameter B
Parameter A
100
10
1
PASTEURIZATION TIME IN MINUTES
128.0 128.5 129.0 129.5 130.0 130.5 131.0 131.5 132.0 132.5 133.0 133.5 134.0 134.5 135.0 135.5 136.0 136.5 137.0 137.5 138.0 138.5
TEMPERATURE IN DEGREES FAHRENHEIT

FIG. 1

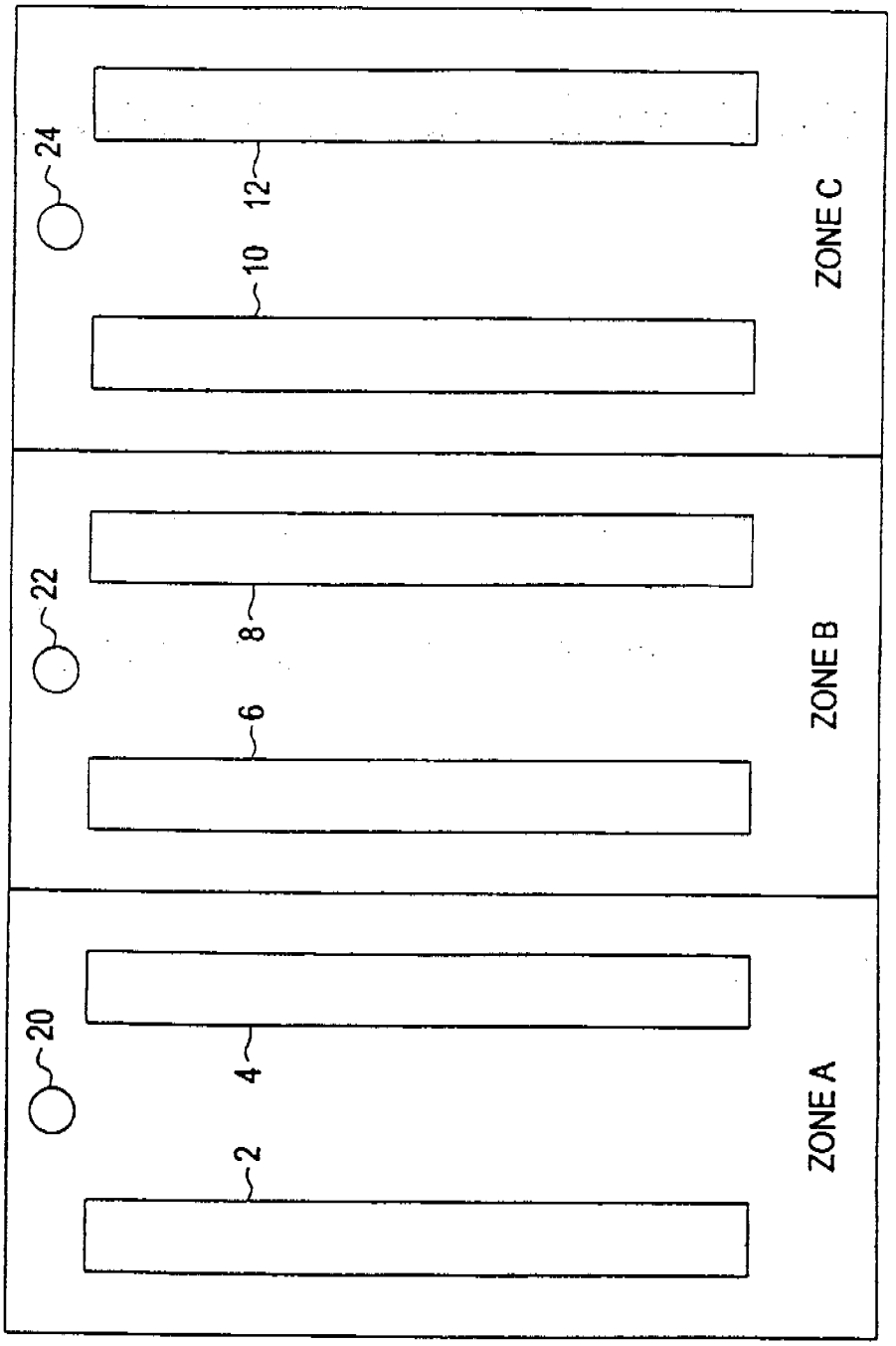

FIG. 2

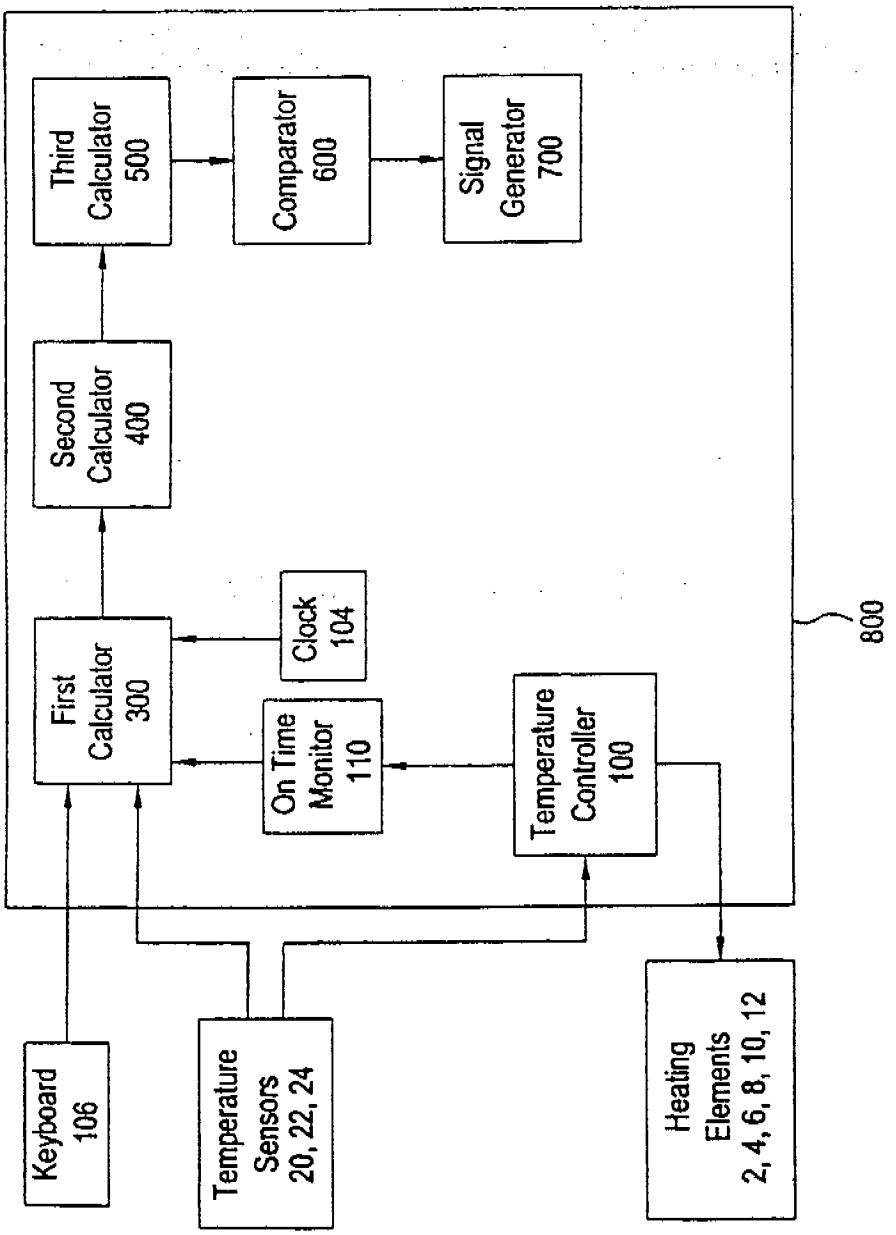
Third Calculator 500
Comparator 600
Signal Generator 700
Second Calculator 400
First Calculator 300
Clock 104
On Time Monitor 110
Temperature Controller 100
800
Keyboard 106
Temperature Sensors 20, 22, 24
Heating Elements 2, 4, 6, 8, 10, 12

FIG. 2a

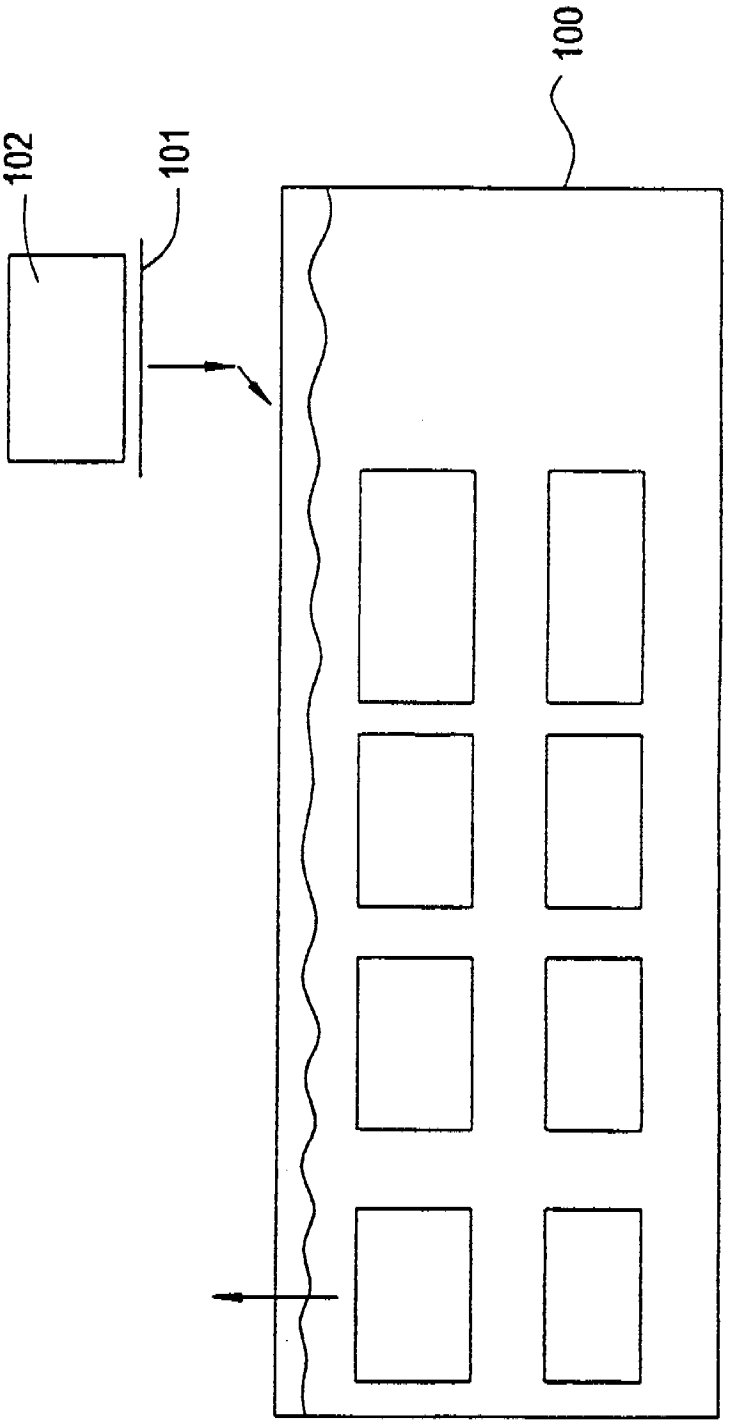

FIG. 3

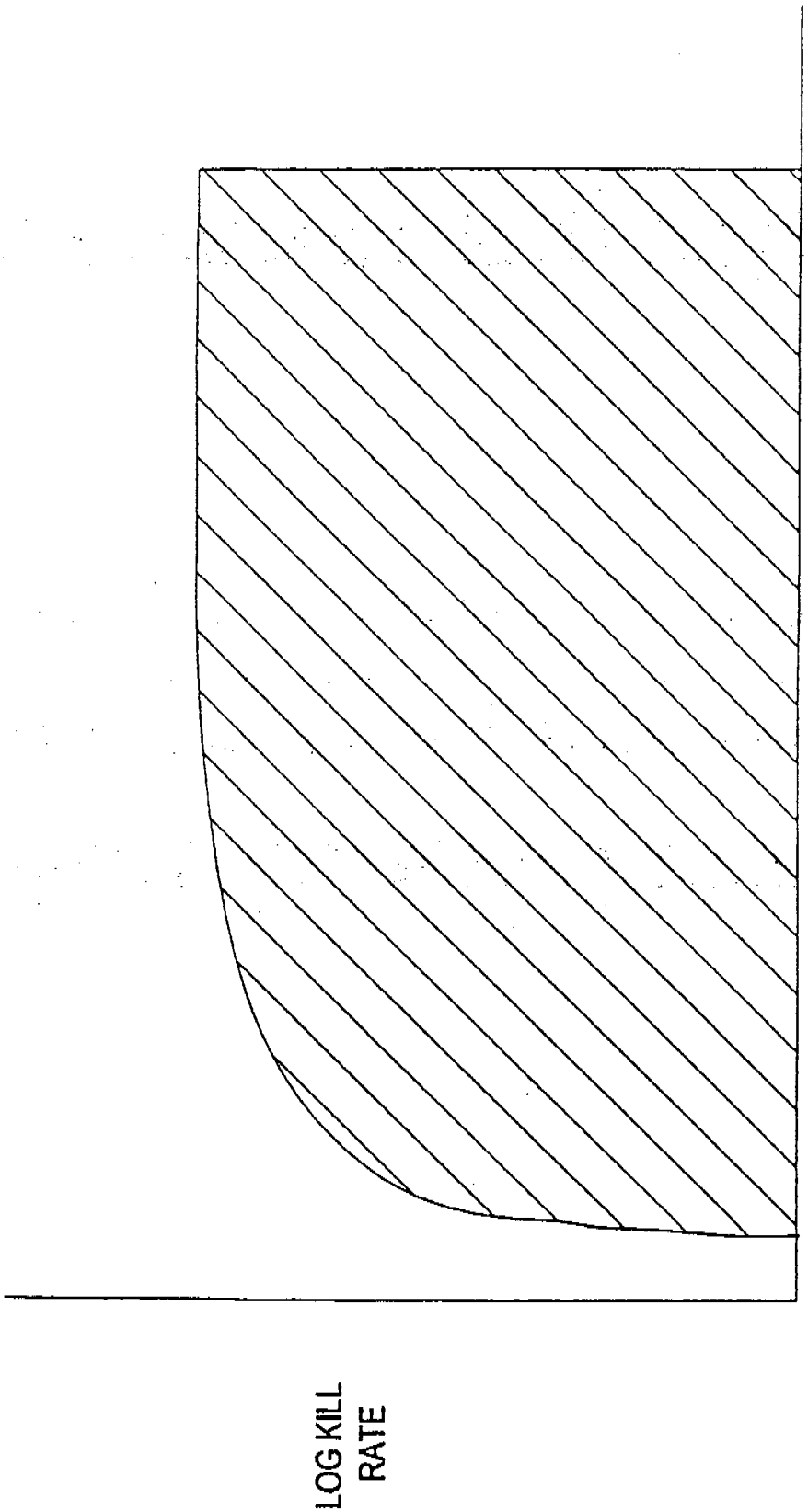

FIG. 6

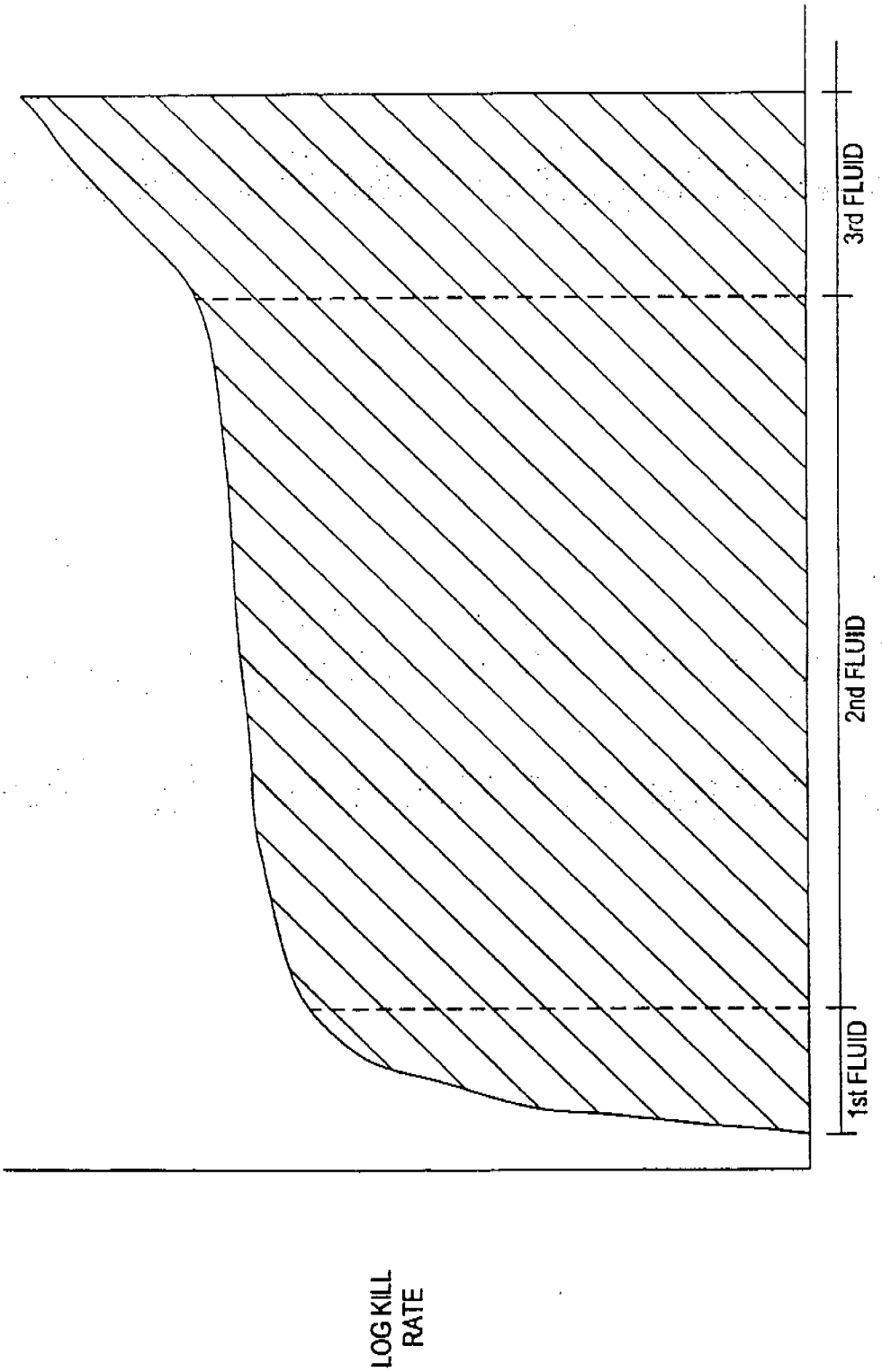

FIG. 7

METHOD AND CONTROL SYSTEM FOR CONTROLLING PASTEURIZATION OF IN-SHELL EGGS

BACKGROUND OF THE INVENTION

1. Field of Invention

The present invention relates to a method and control system for controlling pasteurization of in-shell eggs in a fluid.

2. Description of Related Art

The United States Department of Agriculture (USDA) regulates minimum safety standards for pasteurizing in-shell eggs. These standards are promulgated in order to ensure that certain microorganisms, including such infectious organisms as Salmonella, are substantially destroyed prior to distribution and consumption of the eggs. The USDA defines pasteurization as a heat treatment for the purpose of killing these disease causing organisms.

One source of infection arises when the egg shells come into contact with organic refuse. Contamination results because the egg shells have numerous pores which permit infectious microbes, which are contained in the organic refuse, to penetrate the pores of the eggs. Another source of infection results from trans-ovarian contamination. This occurs when chickens or other poultry ingest or are otherwise infected by infectious microbes and transfer the microorganisms directly into the eggs.

The Nutrition Action Health Letter published by the Center for Science and the Public Interest (July/August 1991 edition, Vol. 18, No. 6, "Name Your (Food) Poison") reports that in-shell eggs are particularly difficult to pasteurize because of their structure. In addition, this article reveals that one in ten thousand eggs is contaminated with salmonella enteritis.

Techniques for improving pasteurization of eggs have been proposed. These techniques attempt to destroy infectious disease causing organisms in in-shell eggs without substantial loss of functionality. One approach to pasteurizing in-shell eggs involves heating the in-shell eggs in water baths, for various times and at various temperatures. The time/temperature ratios vary widely because different approaches involve a compromise between the degree of safety achieved and the quality or the functionality of the eggs retained after pasteurization is completed. The USDA has devised time/temperature ratios, but they are only for liquid eggs.

Cox et al. (PCT/US94/12950) discloses a method for destroying infectious disease causing organisms in in-shell eggs without substantial loss of functionality. Cox et al. employs a temperature versus time relationship in order to accomplish pasteurization of the in-shell eggs. An initial egg temperature and processing temperature at the beginning of the pasteurizing process of a whole shell egg must be known. These temperatures are used to determine the total processing time, e.g., the total length of time over which the eggs are heated. According to a preferred embodiment of Cox et al., minimum temperatures/time requirements for liquid whole eggs are applied equivalently to in-shell eggs once the selected pasteurization temperature has been achieved at the shell egg yolk center.

Cox et al. uses the following temperature time table for determining the pasteurization time of in-shell eggs.

Temperature	Real Processing Time (RPT) (Minutes)
130° F.	=65
131° F.	=49
132° F.	=38
133° F.	=28
134° F.	=20
135° F.	=16
136° F.	=11
137° F.	=8
138° F.	=6
139° F.	=4.75
140° F.	=3.5

This table describes the processing of in-shell eggs after they attain the required pasteurizing preprocessing temperature. The initial temperature is applied until the in-shell eggs reach a temperature equilibrium with the heat transfer medium. The RPT for a given pasteurization regimen can only begin after this point has been reached.

Cox et al. also discloses that factors including the size and internal initial temperature of the eggs may affect the time required for the eggs to reach the effective processing temperature. Thus, an initial temperature that causes pasteurization of one batch of eggs may result in impaired functionality of a second batch of eggs having a smaller size, depending on the variables associated with that particular batch of eggs.

Davidson International Application No. PCT/US96/13006 (U.S. application Ser. No. 08/519,184), also discloses methods to pasteurize in-shell eggs using time/temperature relationships. In particular, Davidson discloses heating a yolk of the egg to within the range of 128° F. to 138.5° F. Once the yolk reaches this temperature range, it must be maintained at this temperature range for a certain time and within certain parameters.

FIG. 1 shows a temperature versus time curve implemented by the Davidson system. This curve is based substantially on the data of the above table. Referring to FIG. 1, the temperature of the egg yolk must be maintained between parameter line A and parameter line B in order for sufficient pasteurization to occur. According to Davidson, this will reduce the Salmonella by at least 5 logs, while at the same time retaining the functionality of the eggs. If the eggs are heated to a limit outside parameter lines A and B, however, the eggs will either lose their functionality or remain insufficiently pasteurized. Thus, according to Davidson it is imperative that the temperature of this system stay within the predefined parameters.

Factors such as loss of water, temperature overshoot (e.g. raising the temperature too high), inefficient temperature sensors (e.g. low response time for raising the temperature to a predefined temperature range), and numerous other factors make it possible for the bath temperature to stray from preferred parameters. The size of the eggs, the number of eggs placed in the bath and the initial internal temperature of the eggs will also affect the pasteurization time and functionality of the eggs.

SUMMARY OF THE INVENTION

The present invention comprises a method and control system for controlling pasteurization of in-shell eggs by a heated fluid.

In the method and control system of the present invention, in-shell eggs are enveloped by a heated fluid. The internal temperature of the eggs, while they are enveloped by the

heated fluid, is periodically or continuously determined. At least one log kill rate of Salmonella in the eggs based on the internal temperature of the eggs is also periodically or continuously determined.

A cumulative log kill of Salmonella as a function of the at least one log kill rate and time is also periodically or continuously determined. The cumulative log kill is compared to at least one predetermined value. A signal is generated when a predetermined relationship between the cumulative log kill and the predetermined value is revealed. The time at which comparing takes place may be before, at and/or after a predetermined time at which sufficient pasteurization is expected to be completed.

A control system for pasteurizing the in-shell eggs is also provided.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be described in conjunction with the following drawings in which like reference numerals designate like elements and wherein:

FIG. 1 shows a temperature versus time curve implemented by the Davidson system;

FIG. 2 is a plan view of a single bath having a plurality of heating elements and a plurality of temperature sensors;

FIG. 2*a* shows an exemplary embodiment of a control system used by the present invention;

FIG. 3 is a cross sectional view of a single bath system;

FIG. 4 shows a log kill rate versus time curve for a single bath system;

FIG. 5 is a side cross-sectional view of a multiple bath system;

FIG. 6 shows a log kill rate versus time curve for a two bath system; and

FIG. 7 shows a log kill rate versus time curve for a three bath system.

DETAILED DESCRIPTION OF EMBODIMENTS

The present invention is directed to a method and control system for controlling pasteurization of in-shell eggs in a fluid. The fluid may include a liquid or a gas, as described in simultaneously filed patent application Ser. No. 09/002,244 (Docket No. WPB 39608) entitled "Apparatus And Methods For Pasteurizing In-Shell Eggs", which is incorporated herein by reference in its entirety.

The present invention can allow a pasteurizing method and apparatus to achieve at least a satisfactory reduction in Salmonella or the like without substantially affecting the functionality of the eggs, despite temperature fluctuations in the fluid and thus inside the eggs. This may be accomplished by providing a method and control system that at least periodically determines (i) an internal temperature of the eggs and thus a log kill of Salmonella and/or other infectious microorganisms in the eggs and (ii) a dwell time of the eggs at each such temperature so that a cumulative log kill of Salmonella and/or other infectious diseases can be calculated and used to control the process.

In order for eggs to be pasteurized they are first enveloped by a fluid. A single, two, three or more fluid system is contemplated for use with the present invention.

Accordingly, once the eggs are enveloped by the fluid, an internal temperature of the eggs is periodically or continuously determined. Repeated experiments have shown that an internal temperature of the eggs may be calculated based on a variety of factors, for example (i) the time the eggs are enveloped by the heated fluid, (ii) the temperature of the heated fluid, (iii) the initial temperature of the eggs and (iv) the size of the eggs. The internal temperature of the eggs may also be determined by (i) fixing the initial temperature of the eggs, (ii) fixing the time the eggs are enveloped by the fluid and (iii) fixing the temperature of the fluid during the time the eggs are enveloped by the fluid.

The initial temperature of the eggs may be determined in various ways. From experimentation, it was found that, for example, the initial temperature of the eggs may be calculated based on (i) the size of the eggs and (ii) the on-time of at least one heating element in the heated fluid required to return a temperature of the heated fluid after the eggs are enveloped by the heated fluid back to a starting temperature of the heated fluid.

That is, the initial temperature of the eggs may be determined by use of known values determined through experimentation. For example, through experiments, the eggs are temperature probed prior to enveloping the eggs in the heated fluid to determine the initial temperature of the eggs. The eggs are then enveloped in the heated fluid and an on-time of the at least one heating element is measured until the temperature of the heated fluid returns to a starting temperature of the heated fluid. By using this process, several on-times of the at least one heating element is determined for varying sized eggs and initial temperatures. These determined on-times of the at least one heating element may then be used to determine the initial temperature of the eggs in future processes.

By way of example, in experiments, eggs were initially probed to determine that the initial temperature of the eggs prior to being enveloped in the heated fluid was 70° F. Two hundred and seventy dozen eggs at the initial temperature of 70° F. were enveloped in a 137° F. heated fluid. The on-time of the at least one heating element was measured until the temperature of the heated fluid returned to a starting temperature of the heated fluid. In this experiment, the on-time of the at least one heating element was approximately 2 minutes and 50 seconds. By way of further example, in experiments, eggs were initially probed to determine that the initial temperature of the eggs prior to being enveloped in the heated fluid was 45° F. Two hundred and seventy dozen eggs at the initial temperature of 45° F. were enveloped in a 137° F. heated fluid. The on-time of the at least one heating element was measured until the temperature of the heated fluid returned to a starting temperature of the heated fluid. In this experiment, the on-time of the at least one heating element was approximately 4 minutes and 25 seconds. It was known during these experiments that the eggs weigh approximately 30 ounces per dozen and that the specific heat of the eggs is 0.88. By using this data, the initial temperature of the eggs for other sized eggs may then be determined by the determined on-times of the at least one heating element. Alternatively, a temperature drop of the fluid may be measured after contacting the eggs.

As another example, the initial temperature of the eggs may be determined by uniformly preheating the eggs to a predetermined initial temperature. This temperature is preferably below a temperature at which pasteurization begins, and more preferably is a temperature that has substantially no effect on the functionality of the eggs. This may be accomplished, for example, by enveloping the eggs in a preheating fluid for at least a minimum period of time to ensure that all of the eggs have a uniform initial internal temperature. In embodiments, the preheating temperature of the fluid may be a temperature in the range of approximately 60°–100° F., and preferably 80°–100° F., and more prefer-

ably 80°–90° F. However, other temperature ranges are also contemplated for use with the invention so long as the temperature range does not affect the functionality of the eggs prior to pasteurization.

At least one log kill rate of Salmonella or other infectious microorganisms is periodically or continuously determined from the internal temperature of the eggs. The log kill rates for various temperatures may be determined from FIG. 1. A cumulative log kill of Salmonella as a function of the at least one log kill rate and time is also periodically or continuously determined.

In preferred embodiments, the data of Table A may be used for determining the log kill rate(s) and the cumulative log kill of Salmonella. The internal temperature of the eggs is monitored as described above. Fluctuating temperatures of the fluid are reflected in changing internal temperatures of the eggs. The log kill rate at each temperature may be multiplied by the time the eggs are at such temperature and the products may be summed to determine a cumulative log kill of the eggs at any given time. The first two columns of Table A are derived from data disclosed in Cox et al. and Davidson, which are both incorporated herein by reference in their entirety.

TABLE A

Temperature	Real Processing Time (RPT) (5 log reduction)	Minutes/log	Pulse Rate (x100)
130° F.	=65	13	770
131° F.	=49	9.8	1,020
132° F.	=38	7.6	1,320
133° F.	=28	5.6	1,790
134° F.	=20	4	2,500
135° F.	=16	3.2	3,130
136° F.	=11	2.2	4,550
137° F.	=8	1.6	6,250
138° F.	=6	1.2	8,330

The first column of Table A shows the temperature of the heated fluid. The second column shows a time needed for a 5 log reduction of Salmonella at a given temperature level. The third column shows a required time for a one log reduction of Salmonella at that temperature level. The fourth column shows an exemplary "pulse rate" that may be used for accurately determining a reduction of Salmonella at a given temperature level. In this table, an arbitrary value of 10,000 pulses per log has been set, and the pulse rate shown is in pulses per minute.

The temperature of the fluid and thus the internal temperature of the eggs may fluctuate over time. Due to this fluctuation, the pulse rate will also fluctuate over time. For example, while the temperature of the bath is 130° F., the counter may, for example, count 770 pulses per minute. When the temperature of the bath increases to 138° F., the pulse rate increases, for example, to 8,330 pulses per minute.

Because of the known relationship between the temperature of the bath and the pulse rate, the present method can accurately calculate the cumulative log kill. For example, a pulse counter may count the pulses until the cumulative log kill reaches a predetermined value, such as 30,000 pulses for a 3 log reduction in Salmonella, or 50,000 pulses for a 5 log reduction in Salmonella. In alternative embodiments, the cumulative log kill may be calculated by integrating an area under a curve, as discussed below.

The cumulative log kill is periodically or continuously compared to at least one predetermined value. The time(s) at which comparing takes place, for example, may be before, at or after a predetermined time at which sufficient pasteurization is expected to be completed.

In embodiments, the comparing may take place at periodic or continuous intervals while the pulse counter is, for example, counting the pulses, as described above. For example, in embodiments, the method of the present system compares the cumulative log kill, e.g., number of counted pulses, to a predetermined value, e.g. at least 3 (or 5) log reduction in Salmonella or at least 30,000 (or 50,000) pulses, for accurately determining when the cumulative log kill substantially indicates a desired degree of pasteurization. Alternatively, or in addition, the comparing may take place at intermediate times in the pasteurization process. In this case, the comparison may, for example, be with predetermined values that reflect an expected degree of pasteurization for the time at which the comparison takes place. Such comparisons may be periodic, e.g. at an expected time of each one or fraction of one log reduction of Salmonella, or even continuous.

A signal is generated when a predetermined relationship between the cumulative log kill and a predetermined value is revealed. In preferred embodiments, a signal may be generated when the cumulative log kill of Salmonella is approximately the desired degree of pasteurization. The eggs can then be removed from the heated fluid in response to the signal and cooled. In a preferred embodiment, they may be enveloped by a cooling bath as disclosed in simultaneously filed patent application Ser. No. 09/001,673 (Docket No. WPB 39610) entitled "Method And Apparatus For Chilling In-Shell Eggs", which is incorporated herein by reference in its entirety.

Several other signals may also be generated at various times during the pasteurization process. For example, a signal may be generated when the eggs are sufficiently pasteurized to be removed from the fluid and placed in a second or subsequent heated fluid. In this example, the eggs may be moved from one temperature zone to another temperature zone, such as in a two or three fluid system, as described below. A signal may also be generated when, for example, the temperature of the heated fluid needs to be increased and/or decreased so that a cumulative log kill of Salmonella within an acceptable time can be achieved. In embodiments of the present invention, a dwell time of the eggs in the heated fluid may be adjusted in response to a signal. That is, a rate of movement through the heated fluid of the eggs may be varied in response to the signal.

Another signal may be generated, for example, if the comparison reveals that the eggs are substantially more or less pasteurized than expected for a given point in the pasteurization process. In such cases, the signal may indicate that the functionality of the eggs would have been substantially impaired or would be substantially impaired by completing pasteurization. In this example, the eggs may be removed from the heated fluid and subsequently, e.g., discarded, cooked or broken and further processed as liquid egg in response to the signal.

The Control System

Referring to FIG. 2, a single fluid bath having a plurality of heating elements and a plurality of temperature sensors is shown. In embodiments, heating elements 2 and 4 are located in zone A, heating elements 6 and 8 are located in zone B and heating elements 10 and 12 are located in zone C. The heating elements may be arranged in zones so that uneven loading will not, for example, cause overheating in the entire bath. Preferably, the heating elements are low watt density heating elements which supply substantially constant heat energy per unit of time to the fluid.

Preferably, if a plurality of heaters is provided per zone, then the heaters may be substantially equally spaced apart. However, the heaters should be located to advantageously maintain the desired fluid temperature substantially uniformly throughout the bath. Exemplary heating elements and arrangements thereof are described in the above-mentioned simultaneously filed Patent Application entitled "Apparatus And Methods For Pasteurizing In-Shell Eggs".

In embodiments, a perturbating means for vertically perturbating the fluid may also be provided. The perturbation is preferably provided in a vertical direction emanating from below and being directed upwards towards and through the at least one layer of in-shell eggs in the fluid—e.g., in the form of bubbles through a liquid bath. The pertubation of the fluid substantially eliminates temperature stratification in the fluid and provides for a more efficient heat transfer between the eggs and the fluid. The perturbation may, for example, reduce the dwell time of the eggs prior to and during pasteurization as well as keep the fluid temperature at a substantially constant level. Pertubating means is described in the above-mentioned simultaneously filed Patent Application entitled "Apparatus And Methods For Pasteurizing In-Shell Eggs".

Referring again to FIG. 2, at least one temperature sensor (preferably two or more where redundancy is desired) is located in each zone of the fluid. For example, temperature sensor **20** is located in zone A, temperature sensor 22 is located in zone B and temperature sensor 24 is located in zone C. The location of the temperature sensors enables the sensors to quickly detect rising and falling temperatures of the fluid, thus avoiding temperature overshoot, i.e. potential overrun of the temperature in a zone. The temperature sensors also may provide the actual temperature of the fluid so as to compute the initial temperature of the eggs.

FIG. *2a* shows a block diagram of an embodiment of the present invention. A temperature controller **100** controls the heating elements for uniformly maintaining the temperature of fluid within the desired temperature range, preferably less than or equal to about ±2° F., preferably, ±1° F., more preferably, ±0.1° F. and, even more preferably, ±0.03° F. Temperature control systems are described in the above-mentioned simultaneously filed Patent Application entitled "Apparatus And Methods For Pasteurizing In-Shell Eggs".

To avoid temperature overshoot and other temperature variations, the temperature controller **100** may, for example, control the variations in the temperature of the fluid by turning on and turning off the heating elements **2, 4, 6, 8, 10, 12**. The temperature controller **100** may turn on the heating elements when the temperature of the fluid falls below a predetermined temperature and turn off the heating elements when the temperature of the fluid substantially equals and/or exceeds the predetermined temperature. In this manner the temperature controller **100** periodically or continuously controls the temperature of the fluid. An on-time monitor **110** may also be provided to monitor the on-time of the heating elements.

A first calculator **300** periodically or continuously determines the internal temperature of the eggs. Preferably, the internal temperature of the eggs is determined by (i) the time the eggs are enveloped by the heated fluid, (ii) the temperature of the heated fluid, (iii) the initial temperature of the eggs and (iv) the size of the eggs. The initial temperature of the eggs may be determined in various manners e.g., calculated (for example by the first calculator **300**) or directly input (e.g., via keyboard **106**), as described above. The temperature of the fluid may be input from temperature sensors **20, 22, 24**, etc. The immersion time may be input from an internal or external clock **104**. The size of the eggs may be automatically entered (e.g., by a bar code reader and a bar code on the egg container(s)) or manually entered (e.g., via keyboard **106**). In embodiments, the eggs are weighed prior to manually entering their size.

A second calculator **400** periodically or continuously determines at least one log kill rate of Salmonella based on the internal temperature of the eggs. A third calculator **500** periodically determines the cumulative log kill of Salmonella as a function of the log kill rate and time. A comparator **600** periodically or continuously compares the cumulative log kill to at least one predetermined value. A signal generator **700** may generate several signals at various times during the pasteurization process, as described above, in response to output of the comparator **600**. In embodiments, a single programmed processor comprises the temperature controller **100**, on time monitor **110**, clock **104**, first calculator **300**, second calculator **400**, third calculator **500**, comparator **600**, and/or signal generator **700**, and thus they need not be separate devices or even separate programs.

The above description has focused on a single fluid system. However, a corresponding discussion applies to two or more fluid systems, as exemplified in more detail below.

Single Fluid Systems

Referring to FIG. 3, in embodiments a loading mechanism **101** envelops a batch of eggs **102** in the single liquid bath **100** and transports the eggs through the liquid for pasteurization of the eggs without substantial loss of functionality. Using the data of Table B, for example, the first calculator **300** periodically or continuously determines the internal temperature of the eggs. The second calculator **400** periodically or continuously determines at least one log kill rate of Salmonella based on the internal temperature of the eggs. (In this example, a count of 100 pulses substantially equals a one log reduction of Salmonella.)

Referring to Table B, in one embodiment, for example, the nominal temperature of the fluid may be approximately 133.5° F. At this temperature the eggs may take approximately 12 to 15 minutes to reach an internal temperature of 130° F. at which time the process of Table B begins. Temperature drops by the fluid due to heat absorption by the eggs may affect the internal temperature of the eggs. However, the temperature drop of the fluid and the affected internal temperature of the eggs is taken into consideration when determining the cumulative log kill of Salmonella or other microorganisms.

Referring again to Table B, for example, at minute one the temperature of the fluid is 130° F., e.g., 770 pulses per minute. At minute two the temperature of the fluid is 132° F., e.g., 1,320 pulses per minute. At minute three the temperature of the fluid is 133.5° F., e.g., 2,080 pulses per minute. At minute four the temperature of the fluid is 135° F., e.g., 3,130 pulses per minute. At minute five the temperature of the fluid is 134° F., e.g., 2,500 pulses per minute. At minute six the temperature of the fluid is 133° F., e.g., 1,790 pulses per minute. At minute seven the temperature of the fluid is 132° F., e.g., 1,320 pulses per minute. At minute eight the temperature of the fluid is 133° F., e.g., 1,790 pulses per minute. At minutes nine through eleven the temperature of the fluid is 134° F., e.g., 2,500 pulses per minute. At minute twelve the temperature of the fluid is 135° F., e.g., 3,130 pulses per minute. At minutes thirteen and fourteen the temperature of the fluid is 133° F., e.g., 1,790 pulses per minute.

The third calculator **500** periodically determines the cumulative log kill of Salmonella as a function of the log kill rate and time. This is calculated by periodically counting the

cumulative number of pulses over a predetermined time that the eggs are enveloped by the fluid. According to the above example, the eggs achieve a 3 log reduction in Salmonella after approximately 14 minutes in the fluid bath, e.g., because the pulse counter reaches approximately a count of 30,000 pulses. (The one-minute temperature sensing intervals and temperature differences are for illustrative purposes only. In practice, the intervals and differences may be smaller. The pasteurization time may also in practice differ from this example, which for clarity of illustration does not reflect the total sloping up of the internal egg temperature and concomitant initial pasteurization.)

TABLE B

Minute	Temperature	Pulse Rate
1	130° F.	770
2	132° F.	1,320
3	133.5° F.	2,083
4	135° F.	3,130
5	134° F.	2,500
6	133° F.	1,790
7	132° F.	1,320
8	133° F.	1,790
9	134° F.	2,500
10	134° F.	2,500
11	134° F.	2,500
12	135° F.	3,130
13	133° F.	1,790
14	133° F.	1,790

In the example of Table B, when the eggs are enveloped by the fluid, the temperature of the fluid initially drops to 130° F. The temperature is then increased by the heating elements until the temperature of the fluid reaches 133.5° F. In this example, the heating elements are initially turned on for approximately three minutes in order for the temperature of the fluid to rise until it substantially equals the initial temperature of the fluid prior to the eggs being enveloped by the fluid. Thereafter, the temperature of the fluid is periodically or continuously controlled.

As an illustrative example of the method of calculating the cumulative log kill, FIG. 4 shows the cumulative log kill as an area under a log kill rate versus time curve. The area under the curve is calculated by integration, e.g., counting the pulses as described above. (The area under the curve of FIG. 4 represents a 5 log reduction in Salmonella and thus does not correspond to the example of Table B.)

As seen in FIG. 4, after an initial time the log kill rate begins to slope upwards. Thereafter, the log kill rate substantially levels off. As described above, however, the internal temperature of the eggs may fluctuate over time, thus, for example, resulting in fluctuations of the log kill rate, as seen in FIG. 4. During this process the comparator **600** periodically or continuously compares the area under the curve, which reflects the cumulative log kill, to one or more predetermined values.

Multiple Fluid Systems

Referring to FIG. 5, a plurality of liquid baths is shown. This system uses appropriate means for transporting one or more stacks of eggs between the various baths (and/or zones of the baths) are provided. Multiple bath systems are described in more detail in simultaneously filed Patent Application entitled "Apparatus And Methods For Pasteurizing In-Shell Eggs".

As an example, a carrier **300** preferably has, for example, mounts represented by the combination of wheels **700** and extensions **800**, as shown in FIG. 5. The exemplary mounts permit a loader/unloader to load and unload the eggs in and out of the fluid as well as transport the eggs laterally from one zone or bath to another, as desired.

Two Fluid System

In the two fluid system, the temperature of the first fluid is preferably higher than the temperature of the second fluid. For example, the first fluid may be heated to approximately 137.5° F. and the temperature of the second fluid heated to, for example, approximately 133.5° F. This provides rapid increase of the internal egg temperature to a pasteurization level and then reduction of the temperature to avoid impairing the functionality of the outer portions of the eggs. Other temperatures are also contemplated for use with the two fluid system.

The present system may, for example, calculate the cumulative log kill by integrating an area under a log kill rate versus time curve for the two fluid system, as shown in FIG. 6. FIG. 6 shows the point at which the eggs are moved from one fluid to the next. In embodiments, the overall speed that the eggs move while enveloped by the fluid may be adjusted to ensure proper pasteurization.

As seen in FIG. 6, after an initial time, the log kill rate begins to slope upwards. Thereafter, the log kill rate levels off. As described above, however, the internal temperature of the eggs may fluctuate over time, thus, for example, resulting in fluctuations of the log kill rate, as seen in FIG. 6.

During this process the comparator periodically or continuously compares the area under the curve to a predetermined value. The cumulative log kill may be determined by integrating the area under the curve and comparing the area to one or more predetermined values.

The eggs processed in the two fluid system may achieve a desired reduction in Salmonella faster than in the one fluid system. This is because the eggs in the two fluid system are initially enveloped by a higher temperature fluid which provides rapid increase of the internal egg temperature to a pasteurization level, thus accelerating the log kill rate. This, in turn, may enable the eggs to reach a cumulative log kill faster than in the one fluid system.

Three Fluid System

In the three fluid system, for example, the first fluid and the third fluid may be at higher temperatures than the second fluid. For example, they may be heated to approximately 137.5° F., while the second fluid is heated, for example, to approximately 133.5° F. The higher third temperature permits more rapid pasteurization toward the end of the process. Again, other temperatures are also contemplated for use with the present invention.

The present system may, for example, calculate the cumulative log kill by integrating an area under a log kill rate versus time curve for the three fluid system, as shown in FIG. 7. FIG. 7 shows the point at which the eggs are moved from one fluid to the next. As seen in FIG. 7, after an initial time, the log kill rate begins to slope upwards. Thereafter the log kill rate levels off. When the eggs enter the third fluid, the log kill rate again increases. As described above, however, the internal temperature of the egg may fluctuate over time, thus, for example, resulting in fluctuations of the log kill rate, as seen in FIG. 7.

The eggs in the three fluid system may achieve a desired reduction in Salmonella faster than in the one and two fluid systems. The higher first temperature provides rapid increase of the internal egg temperature to a pasteurization level and the higher third temperature permits more rapid pasteurization toward the end of the process, thus accelerating the log kill rate. This, in turn, may enable the eggs to reach a cumulative log kill faster than in the one and two fluid systems.

Preferred and alternative embodiments of the control systems and methods for controlling pasteurization of in-shell eggs have now been described in detail. However, this description of specific embodiments is merely illustrative of the principles underlying the inventive concepts. It is contemplated that various modifications of the disclosed embodiments will, without departing from the spirit and scope of the invention, be apparent to persons of ordinary skill in the art.

What is claimed is:

1. A method of controlling pasteurization of in-shell eggs by a heated fluid, comprising:

(a) enveloping the eggs by the heated fluid;

(b) at least periodically determining an internal temperature of the eggs while the eggs are enveloped by the heated fluid;

(c) at least periodically determining at least one log kill rate of Salmonella in the eggs based on the internal temperature of the eggs;

(d) at least periodically determining a cumulative log kill of Salmonella as a function of the at least one log kill rate and time;

(e) at least periodically comparing the cumulative log kill to at least one predetermined value; and

(f) generating a signal when the comparing reveals a predetermined relationship between the cumulative log kill and the predetermined value.

2. The method of claim 1, further comprising determining a time of beginning of pasteurization based on the internal temperature of the eggs.

3. The method of claim 2, wherein the cumulative log kill of Salmonella is first determined after the time of beginning of pasteurization.

4. The method of claim 1, wherein the internal temperature of the eggs is determined by calculation based on a time the eggs are enveloped by the heated fluid, the temperature of the heated fluid, an initial temperature of the eggs and size of the eggs.

5. The method of claim 4, wherein the initial temperature of the egg is determined by:

(a) determining the size of the eggs;

(b) monitoring an on-time of at least one heating element in the heated fluid until a temperature of the heated fluid after the eggs are enveloped by the heated fluid substantially equals a starting temperature of the heated fluid; and

(c) determining the initial temperature of the eggs based on the starting temperature of the heated fluid, the on-time of the heating elements and the size of the eggs.

6. The method of claim 4, wherein the initial temperature of the eggs is determined by uniformly preheating the eggs to a predetermined initial temperature.

7. The method of claim 4, wherein the initial temperature of the eggs is determined by monitoring a temperature of the fluid after the eggs are enveloped by the fluid.

8. The method of claim 1, wherein the predetermined value is calculated based on a total log kill required for a desired degree of pasteurization.

9. The method of claim 1, wherein the predetermined value is a predetermined log kill value for a time at which the comparing takes place.

10. The method of claim 1, further comprising controlling the temperature of the heated fluid in response to the signal.

11. The method of claim 1, further comprising removing the eggs from the heated fluid and cooling the eggs in response to the signal.

12. The method of claim 11, wherein the signal is generated when the cumulative log kill of Salmonella is at least 3 logs.

13. The method of claim 1, further comprising adjusting a dwell time of the eggs in the heated fluid in response to the signal.

14. The method of claim 1, further comprising removing the eggs from the heated fluid and subsequently discarding, cooking or breaking the eggs and further processing the eggs in response to the signal.

15. The method of claim 13, wherein the time at which the comparing takes place is before a predetermined time at which sufficient pasteurization is expected to be completed.

16. The method of claim 1, wherein the heated fluid is in at least two different temperature zones, and the eggs are moved from one of the temperature zones to another of the temperature zones in response to the signal.

17. The method of claim 16, wherein the heated fluid is liquid and the different temperature zones comprise separate baths.

18. The method of claim 1, wherein the heated fluid is a liquid bath.

19. The method of claim 18, wherein the liquid bath is vertically perturbated.

20. An apparatus for controlling pasteurization of in-shell eggs by a heated fluid, comprising:

(a) means for enveloping the eggs by the heated fluid;

(b) means for at least periodically determining an internal temperature of the eggs while the eggs are enveloped by the heated fluid;

(c) means for at least periodically determining at least one log kill rate of Salmonella in the eggs based on the internal temperature of the eggs;

(d) means for at least periodically determining a cumulative log kill of Salmonella as a function of the at least one log kill rate and time;

(e) means for at least periodically comparing the cumulative log kill to at least one predetermined value; and

(f) means for generating a signal when the comparing reveals a predetermined relationship between the cumulative log kill and the predetermined value.

21. The apparatus of claim 20, further comprising:

(a) means for monitoring an on-time of at least one heating element in the heated fluid until a temperature of the heated fluid after the eggs are enveloped by the heated fluid substantially equals a starting temperature of the heated fluid; and

(b) means for determining the initial temperature of the eggs based on the starting temperature of the heated fluid, the on-time of the heating elements and the size of the eggs.

22. An apparatus for controlling pasteurization of in-shell eggs in contact with a heated fluid, comprising:

(a) a first calculator that at least periodically determines an internal temperature of the eggs while the eggs are enveloped by the heated fluid;

(b) a second calculator that at least periodically determines at least one log kill rate of Salmonella based on the internal temperature of the eggs;

(c) a third calculator that at least periodically determines a cumulative log kill of Salmonella as a function of the at least one log kill rate and time;

(d) a comparator that at least periodically compares the cumulative log kill to at least one predetermined value; and

(c) a signal generator that generates a signal when the comparator reveals a predetermined relationship between the cumulative log kill and the predetermined value.

23. The apparatus of claim 22, further comprising a fourth calculator that determines a time of beginning of pasteurization based on the internal temperature of the eggs.

24. The apparatus of claim 22, wherein the first calculator determines the internal temperature of the eggs based on a time the eggs are enveloped by the heated fluid, the temperature of the heated fluid, an initial temperature of the eggs and size of the eggs.

25. The apparatus of claim 24, further comprising:

(a) an on-time monitor that monitors an on-time of at least one heating element in the heated fluid until a temperature of the heated fluid after the eggs are enveloped by the heated fluid substantially equals a starting temperature of the heated fluid; and

(b) a fifth calculator that determines the initial temperature of the eggs based on the starting temperature of the heated fluid, the on-time of the heating elements and size of the eggs.

26. The apparatus of claim 24, further comprising a preheater that preheats the eggs to a predetermined initial temperature.

27. The apparatus of claim 22, further comprising a temperature controller for at least periodically controlling the temperature of the heated fluid in response to the signal.

28. The apparatus of claim 22, further comprising an unloading mechanism configured to remove the eggs from the heated fluid and move the eggs to a cooler in response to the signal.

29. The apparatus of claim 22, wherein the predetermined value is calculated based on a total log kill required for a desired degree of pasteurization.

30. The apparatus of claim 22, further comprising a dwell time adjuster to adjust a dwell time of the eggs in the heated fluid in response to the signal.

31. The apparatus of claim 22, wherein the heated fluid is in at least two different temperature zones, and the eggs are moved from one of the temperature zones to another of the temperature zones in response to the signal.

32. The apparatus of claim 31, wherein the heated fluid is a liquid and the different temperature zones comprise separate baths.

33. The apparatus of claim 22, wherein the heated fluid is a liquid in a bath containing a perturbator for vertically perturbating the liquid.

34. The apparatus of claim 22, wherein the first, second and third calculators comprise a processor programmed to (i) at least periodically determine an internal temperature of the eggs, (ii) at least periodically determine at least one log kill rate and (iii) at least periodically determine a cumulative log kill.

35. A method of controlling pasteurization of in-shell eggs, comprising:

(a) preheating the in-shell eggs to a predetermined initial temperature;

(b) further heating the eggs by contact with a heated fluid while maintaining a temperature of the heated fluid at a substantially constant temperature while the eggs are in contact with the heated fluid;

(c) maintaining the in-shell eggs in contact with the heated fluid for a predetermined time, wherein the predetermined time is a function of a cumulative log kill rate of Salmonella at the temperature of the heated fluid and a desired log kill level; and

(d) removing the eggs from contact with the heated fluid at an end of the predetermined time.

36. The method of claim 35, further comprising chilling the eggs upon removing the eggs from the heated fluid.

* * * * *

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United States Patent [19]

Polster

[11] Patent Number: 6,035,647

[45] Date of Patent: Mar. 14, 2000

[54] METHOD AND APPARATUS FOR CHILLING IN-SHELL EGGS

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[22] Filed: Dec. 31, 1997

[51] Int. Cl.[7] F25D 13/06; A23L 1/32

[52] U.S. Cl. 62/64; 62/373; 426/298; 426/393

[58] Field of Search 62/62, 63, 64, 62/373, 374, 375, 376; 426/298, 393

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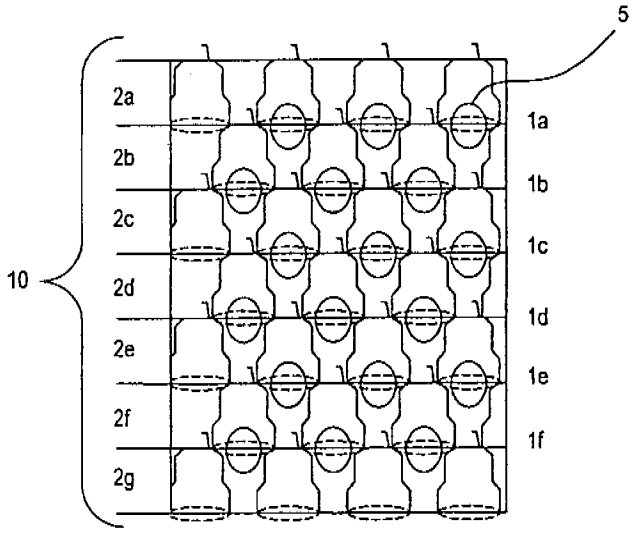
Primary Examiner—Christopher B. Kilner

Attorney, Agent, or Firm—Oliff & Berridge, PLC

[57] ABSTRACT

A method for chilling a plurality of layers of in-shell eggs includes immersing at least one stack of a plurality of layers of in-shell eggs in cooled liquid until the eggs are cooled to a predetermined temperature or below. A preferred apparatus for conducting the method includes a liquid bath container with chilling heat exchangers and a source of bubbles for vertically perturbating liquid in the container.

25 Claims, 4 Drawing Sheets



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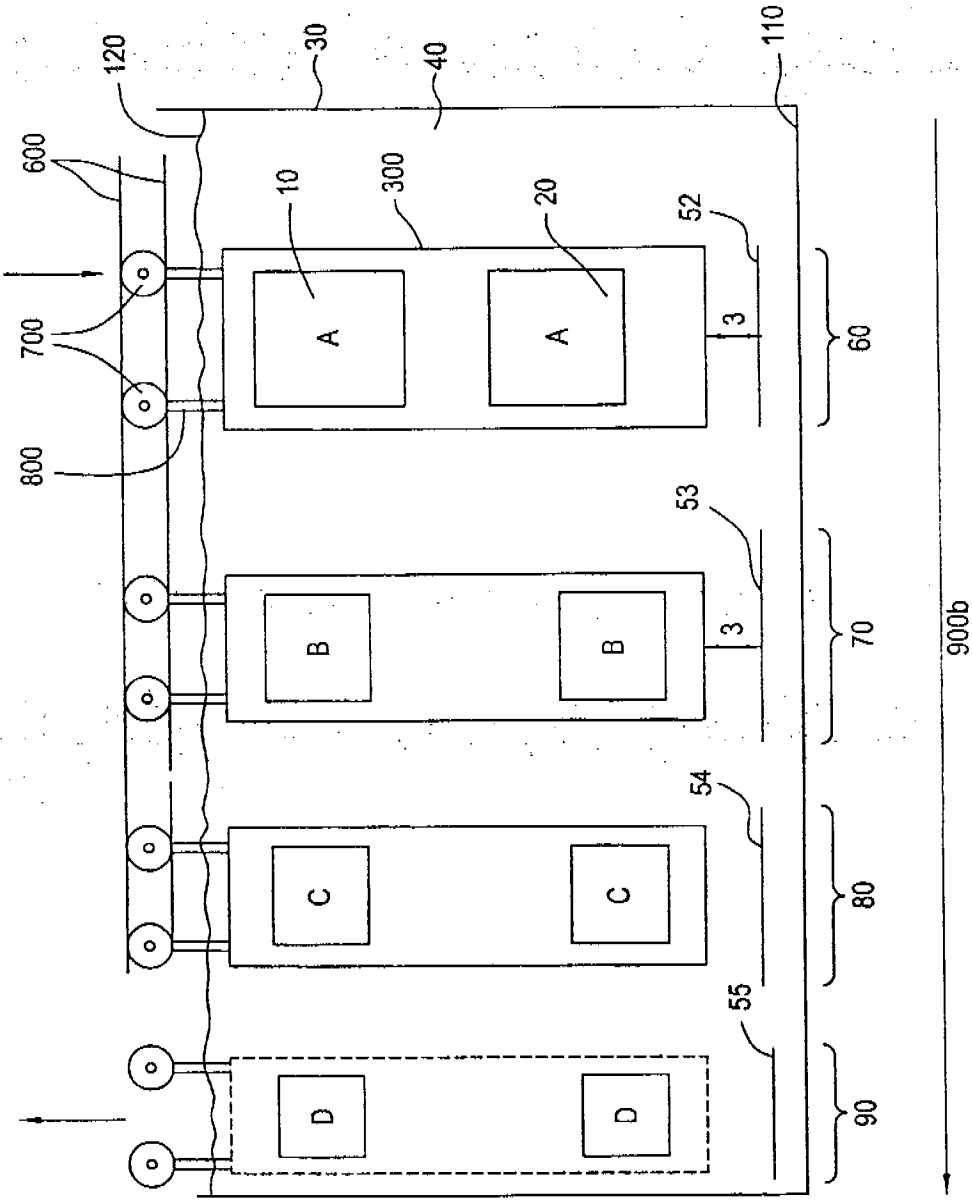
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30
40
110
600
10
300
20
52
700
A
A
3
60
800
53
B
B
3
70
900b
54
C
C
80
55
D
D
90

FIGURE 1A

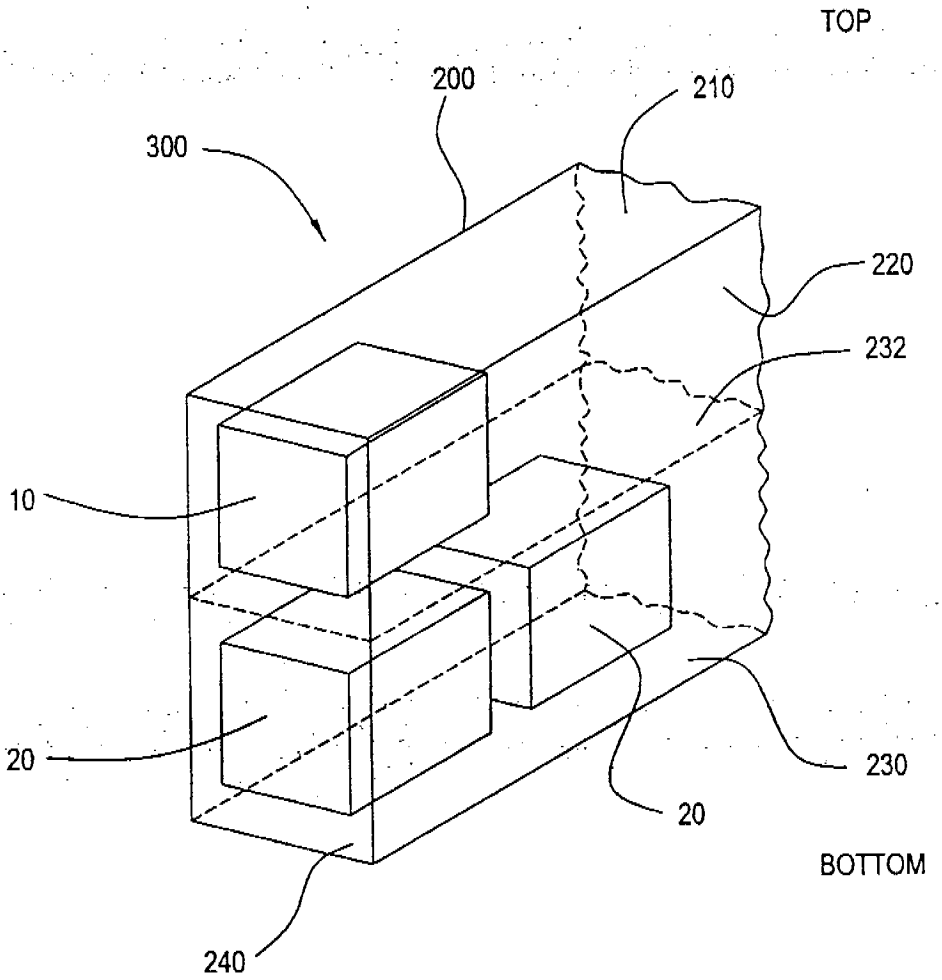

FIGURE 1B

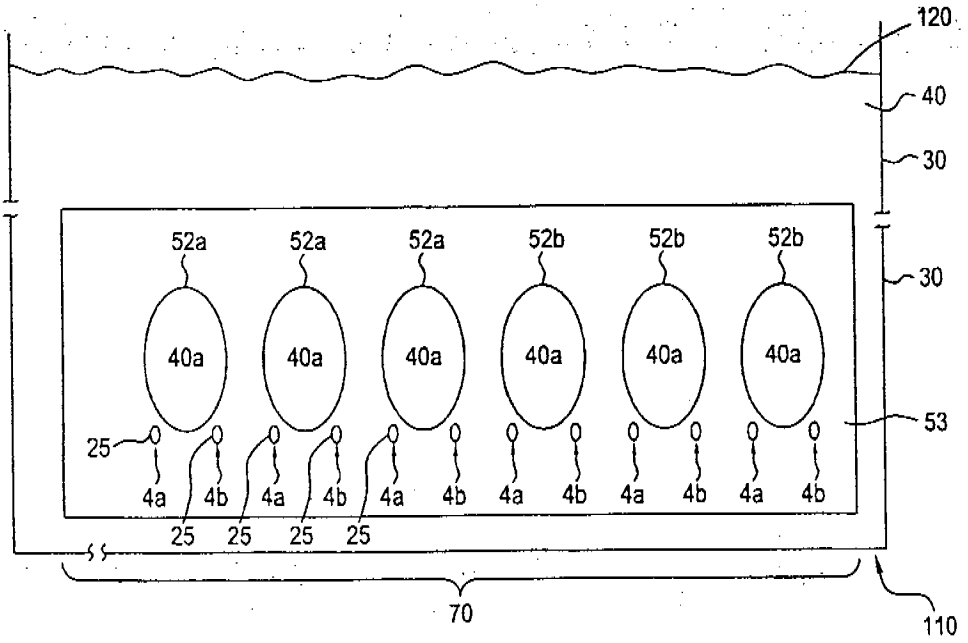

FIGURE 1C

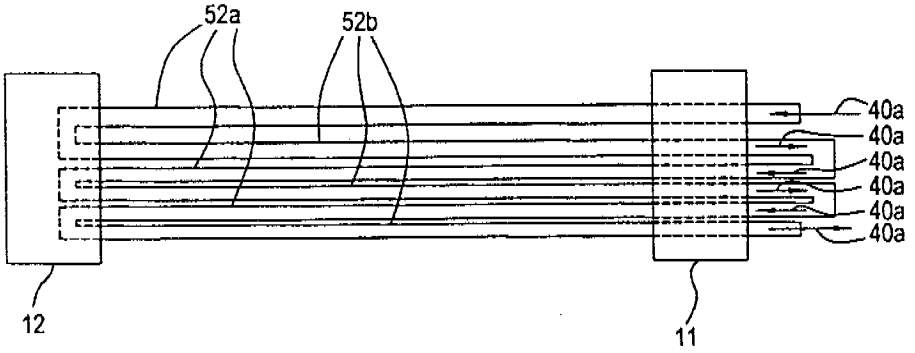

FIGURE 1D

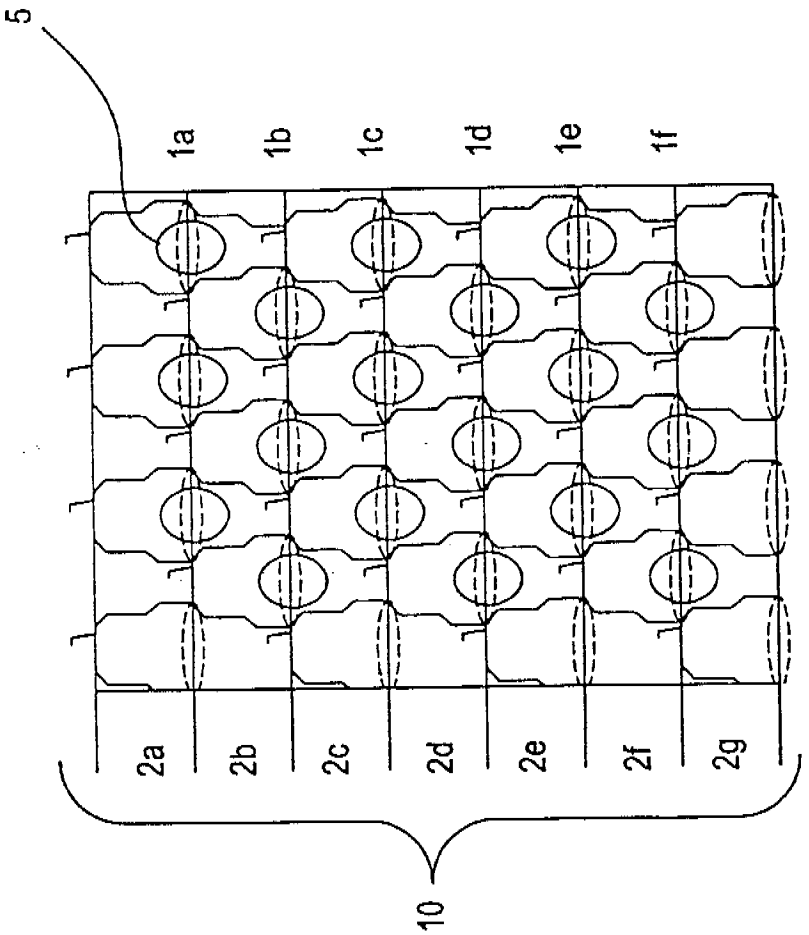

FIGURE 1E

METHOD AND APPARATUS FOR CHILLING IN-SHELL EGGS

BACKGROUND OF THE INVENTION

The present invention is directed to methods and apparatus for chilling in-shell eggs.

Ordinarily, in-shell eggs are collected from the henhouse, washed, graded and separated according to their grading (e.g., S, M, L, XL, Jumbo and the like). Thereafter, optionally, the eggs may be pasteurized to achieve a 3 to 5 log or more reduction in the count of various microorganisms, such as *Salmonella enteritidis*, associated with in-shell eggs. Whether pasteurized or not, it is necessary to chill the in-shell eggs in connection with their storage and transport to comply with U.S. Department of Agriculture/Food and Drug Administration (USDA/FDA) requirements. Such eggs should be chilled to a temperature, for example, from about 41° F. to about 45° F.

Chilling commercial quantities of in-shell eggs in a refrigeration unit is a slow process. Typically, the refrigeration unit contains chilled air. Without being bound by theory, it is believed that due to the "insulating" properties of air (i.e., poor ability to transfer heat away from, for example, in-shell eggs), it takes 9–10 days or more to chill commercial quantities of in-shell eggs (e.g., 270 or more dozen eggs at a time provided in stack(s) of a plurality of layers of in-shell eggs) in a refrigerator. Because of the slow nature of the refrigeration process, conventional means for chilling eggs are very expensive. During refrigeration, the eggs have to be stored in expensive refrigerated warehouses for extended periods of time. In addition, the prolonged chilling times increase handling costs and reduce the freshness of the eggs.

With respect to optionally pasteurized eggs, chilling may be used to stop further pasteurization thereof. Alternatively (or in addition), eggs may be chilled without pasteurization. Either way, chilling slows down the growth rate of various microorganisms (e.g., pathogenic and non-pathogenic bacteria such as rot bacteria) that are typically present both on the shell and inside the shell of a whole egg, including within the egg albumin and within the egg yolk. Further, chilling also slows down loss of functionality of the eggs.

With regard to pathogens present on and/or inside an in-shell egg, especially a chicken egg, a common pathogen is Salmonella. A variety of other microorganisms may also be present on and/or within in-shell chicken eggs. See E. M. Funk, Pasteurization of Shell Eggs, University of Missouri, College of Agriculture, Agricultural Experiment Station, Research Bulletin 364, pp. 1–28 (May 1943), incorporated herein by reference in its entirety.

While the following comments are directed to chicken eggs, these comments also apply to other types of in-shell eggs.

In the early 1900's, it was appreciated that chicken eggs were pathogenically contaminated on their outer shell. Such contamination was believed to be caused by surface contact with, for example, fecal matter, contaminated animal feed, other contaminated material and the like. It was further believed that in-shell eggs were contaminated within the egg shell by penetration of pathogens through the checks or cracks thereof. It was recognized that microorganisms may enter the pores of an in-shell egg, especially when being chilled in cold water. Further, it has only recently been discovered that bacteria such as Salmonella and, especially, *Salmonella enteritidis*, enters the egg yolk of an in-shell egg via trans-ovarian transmission (i.e., from the mother to the egg even before the egg is laid by the hen). See M. E. St. Louis et al., The Emergence of Grade A Eggs as a Major Source of *Salmonella enteritidis* Infections, Journal of the American Medical Association, Vol. 259, No. 14, pp. 2103–2107 (Apr. 8, 1988), incorporated herein by reference in its entirety.

As noted, chilling is used to slow down the growth rate of the various microorganisms that may be present within and/or on in-shell eggs. Chilling may also be used to halt further pasteurization or cooking of eggs once a desired level of pasteurization or cooking has been achieved.

The ability to rapidly chill large numbers of in-shell eggs may be critical to pasteurizing eggs without substantially impairing egg functionality. This is because eggs are typically pasteurized by heating them to a desired temperature range for a desired time. See co-pending Davidson International Application No. PCT/US96/13006 (U.S. application Ser. No. 08/519,184), incorporated herein by reference in its entirety. See also, International Application No. PCT/US95/00254 (WO 95/18538), and U.S. Pat. No. 2,423,233, each incorporated herein by reference in its entirety.

Without rapid chilling of these eggs, they slowly cool towards room temperature. However, the slow cooling may result in the eggs spending too much time at an elevated temperature, causing substantial impairment of egg functionality.

Typically, large volume commercial operations involve transporting one or more batches of, for example, several hundred to thousands of dozens of eggs (e.g., 1,000 to 6,000 dozen eggs) at a time. However, often times such large commercial quantities of in-shell eggs cannot be rapidly chilled together as a single batch sufficient to prevent substantial impairment of egg functionality (e.g., at least about 60 Haugh units per batch) using known refrigeration techniques. Thus, for commercial size operations, in order to halt further pasteurization and avoid substantial impairment of egg functionality, and/or to slow the growth rate of microorganisms associated with in-shell eggs there is a need to rapidly chill a large number of in-shell eggs.

When chilling commercial quantities of in-shell eggs, the ability to maintain their market quality is critically important. For example, the market quality of pasteurized chilled eggs or unpasteurized chilled eggs should be sufficient to market them to the public (for consumption). Thus, chilling of in-shell eggs (with or without prior pasteurization) in a cost efficient manner is paramount, especially for large scale commercial operations to remain efficient, cost-effective and successful. There is, therefore, a need to provide methods and apparatus for rapidly and cost effectively chilling commercial quantities of in-shell eggs.

SUMMARY OF THE INVENTION

In embodiments of the invention, a process for chilling in-shell eggs comprises immersing at least one stack of a plurality of layers of eggs into at least one cooled liquid until the eggs are cooled to a predetermined temperature by dissipating heat from the eggs to the liquid.

The above-noted process may be carried out, for example, in an apparatus for chilling in-shell eggs comprising a container for holding a liquid bath; a heat exchanger adapted to cool liquid in the bath to a predetermined temperature; and a source of bubbles of at least one gas sufficient to provide vertical perturbation of the liquid.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A schematically represents one embodiment of the claimed process.

FIG. 1B schematically depicts a perspective view of one embodiment of carrier for use with the present invention.

FIG. 1C depicts a cross-sectional view of one embodiment of a heat exchanger for use in accordance with the present invention.

FIG. 1D is a top view of the heat exchanger of FIG. 1C.

FIG. 1E depicts a stack of a plurality of layers of in-shell eggs.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

In commercial operations, it is not efficient or cost-effective to chill a single egg, a single row or even a single layer of in-shell eggs at a time. To the contrary, in a competitive market, it is most desirable to chill at least one batch of several, tens, hundreds, or thousands of dozens of eggs together.

To handle large batches of in-shell eggs for transportation or the like, these in-shell eggs may be provided in a plurality of layers formed into stacks. The stacks most standard in the industry contain about 6 layers of in-shell eggs per stack (or multiples thereof, e.g., 12, 18, 24, 30, 36, etc.). Further, each layer of in-shell eggs may contain about 30 in-shell eggs (or multiples thereof, e.g., 60, 90, 120, 150, 180, etc.). When a plurality of these layers of in-shell eggs are formed into one or more stacks, the stacks contain in-shell eggs located at their periphery extending all the way to their center. Conveniently, each layer of eggs is held in a 6 egg by 5 egg flat. Sometimes, such flats may not all be fully filled with 30 eggs; however, incompletely filled flats add to the cost and inefficiency of the process.

As previously noted, refrigeration of stacks of in-shell eggs is slow, inefficient, expensive and undesirable. One reason for the inefficiency is that refrigeration is accomplished by placing the stack(s) of in-shell eggs in a refrigeration unit. Therein, the eggs are surrounded by chilled air. Because air is a poor conductor of heat, heat slowly dissipates from the eggs to the chilled air and away from the eggs. The stack(s) of eggs typically require from about 9–10 or more days of chilling time to achieve a chilling temperature, for example, of about 40–45° F. Without being bound by theory, it is believed that the chilling inefficiency inherent to refrigeration is at least partly due to the poor thermal conductivity of air.

A further problem that has prevented rapid chilling of at least one stack of a plurality of egg layers is that the in-shell eggs within a stack nearest the periphery of the stack would chill much faster than the eggs located in the center of the stack. Without being bound by theory, it is believed that the eggs nearer the periphery would trap air in the stack and thus insulate the eggs in the center of the stack. Thus, for example, the result would be that (1) the in-shell eggs nearest the periphery are properly chilled while the in-shell eggs nearest the center are insufficiently chilled; or (2) for those eggs that are optionally pasteurized, the in-shell eggs nearest the periphery are sufficiently chilled but the in-shell eggs nearest the center have their functionality substantially impaired from staying too long at a high temperature. Other such undesirable combinations of improper chilling and/or impaired functionality could also be encountered.

Thus, the peripheral eggs of the stack would have chilled faster than eggs centrally located in the stack. As a result, a disparity in temperature of the eggs in the stack would become more and more pronounced as the stack and/or batch size increases. This disparity would have become even more dramatic when the size of the eggs, the size of the layers (i.e., number of eggs per layer), the number of layers per stack and/or the number of stacks being chilled together in one or more batches of a plurality of stacks are increased.

It is preferred that the chilling cycle for a single batch (e.g., one or more stacks of 5 dozen to 6,000 or more dozen eggs per batch) is several hours or less, preferably from several minutes to about 1 hour and, more preferably, under about 15 minutes, for example from about 5 minutes to about 10 minutes.

According to the invention, it has surprisingly been discovered that at least one stack of a plurality of layers of in-shell eggs can be rapidly, efficiently and cost-effectively chilled at the periphery (or at locations nearest a heat exchanger), at locations farthest away from the heat exchanger, and in the interior (all the way to the center) of the stack.

In FIG. 1A, stacks **10** and **20** of six layers (**1***a*, **1***b*, **1***c*, **1***d*, **1***e* and **1***f*; see FIG. 1E) of in-shell eggs **5** in a plurality of flats (**2***a*, **2***b*, **2***c*, **2***d*, **2***e*, **2***f* and **2***g*; see FIG. 1E) are shown. Instead of top flat **2***a*, a wire mesh cover or the like may be used. Further, a plurality of stacks **10** and **20** is depicted. At various stages of the chilling process, these stacks are immersed in liquid **40**, which may be contained in bath **30**. While only one bath **30** is shown, a plurality of baths may be used. More particularly, the stacks (**10** and **20**) are lowered into a receiving zone **60** of bath **30**. Further, in accordance with various stages of the chilling process as shown in FIG. 1A, the eggs in the stacks are enveloped by chilled liquid **40** contained in baths **30**.

The desired precision to which the eggs are chilled may be provided by a combination of several elements. These elements may include, but are not limited to, at least one heat exchanger, at least one temperature sensor, at least one means for perturbating fluid in the bath(s) sufficient to substantially uniformly chill each of the eggs in the stack, preferably by vertical perturbation, and one or more flats for holding the eggs and allowing perturbation of the fluid around the entire surface of each egg held therein. U.S. Pat. No. 4,503,320 (Polster), incorporated herein by reference in its entirety, describes an exemplary temperature sensor and temperature control system suitable for use in conjunction with the present invention. See also Patent Cooperation Treaty application no. PCT/US94/12790 (WO 95/12320), incorporated herein by reference in its entirety. However, heat exchangers may be located in other portions of the bath, outside the bath, or may even be eliminated if the liquid is obtained from a cold enough source.

According to the embodiment of FIG. 1A, a plurality of temperature sensors may be placed throughout bath **30**. Preferably, at least two sensors per zone (e.g., **60**, **70**, **80**, and/or **9**) are provided. These sensors are preferably spaced substantially vertically apart sufficient to accurately monitor the temperature of liquid **40**. These sensors are also connected to the control system. The temperature sensors and the control system may thus be used to maintain the cooling temperature sufficient to rapidly chill the stack(s) of in-shell eggs. If the eggs have been previously pasteurized, then, preferably, chilling the eggs should be sufficiently rapid to prevent substantial impairment of their functionality.

A means for perturbating the fluid next to, between and around the in-shell eggs in the stacks (e.g., stacks **10** and **20**) is preferably provided. The perturbation is preferably provided in a vertical direction emanating from below and being directed upwards towards and through the layers of in-shell eggs. The perturbation should be sufficient to substantially perturbate the fluid around the entire surface of

each egg held in the stack(s). A preferred means for vertically perturbating a liquid surrounding the in-shell eggs held in one or more stacks of flats comprises flowing bubbles of at least one gas, such as CO_2(g), Ar(g), air or the like through liquid **40**. Air is, of course, inexpensive, abundant and safe for handling.

Preferably, the gas is provided through a gas supply line. Preferably, the gas line outlet(s) are located at or near the bottom **110** of bath **30**. For example, the gas line outlet(s) may be located at level **110**. Further, the gas line outlet(s) are preferably located between and/or below the heat exchangers **52**, **53**, **54**, and/or **55** depicted in FIG. 1A. As the gas is released, bubbles of the gas rise through liquid **40**, through carrier **300**, through stacks **10** and **20**, through flats *2a–2g*, around the entire surface of each egg, to the surface **120** of liquid **40**. The bubbles on their way to the surface **120** help to equalize the temperature of liquid **40** and thus the temperature of eggs in the stacks immersed in liquid **40**.

In embodiments, the supply of bubbles to perturbate the fluid around the entire surface of each in-shell egg in one or more stacks may be provided by a regenerative blower. Preferably, the regenerative blower will have a capacity (e.g., measured in cubic feet per minute (CFM)) at least equal to about the surface area (e.g., measured in square feet) of the fluid being perturbated in the bath(s). For example, for a surface area at surface **120** of about 100 square feet, the blower should have a capacity of generating at least about 100 CFM of gas.

Now referring to FIGS. 1C and 1D, heat exchanging coils or tubes *52a* and *52b* may form one or more loops having heat exchange fluid *40a* flowing therein. Additionally, in FIG. 1C, cross-sections of sets of gas tubes *4a* and *4b* are depicted. These gas tubes *4a* and *4b* provide a source of bubbles of gas **25** flowing therein and being released into the bath. Preferably, the gas tubes are located below or adjacent to chilling tubes *52a* and/or *52b*. However, configurations other than that depicted in FIGS. 1C and 1D may also be used. Such other configurations should be sufficient to perturbate and thereby uniformly chill liquid **40**. It should also be sufficient to perturbate the fluid along the entire surface of each egg and thereby ensure uniform chilling of the eggs in the stacks.

When a plurality of baths is used, appropriate conveyor means for transporting one or more stacks of eggs between the various zones contained therein are provided. Preferably, however, a single bath may be used. According to the embodiment of FIG. 1A, eggs are preferably received in a batch of stacks of 15 dozen eggs per stack or the like. Preferably, each stack comprises about 2, 3, 4, 5, 6 or more perforated flats (e.g., perforated trays described in greater detail below for holding at least one layer of eggs per flat) of 6, 12, 24 to 30 or more in-shell eggs or the like per flat. In embodiments, eighteen stacks of eggs may be placed, for example in two rows of nine stacks per row, on a carrier **300**. See FIG. 1B. This carrier is preferably compatible with standard egg handling equipment used in the egg industry.

Carrier **300** preferably has, for example, mounts represented by the combination of wheels **700** and extensions **800** shown in FIG. 1A. Other types and configurations of mounts or other conveying, loading and unloading means may suitably be used with the present invention as will be readily understood by one of ordinary skill in the art. Therefore, while too numerous to list, such mounts and such other loading, unloading and/or conveying means and conveying systems are useful in the present invention. The exemplary mounts (comprising wheels **700** and extensions **800** in FIG. 1A) permit the loader/unloader to load and unload the stacks in and out of liquid **40** as well as transport the stacks laterally from one zone to another as desired. The mounts, if any, should preferably allow continuous and/or discontinuous (e.g., intermittent) lateral movement of the stacks of eggs enveloped by liquid **40** as well as movement of the stacks in and out of liquid **40**. Alternatively, the stacks may simply be lowered into liquid **40** until sufficiently chilled and then taken out of liquid **40** without any lateral movement of the stacks.

As depicted in FIG. 1B, carrier **300** may be of a rectangular or square shape; however, any shape sufficient to hold one or more stacks may be used. Further, carrier **300** may be provided with one or more intermediate shelves such as shelf **232** for supporting one or more rows of stacks such as **10** and **20**. Further, some or all of the faces of carrier **300** should be sufficiently perforated (i.e., open or permeable) to permit liquid **40** to readily enter into carrier **300** and to pass through all the stacks and layers and to envelope all the eggs contained therein. Also, carrier **300** should be sufficiently open to ensure adequate perturbation, preferably vertical perturbation, of the liquid over the entire surface of all the eggs to ensure uniform cooling of all the eggs. For example, at least faces **210** and **230** and shelf **232** may be formed from a wire mesh or some other open structure sufficient to allow liquid **40** to envelope all the eggs and yet strong enough to support the weight of the stacks whether in or out of liquid **40**. In addition, carrier **300** is preferably formed of a material that can be reused and that does not interfere with the process, apparatus, and flats of the present invention.

One or more carriers **300** may be used. For example, one carrier for each batch A, B, C and D may be provided in the embodiment of FIG. 1A. Further, while each carrier is depicted as holding two rows of stacks, any number of one or more rows, one or more stacks and one or more batches may be chilled together in one chilling cycle.

Preferably, the egg carrier **300** is strong enough to hold at least about 270 dozen eggs while being loaded, unloaded or otherwise moved by the material handling system. In addition, it is preferred that the carrier **300** be compatible with standard egg loading, unloading and moving equipment used in the egg industry. It is preferred that the carrier **300** have a shape and a size such that it rests in a stable position when placed on a substantially horizontal surface—i.e., the carrier **300** should not readily tip over either when empty or when filled with stacks of eggs.

It is also preferred that carrier **300** be heavy enough to overcome the buoyancy of the perforated flats and eggs forming the stacks contained therein. Preferably, the weight of the carrier **300** should be sufficient such that it will not float out of its carrier track as it moves through a bath. The carrier **300** should preferably also maintain the stacks contained therein in a relatively secure fashion such that the stacks can be readily loaded and unloaded into the carrier **300** and the carrier **300** can be readily moved vertically and/or laterally through the bath(s) without tipping, breaking or otherwise damaging the in-shell eggs.

Examples of a suitable liquid **40** include water, including salt water, and the like. The liquid may also comprise a mixture of liquids; an emulsion, a dispersion, a suspension or the like. The liquid may contain one or more preservatives or other additives, so long as it is compatible for use with chilling of in-shell eggs for edible consumption. It is preferred that the liquid **40** be substantially non-volatile at the chilling bath temperature, and at ambient temperature and pressure.

Referring to FIG. 1A, bath **30** may, for example, contain a chilled liquid **40** such as water. In the bath, it is possible to provide several, for example, six or more zones per bath (e.g., zones **60**, **70**, **80**, and/or **90** as depicted in FIG. 1A). Further, it can be helpful to provide additional lateral space in the bath. It is of course understood that the minimum width of each zone can be dictated by the size of the carrier **300** to be used. Further, the minimum height of each bath can also be determined by the height of carrier **300** and the space required between the top and bottom rows of stacks of eggs contained therein. Additional space may also be provided above the height of the carrier **300** immersed in liquid **40**. This additional height can accommodate the further addition of liquid **40** to the bath(s).

While various zones are depicted in the embodiment of FIG. 1A, it is understood that the bath **30** may only contain one zone into which the eggs to be chilled are immersed and removed therefrom after appropriate chilling is achieved. In other words, though lateral movement of the eggs through the various zones is depicted in FIG. 1A (see arrow **900***b*), lateral movement is optional. However the eggs are moved, it is preferred that the eggs be immersed in liquid **40** sufficiently to rapidly chill all (or substantially all) of the eggs in a batch thereof to the desired or necessary temperature, for example a temperature required by the USDA/FDA.

In addition, it is preferred that the bath be of a sufficient size to allow complete immersion therein of one or more carriers **300** (fully loaded with one or more stacks of eggs) without spilling liquid **40** from the bath. Preferably, the bath contains a drain and a drain system to allow removal of liquid **40** from the bath as necessary. It is also preferred that space be provided between each carrier and any heat exchangers provided within the bath.

The bath of FIG. 1A contains liquid **40** which is chilled by exemplary heat exchangers (e.g., **52**, **53**, **54**, and **55**). These heat exchangers may, for example comprise metallic or other heat conductive material in the form of tubing, preferably formed to maximize the transfer of heat from liquid **40** of the bath to fluid **40***a* flowing therein. Heat exchangers **52**–**55** may be placed near the bottom and/or sides of the bath. Alternatively, the heat exchangers may be situated at other locations of the bath sufficient to rapidly and uniformly chill the batch of in-shell eggs immersed in liquid **40**. Other configurations may also be used. These configurations should be sufficient to rapidly and uniformly chill the batch of in-shell eggs immersed in liquid **40**. One example of tubes forming the heat exchangers is shown in FIGS. 1C and 1D.

Typically, the initial temperature of the stack(s) of eggs being lowered into the receiving zone **60** is from about 70° F. to about 140° F., for example from about 75° F. to about 138° F., from about 90° F. to about 138° F., or from about 110° F. to about 138° F. However, the in-shell eggs may be warmer or cooler. Thus, the chilling time may vary. During chilling, these eggs preferably release a sufficient amount of energy into liquid **40** to lower the yolk temperature of substantially all the eggs to 110° F. or lower, for example to a range from about 35° F. to about 110° F., preferably below 50° F. (e.g. from about 40° F. to about 50° F.), more preferably below 45° F. (e.g. from about 41° F. to about 45° F.) and even more preferably below 42° F.

The chilling time may vary depending upon such factors as the type of eggs, the number of eggs per layer, the size of the eggs in each layer, the number of layers, the number of stack(s), and the initial egg temperature.

Typically, the chilling time for all the stacks is from about 3 minutes to about 20 minutes, for example from about 6 minutes to about 12 minutes or about 9 minutes to about 12 minutes for chilling about 270 dozen eggs contained in at least one batch of about eighteen stacks of 6 layers per stack, each layer containing about 30 in-shell eggs. For example, it takes about 6 minutes to chill eggs from about 137° F. to about 80° F. using about 60° F water. Likewise, for example, it takes about 18 minutes to chill eggs from about 137° F. to about 40° F. using 35° F. water. These eggs may or may not be pasteurized.

For a water containing bath, exemplary bath temperatures (for chilling unpasteurized eggs or for chilling pasteurized eggs while maintaining substantially unimpaired egg functionality) are from about 35° F. to about 75° F. Even more preferably, the desired bath temperature to which all the eggs occupying the various zones of the bath are chilled is from about 33° F.±2° F. to about 70°±2° F. Even more preferably, the desired bath temperature is from about 35° F.±1° F. to about 37° F.±1° F. The precision of the bath temperature may be loosely or tightly controlled. Examples of temperature precision include, but are not limited to, about ±4° F., about ±3° F., about ±2° F., about ±1° F., about ±0.1° F. and about ±0.03° F.

A plurality of heat exchangers (such as **52**, **53**, **54**, and/or **55**) per zone (e.g., **60**, **70**, **80**, and/or **90**) may be provided in liquid **40**. Preferably, if a plurality of heat exchangers is provided per zone, then the heat exchangers may be substantially equally spaced apart. However, the heat exchangers should be located to advantageously maintain the desired liquid temperature substantially uniformly throughout the bath. In addition to heat exchangers, at least one temperature sensor is preferably connected to the bath **30**.

Ordinarily, the first zone **70**, intermediate zone(s) **80**, and/or exit zone **90** are provided with at least one heat exchanger. Optionally, the receiving zone **60** is also provided with at least one heat exchanger (e.g. **52**). The heat exchangers are preferably disposed adjacent to and below the lowest stack (e.g., stack **20**) and separated by a distance **3**. Distance **3** depends, for example, upon the chilling capacity of heat exchangers such as **52**, **53**, **54**, and **55**. Distance **3** should be sufficient to allow chilling of all eggs provided within all stacks of at least one batch (e.g., batch A of stacks **10** and **20** depicted in FIG. 1A) in one chilling cycle.

While the receiving zone **60**, the first zone **70**, the optional intermediate zone **80** and the exit zone **90** are depicted as part of a single bath **30** in FIG. 1A, some or all of these various zones may each comprise a separate bath. In addition, while these zones are discretely represented in FIG. 1A, the zone boundaries (not shown) can be contracted or expanded to accommodate the size of the eggs, the size of the batch, the type of egg (e.g., chicken egg versus other types of eggs), the level of chilling desired, the bath temperatures, and the like. Thus, for example, zone **60** and the other zones may be narrower or wider depending on at least the above-noted factors, and may even be combined into a single area of a single bath.

In FIG. 1A, each of the zones **60**, **70**, **80**, and **90** is depicted with one heat exchanger **52**, **53**, **54**, and **55** per zone, respectively. While FIG. 1A depicts an embodiment of the invention, the number and location of zones, heat exchangers and temperature sensors, means for perturbation of liquid **40** and the like may be varied so that the rapid chilling of one or more stacks of a plurality of layers of in-shell eggs can be accomplished.

Thus, for example, for chilling 350 stacks of in-shell eggs containing 6 layers per stack of 30 in-shell eggs per layer,

the total chilling cycle time may, in embodiments, be from about 2 minutes to about 3 hours, preferably, under 2 hours, and more preferably, well under 1 hour (e.g., from about 6 minutes to about 20 minutes).

Preferably, when all of the liquid **40** in the zones (e.g., **60**, **70**, **80**, and/or **90**) is appropriately chilled, the system is ready to receive a batch of one of more stacks of eggs. Thus, a loader or a material handling system (MHS) engages a loaded carrier **300** for transport. See FIG. 1B for a depiction of an exemplary carrier **300** filled with a plurality of stacks of eggs. The loader then lowers carrier **300** into receiving zone **60**.

Then, referring to FIG. 1A, the conveyor **600** may move the eggs from zone **60** to zone **70** in, for example, bath **30**. Further, in general, conveyor **600** may be used to move eggs from one zone to any one of the other zones of a single or multiple baths.

In FIG. 1A, dashed lines outlining carrier **300** loaded with batch D indicate the position of batch D immediately before its removal from bath **30**. In general, arrow **900***b* (FIG. 1A) indicates the overall direction of movement of a single batch through the apparatus of FIG. 1A. It is noted that movement in the direction of arrow **900***b* is optional and may be continuous or intermittent (i.e., discontinuous) or some combination thereof.

The loader may be configured to load batch A into liquid **40** and unload batch D out of liquid **40**. While such a loader or its motion in and out of liquid **40** is not shown, it is imputed herein and is readily understood by one of ordinary skill in the art of moving in-shell eggs, especially chicken eggs and the like.

Typically, the movement of stacks of eggs from one zone to another is accomplished sequentially and/or simultaneously. If transferred sequentially, any of the stacks of eggs in the exit zone **90** are removed first, then eggs nearest the exit zone (e.g., zone **80**) are transferred to the exit zone **90** and so on until eggs from the receiving zone **60** are transferred to the first zone **70**.

By the time the eggs have been finally removed from exit zone **90**, that batch of eggs has been sufficiently chilled in a substantially uniform and rapid manner to a safe storage and/or transportation temperature to avoid growth of pathogens (associated with the eggs) to an unacceptable level for human consumption.

The chilling cycle represents the time from the moment the stacks are enveloped by the chilled liquid until the eggs are finally removed from the chilled liquid for the last time.

During a single complete chilling cycle of at least one batch of stacked layers of in-shell eggs, the temperature of the egg albumin, egg yolk and the intact shell should be sufficiently lowered to maintain the eggs suitable for prolonged storage and subsequent consumption.

During chilling of in-shell eggs, the in-shell egg contents are cooled and thus contract. As a result, if the pores of an in-shell egg are not encapsulated (e.g., in a wax shell) or are not otherwise sealed (e.g., with wax), then during chilling, the chilling liquid and other surrounding materials (e.g., including, but not limited to, pathogens, other micoroorganisms, other contaminants, other chemicals and the like) may be sucked into the in-shell egg through its pores.

Further, Applicants have observed that in-shell eggs readily shed surface liquid (e.g., water and the like) and dry more quickly, if waxed. Alternatively stated, waxed in-shell eggs dry faster than un-waxed in-shell eggs after exposure to a cool chilling liquid. Thus, prior to chilling, the in-shell eggs may optionally be waxed to form an external wax coating around the egg and/or to seal the pores of the in-shell egg. See simultaneously filed co-pending U.S. patent application Ser. No. 09/001,674 (WPB 39609), incorporated herein by reference in its entirety. Further, the waxing of in-shell eggs may be accomplished immediately after or concurrently with pasteurization thereof. See simultaneously filed U.S. patent application Ser. No. 09/002,244 (WPB 39608) and Ser. No. 09/001,677 (WPB 39611), incorporated herein by reference in their entirety, for a description of exemplary pasteurization procedures and equipment.

What is claimed is:

1. A process for chilling in-shell eggs, comprising immersing at least one stack of a plurality of layers of said eggs into at least one cooled liquid until said eggs are cooled to a predetermined temperature by dissipating heat from said eggs to said liquid, wherein said liquid is vertically perturbated by introducing bubbles of gas into an area of said liquid below said immersed eggs.

2. The process of claim **1**, wherein said liquid is vertically perturbated to substantially equalize a temperature of said liquid.

3. The apparatus of claim **1**, wherein said predetermined temperature is at least about 33° F.

4. The process of claim **1**, wherein said bubbles perturbate said fluid along substantially an entire surface of shells of each of said eggs.

5. The process of claim **1**, wherein said at least one stack comprises at least 6 said layers.

6. The process of claim **2**, wherein said at least one stack comprises at least 12 said layers.

7. The process of claim **5**, wherein each of said layers comprises at least 24 said eggs.

8. The process of claim **6**, wherein each of said layers comprises at least 24 said eggs.

9. The process of claim **1**, wherein all of said eggs are substantially uniformly cooled to said predetermined temperature without cracking shells of any of said eggs.

10. The process of claim **9**, wherein said predetermined temperature is below 50° F.

11. The process of claim **10**, wherein said predetermined temperature is below 45° F.

12. The process of claim **11**, wherein said predetermined temperature is below 42° F.

13. The process of claim **1**, wherein said plurality of layers of said eggs are held in a plurality of flats, each flat holding at least one layer of said eggs in cooperation with another vertically adjacent flat.

14. The process of claim **13**, wherein said flats are stacked to form at least one cavity for loosely holding said eggs in said egg layers.

15. The process of claim **14**, wherein said vertical perturbation is provided by introducing said bubbles through said flats, through said layers of said eggs and around an entire surface of each of said eggs.

16. The process of claim **15**, wherein said stacked flats form a plurality of cavities configured to allow said bubbles to propagate through said cavities, through said egg layers and along the entire surface of said eggs in said cavities, and wherein each cavity is sufficient to loosely hold one egg.

17. The process of claim **1**, wherein said eggs are at a pasteurization temperature, and wherein said chilling process stops further pasteurization of said eggs.

18. The process of claim **17**, wherein pores of shells of said eggs are sealed with wax adhesively sealed to said shells before said eggs are immersed in said liquid.

19. The process of claim 1, wherein pores of shells of said eggs are sealed before said eggs are chilled.

20. The process of claim 19, wherein said pores are sealed with wax adhesively sealed to said shells.

21. The process of claim 1, wherein said eggs are immersed in said liquid following washing and grading of said eggs and before refrigerated storage or shipping of said eggs.

22. The apparatus of claim 1, wherein said at least one stack of a plurality of layers of said eggs is immersed in said at least one cooled liquid for one hour or less.

23. An apparatus for cooling in-shell eggs comprising:

a container for holding a liquid bath;

a heat exchanger adapted to cool liquid in said bath to a predetermined temperature below 50° F.; and

a source of bubbles of at least one gas at a lower portion of said bath to provide vertical perturbation of said liquid;

wherein said container is configured to hold at least one stack of a plurality of layers of eggs in said liquid bath.

24. The apparatus of claim 23, wherein said liquid is water and said predetermined temperature is below 45° F.

25. The apparatus of claim 23, wherein said source of bubbles is below a location of a bottom of said stack and is adapted to cause said bubbles to vertically perturbate said liquid along an entire surface of shells of each of said eggs.

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February 17, 2000

Mr. Gregg Clanton
Operations Manager
ISE America, Inc.
3335 Galena Sassafrass Road
Golts, MD 21637

Dear Mr. Clanton:

We understand that you have recently entered into an arrangement with the Davidson Group Shell Egg Corporation, Pasteurized Eggs, L.P. or John Davidson for the production of pasteurized eggs in the shell. We understand this facility will be located in Maryland and the business will be conducted in conjunction with Koffkoff Egg Company.

I would like to remind you that on March 3, 1997 you entered into a confidentiality agreement with Michael Foods. As a result of agreeing to its terms, you received substantial confidential information from Michael Foods which allowed you to assess the feasibility of our pasteurized shell egg process for your business base. You then received sample products from our Wakefield, Nebraska plant in May of 1997.

As you may or may not know, since that time Michael Foods' licensor, the University of Missouri, has received a patent for its process whose claims cover a process for the pasteurization of eggs in the shell. Michael Foods believes that the process that you intend to use may infringe this patent. A copy of the patent is enclosed for your convenience. Please be advised that Michael Foods will vigorously defend its intellectual property rights if necessary.

Please describe to us why you believe that the process you are about to use does not employ the information disclosed by us to you under the confidentiality agreement and why you believe it will not infringe our patent. If you are unable to do so, we request that you do not commence, or discontinue if you have commenced, sale of products produced using the infringing process.

I look forward to your response.

Sincerely,

Jeffrey M. Shapiro
Executive Vice President