UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF NORTH CAROLINA
WESTERN DIVISION

MICHAEL FOODS, INC. and NORTH CAROLINA STATE UNIVERSITY	)))	
	)	CIVIL ACTION NO. _____
Plaintiffs,	))	5:02-CV-559-BO (3)
	)	**COMPLAINT AND JURY DEMAND**
v.	)	
	)	
CUTLER AT ABBEVILLE, L.L.C.	))	
Defendants.	)	

Plaintiffs, Michael Foods, Inc. ("Michael Foods") and North Carolina State University

("NCSU"), by and for its complaint against defendant, Cutler at Abbeville, L.L.C. ("Cutler"),

alleges as follows:

I.   THE PARTIES

1.   Michael Foods is a corporation duly organized and existing under the laws of the

State of Minnesota, having a principal place of business at Minnetonka, Minnesota.

2.   North Carolina State University is a constituent institution of the University of

North Carolina, has its principal place of business at Raleigh, North Carolina, and is an arm of

the State of North Carolina.

3.   Upon information and belief, defendant Cutler is an entity identified as registered

under the laws of the State of Missouri, having a principal place of business at Abbeville,

Alabama and is associated with and the alter ego of Abbeville Egg Products, Inc. and Cutler Egg

Products, Inc., all of Abbeville, Alabama.

II. STATEMENT OF JURISDICTION AND VENUE

4.   This is an action for patent infringement arising under the patent laws of the United States, Title 35 of the United States Code.

5.   The Court has subject matter jurisdiction over this matter pursuant to 28 U.S.C. §§ 1331 and 1338(a).

6.   Upon information and belief, defendant does business in this state generally, has substantial sales of egg products, advertises in trade journals directed to residents and companies in this district, advertises products at issue in this complaint on a web page or web pages, thereby offering such products for sale in this district.

7.   Venue is proper in this Court pursuant to 28 U.S.C. §§ 1391 and 1400.

III. CAUSE OF ACTION FOR PATENT INFRINGEMENT

8.   The invention of United States Patent Nos. 4,808,425; 4,994,291; 4,957,759; and 5,019,408, all reexamination certificates thereto and for Reissued Patent RE37,225E (the "'425," "'291," "'759," "'408" and "'225" or collectively referred to as "the patents in suit," copies provided as Exhibits 1-8) were developed at NCSU in Raleigh, North Carolina by Kenneth Swartzel, Hershell Ball and Mohammad Hamid Samimi.

9.   The patents in suit are owned by NCSU and rights have been licensed to Michael Foods, Inc. and has the right to bring suit for infringement thereof.

10.   On information and belief, Cutler has been, for a time past, and is currently infringing, contributing to the infringement of, and inducing the infringement of directly and indirectly, the patent in suit by, among other things, making, using, selling and/or offering for sale, certain liquid whole egg products within the territorial boundaries of the United States that are covered by one or more claims of the patents in suit.

11.   On information and belief, Cutler's infringement of the patents in suit has been

and is willful, and will continue unless enjoined by this Court. Michael Foods and NCSU have

suffered, and will continue to suffer, irreparable injury as a result of this willful infringement.

Pursuant to 35 U.S.C. § 284, Michael Foods and NCSU are entitled to damages for infringement

and treble damages pursuant to 35 U.S.C. § 283, Michael Foods and NCSU are entitled to a

preliminary permanent injunction against further infringement.

12.   Michael Foods and NCSU have given Cutler notice of said infringement.

Notwithstanding such notice and action by Michael Foods, Cutler has continued to willfully and

deliberately infringe the patents in suit by manufacturing, using and selling liquid whole egg

products made in accordance with the inventions of the patents in suit, in this district and

elsewhere.

13.   On information and belief, Cutler and/or its agents monitored the progress of the

patents in suit during their reexamination and/or reissue. Further, Cutler and/or its agents filed at

least one protest on February 16, 1995 in the reissue proceeding in an effort to impede the

prosecution of the patents.

14.   On information and belief, Cutler and/or its agents collaborated with one or more

third parties in the filing of at least one of the third party requests for reexamination or protest of

the NCSU patents.

15.   This case is exceptional and, therefore, Michael Foods and NCSU are entitled to
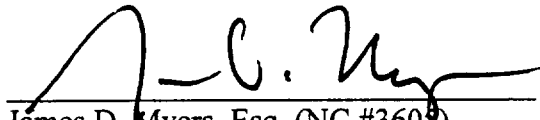
attorneys' fees pursuant to 35 U.S.C. § 285.

IV.   DEMAND FOR JURY TRIAL

16.   Plaintiffs Michael Foods and NCSU demand a trial by jury on all disputed issues.

WHEREFORE, Michael Foods and NCSU pray for relief as follows:

V. PRAYER FOR RELIEF

A. That Cutler be adjudged to have infringed the patents in suit;

B. That Cutler, their officers, agents, servants, employees, attorneys, and those persons in active concert or participation with any of them, be preliminarily permanently restrained and enjoined from directly or indirectly infringing the patents in suit;

C. An accounting for damages by virtue of Cutler's infringement of the patents in suit;

D. An award of damages to compensate Michael Foods and NCSU for Cutler's infringement, pursuant to 35 U.S.C. § 284, said damages to be trebled because of Cutler's willful infringement.

E. An assessment of pre-judgment and post-judgment interest and costs against defendants, together with an award of such interest and costs, in accordance with 35 U.S.C. § 284;

F. That Cutler be directed to pay Michael Foods and NCSU's attorneys' fees incurred in connection with this lawsuit pursuant to 35 U.S.C. § 285; and

G. That Michael Foods and NCSU have such other and further relief as this Court may deem just and proper.

This 12th day of August 2002.

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United States Patent [19]

Swartzel et al.

[11] Patent Number: 4,808,425
[45] Date of Patent: Feb. 28, 1989

[54] METHOD FOR THE ULTRAPASTEURIZATION OF LIQUID WHOLE EGG PRODUCTS

[75] Inventors: Kenneth R. Swartzel; Hershell R. Ball, Jr.; Mohammad-Hossein Hamid-Samimi, all of Raleigh, N.C.

[73] Assignee: North Carolina State University, Raleigh, N.C.

[56] References Cited

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E. O. Essary, P. R. Rony and W. F. Collins, New Uses of Heated Aseptically Packaged Fluid Egg Products.

Laura C. Jacobs, Aseptic Packaging Promises New Role for Pasteurized Liquid Eggs.

M. H. Hamid-Samimi and K. R. Swartzel, Journal of Food Processing and Preservation 8, 219 (1984).

Kenneth R. Swartzel, Journal of Agricultural and Food Chemistry, 34 396 (May/Jun. 1986).

Abstract concerning Poultry Science Association Annual Meeting, Jul. 29–Aug. 2, 1985, Iowa State University, Ames.

Mohammad-Hossein Hamid-Samimi, Thesis: Criteria Development for Extended Shelf-Life Pasteurized Liquid Whole Egg (1984).

Primary Examiner—Donald E. Czaja
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[57] ABSTRACT

Methods of ultrapasteurizing liquid whole egg products in continuous flow, high temperature, short time pasteurization equipment are provided. The equivalent point method is preferably used to evaluate the total thermal treatment received by the product in this equipment. Also disclosed is a method of making liquid whole egg products having preselected, extended, refrigerated shelf lives.
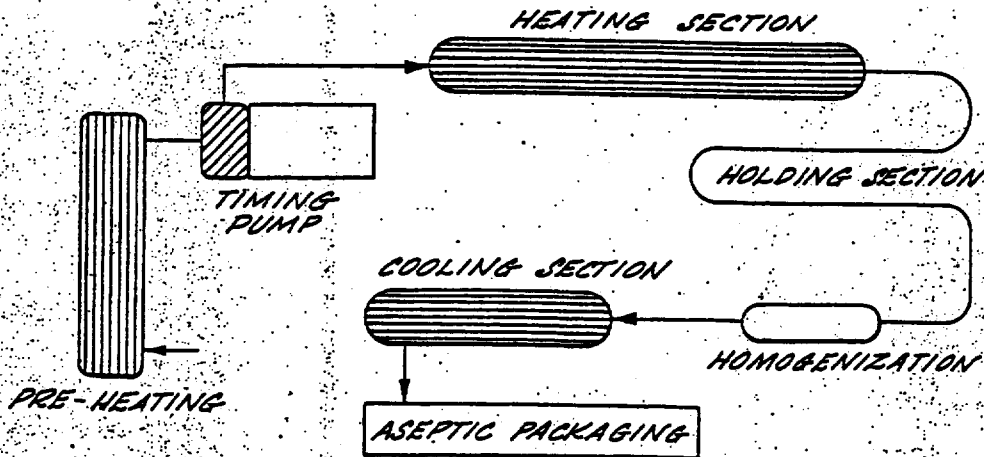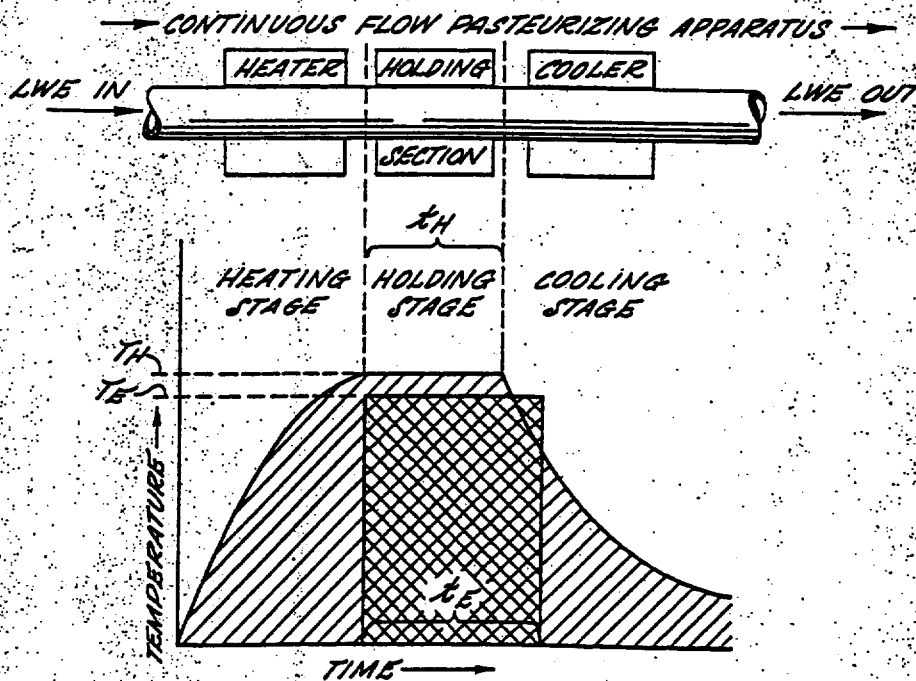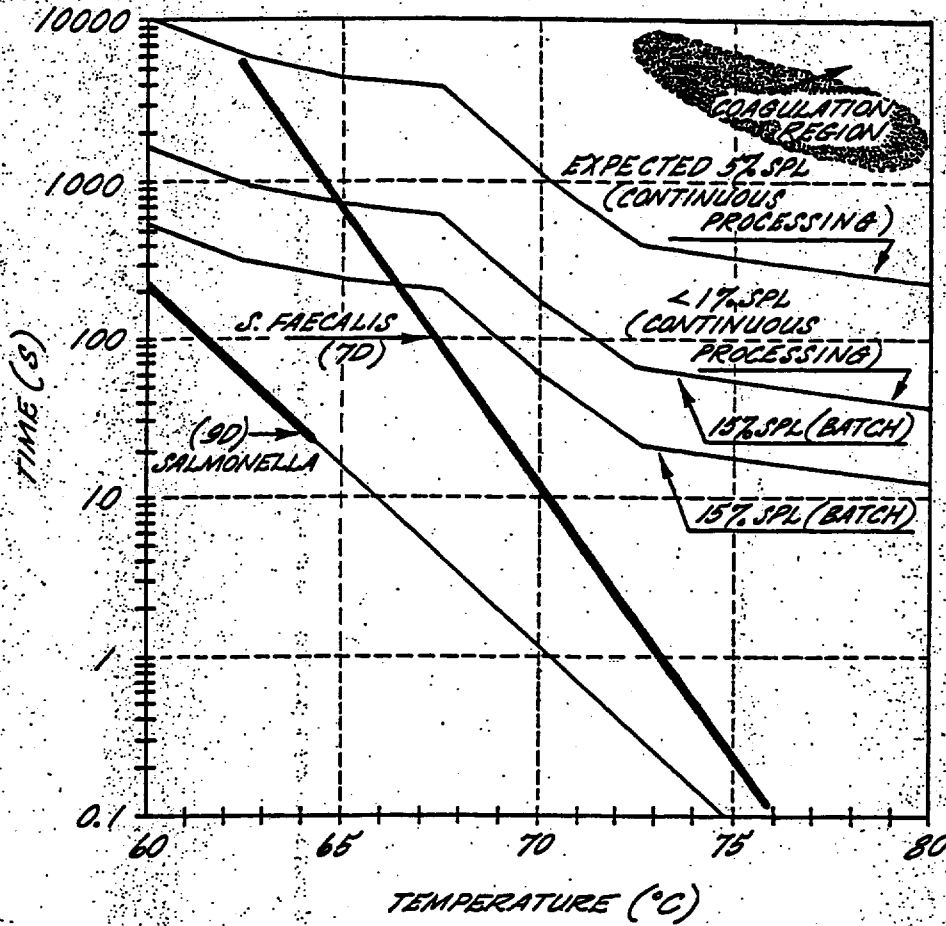
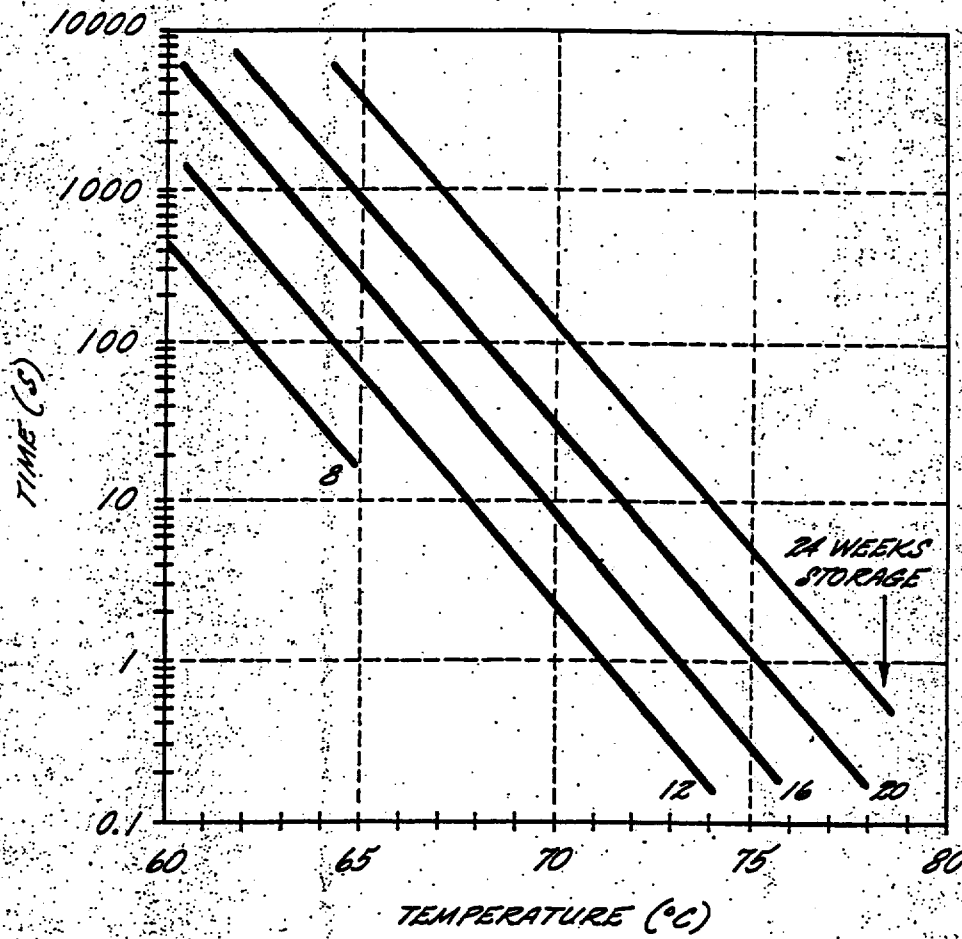26 Claims, 4 Drawing Sheets
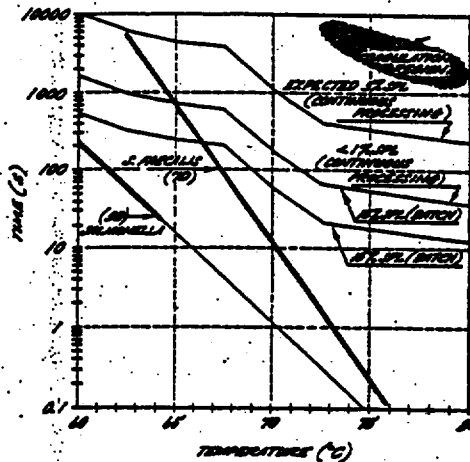
Fig. 1.

Fig. 2.

FIG. 3.

FIG. 4.
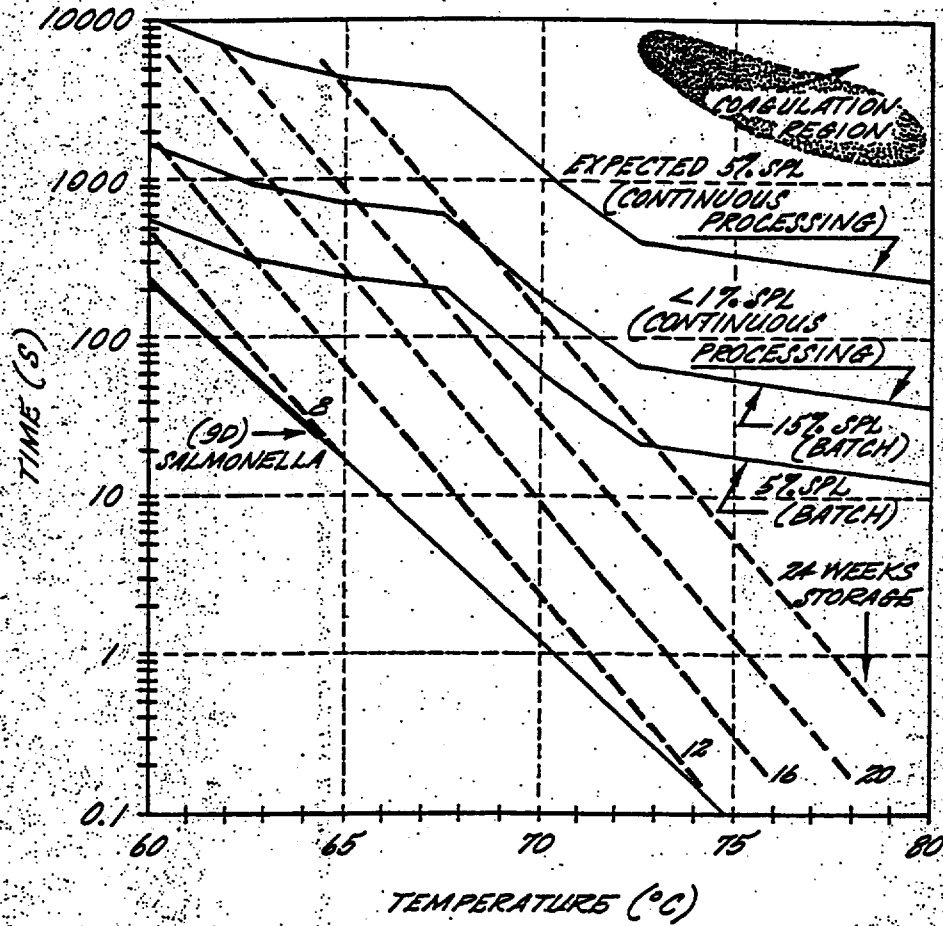
Fig.5.

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METHOD FOR THE ULTRAPASTEURIZATION OF LIQUID WHOLE EGG PRODUCTS

DESCRIPTION OF THE INVENTION

The present invention relates to the pasteurization of liquid whole egg products generally, and particularly relates to ultrapasteurization methods which can be used to produce liquid whole egg products which have good functional properties and which have extended refrigerated shelf lives.

BACKGROUND OF THE INVENTION

The U.S. egg industry produced more than 300 million pounds of frozen pasteurized egg products in 1985. The relatively mild pasteurization processes used are designed to eliminate Salmonella from eggs for all practical purposes, but do not destroy organisms capable of spoiling egg products held under refrigerated temperatures above freezing. The survival of spoilage organisms in pasteurized egg, coupled with conventional packaging technology, results in products with limited shelf life (7–14 days at 40° F.) that require freezing and frozen distribution systems for preservation. Freezing is cost intensive, lowers the functional quality (flavor, performance, etc.) of the egg product, and results in an inconvenient product that requires thawing prior to use.

Standard pasteurization practices for liquid whole egg products are generally discussed in the *Egg Pasteurization Manual* (USDA Agricultural Research Service 1969). See also U.S. Pat. No. 3,949,099 to Kaufman, at column 1, lines 46–58 (summarizing pasteurization processes). The *Egg Pasteurization Manual* notes that experiments conducted in England to establish treatment conditions used there, which were carried out in a high temperature, short time pasteurization unit, included trials with holding times of two and one-half minutes and temperatures up to 151 degrees Fahrenheit (66.1 degrees Centigrade). The functional quality of these eggs is not discussed; however, it is noted that England adopted a lower temperature of 148 degrees Fahrenheit as a treatment condition. The Manual observes that such "severe" treatments help increase the stability of egg products in liquid form, but does not teach how this can be accomplished without sacrificing desirable functional properties of the products. For other types of egg products which are more heat stable, pasteurization temperatures as high as 152 degrees Fahrenheit (66.67 degrees Centigrade) have been reported. Again, little is known about how to ultrapasteurize (decrease the number of spoilage microorganisms to levels lower than obtained with a pasteurization procedure) these products by heating without sacrificing functional performance.

Higher temperatures than those investigated in England have been explored. See e.g., Essary, E. O., Rony, P. R., and Collins, W. F., *New uses of heated aseptically packaged fluid egg products*, Report to the American Egg Board (1983). This work suggested that merging techniques of ultrapasteurization with aseptic packaging can be accomplished to yield safe, stable, and functional liquid whole egg. This research suggested and used a heat exchanger operated in laminar flow to process whole egg at elevated temperatures, and used an ethylene oxide-flushed glove box to aseptically package the product (neither device approved for the commercial production of a salable product). Holding temperatures of up to 154 degrees Fahrenheit (67.8 degrees

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Centigrade) were reported. The results of this pioneering work demonstrated the possibility of extending the refrigerated shelf life of liquid whole egg products, but did not enable the commercial production of a refrigerated product which could be sold to consumers.

To carry out ultrapasteurization of liquid whole egg products on commercial equipment, the time and temperature parameters of the thermal treatment must be selected with care. Arbitrary increases in thermal treatment will likely produce a functionally unacceptable product, or—even worse—coagulation of the product and blockage of the pasteurizing equipment. Because such pasteurizing equipment operates at high pressures (e.g., 1,500 p.s.i. and more) the consequences of blockage are serious. For these reasons, it is essential to know how liquid whole egg products respond to various thermal treatments before experimenting with the production of these products on commercial equipment.

Because this essential information was not available, Hamid-Samimi investigated the time and temperature parameters which should be used in commercial equipment to obtain a functionally acceptable, ultrapasteurized, liquid whole egg product. M. H. Hamid-Samimi, Criteria Development for Extended Shelf-Life Pasteurized Liquid Whole Egg. Ph.D. Thesis, North Carolina State University (1984). This research was carried out at the laboratory bench, with a Brookfield viscometer, which processed the product in small batches rather than continuously. Processing times and temperatures defining thermal treatments producing a soluble protein loss (SPL) of up to 5% from the product, as an upper limit, were suggested as producing a functionally acceptable product. The suggested 5% SPL limit was defined by a graph line in the thesis: this line is reproduced herein in FIG. 3 as the 5% SPL (Batch) line. Time and temperature values tested by other investigators which were believed to be the limits of pasteurization are summarized in M. H. Hamid-Samimi and K. R. Swartzel, *J. Food Processing and Preservation* 8: 219, 221 FIG. 1 (1984). All are below the 5% SPL (Batch) line.

The present inventors sought to test the predictions of Hamid-Samimi by ultrapasteurizing liquid whole egg on continuous flow, high temperature, short time pasteurization equipment. It was unexpectedly found that functionally acceptable liquid whole egg can be produced at times and temperatures greater than previously believed. These findings, which will be explained in detail below, enable the commercial production of functionally acceptable products with longer refrigerated shelf lives than heretofore available. As will also be explained below, discovery of these unexpected results has led to the identification of several steps which should be taken to produce ultrapasteurized liquid whole egg products that have superior functional properties.

The object of the present invention, in short, is to provide liquid whole egg products for refrigerated distribution which have greatly reduced levels of spoilage microorganisms, while still having good functional properties.

SUMMARY OF THE INVENTION

This object is achieved by a method for ultrapasteurizing liquid whole egg products. The method comprises passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is heated to a pre-

determined real temperature. The method is practiced so that the total thermal treatment received by the liquid whole egg product is described by an equivalent temperature and an equivalent time (these terms are explained in detail below) defining a point above the 5% SPL (Batch) line of FIG. 3, but insufficient to cause coagulation of the product.

Also disclosed herein is a method of making a packaged liquid whole egg product characterized by a preselected refrigerated shelf life of from about four weeks to about 36 weeks. This method comprises passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is heated for a predetermined time and to a predetermined temperature. The predetermined time and the predetermined temperature are chosen to impart the preselected shelf life to the liquid whole egg product. After it is heated, the liquid whole egg product is aseptically packaged.

Preferably, the continuous stream of liquid whole egg product referred to in each of the methods above is at least periodically subjected to turbulence while it is heated. The liquid whole egg products are also, preferably, homogenized after they have been heated. In addition, the methods described above are more narrowly described as methods in which the liquid whole egg product is heated to a predetermined holding temperature, then maintained at said predetermined holding temperature for a predetermined holding time, and then cooled.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of a continuous flow pasteurizing apparatus suitable for carrying out the present invention.

FIG. 2 is a diagram illustrating the differences and relations between real holding times and holding temperatures, and equivalent times and equivalent temperatures for describing total thermal treatments, in continuous flow pasteurizing equipment.

FIG. 3 is a graph showing time and temperature regions for the ultrapasteurization of liquid whole egg products.

FIG. 4 is a graph showing equivalent times and equivalent temperatures that give particular refrigerated shelf lives for liquid whole egg.

FIG. 5 is a combination graph in which FIGS. 3 and 4 are superimposed, with the *S. faecalis* line removed.

DETAILED DESCRIPTION OF THE INVENTION

Thermal treatments simultaneously produce beneficial and undesirable changes in food products. Knowledge of kinetic methods, and how they can be applied to the mechanics of designing a thermal process, aids in attaining food quality retention and process efficiency. Determining the time and temperature requirement for a thermal process depends upon destruction of spoilage and disease causing microbial spores while minimizing undesirable physical, chemical and biological transformations that occur within the product.

As schematically shown in FIG. 1, with arrowheads indicating direction of flow, continuous flow thermal processing equipment comprises heating, holding, and cooling sections. The thermal treatment received by the product in the heating and cooling stage, (illustrated in FIG. 2), is oftentimes not considered: instead, only the holding time (t_H) and holding temperature (T_H) are considered. However, when products are pasteurized in such equipment at higher temperatures and shorter times, as is taught herein, the contribution of the heating stage, and perhaps the cooling stage, to the total thermal treatment of the product becomes significant, and must be accounted for if a product with good functional qualities is to be obtained and coagulation during pasteurization is to be avoided. It is accordingly recommended that the equivalent point method for evaluating thermal treatments be applied in practicing the present invention. As explained in detail below, this method describes the total thermal treatment received by a product in continuous flow equipment with one equivalent time (t_E) and one equivalent temperature (T_E) (see FIG. 2).

Procedures for use of the equivalent point method for analyzing the thermal effects on products during continuous flow heating have been previously outlined (Swartzel, 1982, *J. Food Sci.* 47:1886 and Swartzel, 1986, *J. Agric. Food Chem.* 34:397) and are known to those skilled in the art. This method differs substantially from previous methods in that all other methods define the thermal treatment based upon a single factor such as enzyme inactivation, microbial destruction, protein denaturation, nutrient loss, etc. The problem with these other methods is that a physical and/or chemical effect (flavor, color, product separation and gelation during storage if thermally related) may actually be the shelf life limiting factor.

The unique feature of the equivalent point method lies in the fact that, for any thermal curve, one equivalent time and equivalent temperature combination exists (see FIG. 2). This equivalent time and temperature combination will yield the exact thermal effect on all constituents within the product as would the original thermal curve. This unique time and temperature combination is not dependent on individual constituent kinetics, as are all previous thermal evaluation procedures (it is independent of constituent activation energy).

To determine the equivalent point of a thermal system, a complete thermal history of the treatment must be available. This is obtained by measuring mixed mean product temperatures at various locations (entrance to the heat exchanger, exit of the heat exchanger and at least two locations inside the heat exchanger). Time is calculated by correlating mean residence time with location of the temperature probe. With heat exchangers into which it is difficult or impractical to insert thermal probes, time-temperature curves are calculated based on knowledge of the product's physical characteristics and on the geometry of the processing equipment.

With available time-temperature curves and a basic knowledge of kinetic relationships, equivalent points can routinely be calculated. The log of a product constituent concentration ratio (initial concentration divided by concentration after treatment) is set equivalent to the integration of that constituent's Arrhenius equation (or any other appropriate function describing the temperature dependency of the rate of the reaction associated with the constituent change) for the particular time-temperature interval (thermal history previously defined). For a given activation energy each section of a thermal treatment (heating, holding, and cooling) will produce a unique thermal constituent concentration ratio. For the different sections the effect may be summed. For the original activation energy selected, a linear infinite log (time)-temperature relationship exists.

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Any and all of these infinite time and temperature combinations would produce the same thermal effect on a constituent (with the same activation energy) as during the original thermal treatment. By reexamining the original thermal curves with different activation energies a series of infinite linear log (time)-temperature relationships are developed (one line in a log (time)-temperature plot per activation energy). Uniquely all lines intersect at one point. This unique time-temperature is the equivalent point for the original thermal curve. It accounts for all thermal treatment and is used to accurately predict constituent change, or product characteristic.

FIG. 3 sets forth thermal treatments which should be used to ultrapasteurize liquid whole egg products. Thermal treatments defined by points above the 5% SPL (Batch) line have not heretofore been suggested. For practicing the present invention in continuous flow processing equipment, the thermal treatment is described by a point on FIG. 3 defining an equivalent time and an equivalent temperature, as explained above. The thermal treatment should be more than sufficient to pasteurize the liquid whole egg product. "Pasteurize" means to cause a nine log cycle (9D) or 99.9999999% reduction in Salmonella in the product being treated. The thermal treatment should be insufficient to cause the liquid whole egg product to coagulate. The thermal treatment should more particularly cause not more than a 15% soluble protein loss (SPL) in the liquid whole egg product being treated, and will preferably cause not more than a 5% soluble protein loss in the product being treated. The expected 5% SPL (continuous processing) line on FIG. 3 indicates approximately the upper limit on thermal treatments which can be tolerated without sustaining more than a 5% soluble protein loss (the exact location of this line for any one process will depend on the physical factors discussed below). More preferably, the thermal treatment will be designed to produce not more than about a 1% soluble protein loss from the product. As shown in FIG. 3, equivalent times and equivalent temperatures defining points along the line previously believed to represent the line at which a 15% soluble protein loss would be obtained (the 15% SPL (Batch) line), are now known to represent thermal treatments which produce ultrapasteurized products having less than a 1% soluble protein loss under continuous flow.

The line defining thermal treatments causing a seven log cycle reduction in the spoilage bacteria Streptococcus faecalis is labeled in FIG. 3 as the S. faecalis (7D) line. The S. faecalis line has a steeper slope than the several SPL lines. This illustrates that thermal treatments employing higher temperatures and shorter times are preferred for practicing the present invention. Thus, holding soluble protein loss constant (so that treatment time must be decreased as treatment temperature is increased), thermal treatments in which the product is subjected to treatment temperatures of about 67.0 degrees Centigrade or more are preferred to thermal treatments in which the product is subjected to treatment temperatures of 65° C.; treatment temperatures of about 69.0° C. or more are preferred to treatment temperatures of 67° C.; treatment temperatures of about 71.0° C. or more are preferred to treatment temperatures of 69° C.; treatment temperatures of about 73.0° C. or more are preferred to 71° C.; and so on. The foregoing statement is true whether the real temperatures (or holding temperatures) of the processes are being compared, or

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equivalent temperatures are being compared (thus the term "treatment temperature" is used to encompass both).

Treatment temperatures are primarily limited by the ability to accurately time the duration of the thermal treatment: as temperature is increased the treatment time must be decreased, and shorter treatment times are more difficult to administer with precision. Generally, equivalent temperatures not more than about 90° C. are preferred, and equivalent temperatures not more than about 80° C. are more preferred.

Desirable thermal treatments for practicing the present invention can also be described with reference to the S. faecalis lines. Preferably, the thermal treatment will define a point above the S. faecalis (7D) line, and more preferably the thermal treatment will define a point above the S. faecalis (9D) line. While this latter line is not plotted in FIG. 3, it can be plotted in accordance with the equations given below.

Equations for lines in the figures are as follows, where t=time in seconds, T=temperature in degrees Centigrade, and n=number of decimal reductions. Salmonella line: $\log(t)=15.96-0.227(T)$. S. faecalis lines: $\log(t)=24.62+\log(n)-.346(T)$. % SPL lines: $\log(t)=\log(\%SPL)+a-b(t)$, where a and b are given in Table 1 below:

TABLE I

T range °C.	a (for Batch lines)	b	a (Expected) (for continuous flow lines)
60–62.5	7.494	0.091	8.761
62.5–67.5	4.103	0.037	5.370
67.5–72.5	14.68	0.194	15.942
72.5 and above	3.014	0.033	4.281

These equations can be used to extend the teaching of the figures beyond their depicted scope.

The liquid whole egg product is preferably heated by contacting the product to a heated surface. The heated surface is comprised of a corrosion-resistant, nontoxic and nonabsorbent material such as stainless steel. Standards for evaluating the acceptability of such product contact surfaces (the 3-A Sanitary Standards) are known and established. See, e.g., Egg Pasteurization Manual, supra, at 27.

To obtain a product with reduced amounts of spoilage microorganisms, the pasteurizing apparatus should be sterilized before the liquid whole egg product is passed therethrough. Sterilizing is preferably accomplished by passing hot water under pressure through the pasteurizing apparatus, as is known in the art, so that, among other things, hot water is contacted to the heating surface at a temperature and pressure and for a time sufficient to sterilize the heating surface.

In addition, the product, after ultrapasteurization, should be aseptically packaged. Aseptically packaged means packaged to the exclusion of microorganisms other than those carried by the liquid whole egg product. Equipment suitable for aseptically packaging liquid whole egg products is commercially available.

FIG. 4 illustrates the refrigerated shelf life of liquid whole egg after it is ultrapasteurized and aseptically packaged, as explained above. The term "refrigerated," as used herein, means stored at a temperature of 4° C. Time and temperatures for points on each line represent equivalent times and temperatures, as also explained above. A liquid whole egg product having a preselected

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shelf life of from about 4–36 weeks is made by selecting a point on a line or in a region which will provide the desired shelf life, determining the equivalent time and equivalent temperature which correspond to the point selected, and—preferably through the use of the equivalent point method—establishing the operating conditions on the particular pasteurizing apparatus being used that will provide the selected thermal treatment. Products having shelf lives not depicted in FIG. 4 are made by extrapolating the teachings of the figure, in light of the teachings above. Preferably, this process is carried out in pasteurizing apparatus which has been sterilized before the liquid whole egg product is passed therethrough, as explained above, to produce products having shelf lives of about eight weeks or more. In addition, it will be appreciated that longer shelf lives are generally obtained at the expense of greater levels of soluble protein loss. Thus, if product distribution systems do not require otherwise, products with shelf lives of up to about 32 weeks are preferred, and products with shelf lives up to about 24 weeks are more preferred.

FIG. 5 combines portions of FIGS. 3 and 4. It shows how the thermal treatments selected to provide a desired shelf life can at the same time be selected to provide products with good functional properties. More particularly, thermal treatments can be selected which produce liquid whole egg products having the desired shelf life and a soluble protein loss not greater than 5%.

The foregoing graphs have been presented to aid the understanding of the present invention. Some variation about the plotted lines is to be expected when the present invention is practiced on different equipment, or with different products. These graphs are accordingly not to be taken as limiting the present invention, as departures could be made therefrom while still capturing and benefitting from the teachings of the invention.

To obtain a superior ultrapasteurized liquid whole egg product, the contact time of the liquid product to heated surfaces during pasteurization should be reduced. More particularly, every particle of liquid whole egg product should be in contact with the heated surface or surfaces of the unit in which the product is heated for a total time less than the residence time of the particle in the heating unit. (The term "particle" as used herein has its standard meaning in the egg pasteurization field. See, e.g., 7 C.F.R.§59.570(b) (1985)). This is accomplished by mixing the product at least periodically while it is being heated. In a continuous flow pasteurizing apparatus, such mixing is accomplished by introducing turbulence into the stream of the product at least periodically while it is being heated, as discussed below. Other steps which are preferably employed to reduce fluid element contact time to heated surfaces include providing portions of the thermal treatment in which fluid elements are not in contact with heated surfaces, such as by providing a portion of the thermal treatment in a holding section, and by providing heated contact surface area to product volume ratios of less than 18 cm²/cm³ (Thus the surface area to volume ratio is preferably less than about 10, and is more preferably in the area of about 2).

It is also desirable to induce physical forces to make the product more homogeneous prior to thermal treatment, such as by inducing shear forces capable of reducing protein and fat unit size. This is preferably accomplished by dispersing the product prior to heating. Dispersing may be carried out with dispersing valve or with a timing pump, as is known in the art. Such treat-

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ment advantageously reduces fouling, and serves to reduce any tendency of the product to coagulate. Such a dispersing step may be carried out by conducting a more rigorous homogenization step, but it is recommended that such more expensive homogenizing equipment be used as described below.

It is preferable that a homogenization step after heating be included. The term "homogenized," as used herein, means to subject the product to physical forces to reduce particle size. Such procedures are known in the art, and may be carried out on different types of equipment. It is preferable to carry out this homogenizing step with homogenizing equipment at total pressures of about 1,000 p.s.i. or more. Pressures of about 1,500 p.s.i. or more are more preferred, and pressures of 2,000 p.s.i. or more are still more preferred.

Of these steps, it is particularly desirable to mix the liquid whole egg product at least periodically while it is heated. As noted above, in continuous flow equipment mixing is carried out by at least periodically subjecting the stream of liquid whole egg product to turbulence while it is heated. Turbulence, which is the mixing of particles over the cross-section of the product stream, is discussed in the *Egg Pasteurization Manual* at pages 6–8. Such turbulence is characterized by a Reynolds number greater than about 2,300, and preferably greater than about 4,600. Commercial high temperature, short time pasteurizing units are available which at least periodically impart turbulence to the stream of product being pasteurized while the product is being heated. For the purposes of the present invention, greater levels of turbulence are preferred. Thus the liquid whole egg product is preferably subjected to turbulence for a major portion of the time it is heated. Plate heat exchangers, trombone heat exchangers, spiral heat exchangers, and scrape surface heat exchangers are illustrative of the types of known heat exchangers which can be used to subject liquid whole egg products to turbulence while they are heated. The physical forces induced in scrape surface heat exchangers are generally thought of as "mixing," but these exchangers induce turbulence at least in regions of the product stream, and are therefore considered to induce turbulence for purposes of the present invention.

Examples of whole egg products which can be pasteurized in liquid form by the method of the present invention include whole egg, fortified whole egg (whole egg with added yolk), salt whole egg (e.g., salt 10%), sugar whole egg (e.g., sugar 10%), blends of whole egg with syrup solids, syrups, dextrose and dextrins and/or gums and thickening agents, blends of whole eggs with less than 1% sugar and/or salt, scrambled egg mixes (for example, a mix of about 51% egg solids, 30% skim milk solids, 15% vegetable oil and 1.5% salt), reduced cholesterol egg products and blends thereof, custard blends, and the like. Products which are extremely sensitive to thermal processing and which are particularly suitable for ultrapasteurization by the present invention include, for example, liquid whole egg and blends thereof (less than 2% added nonegg ingredients), fortified whole egg and blends thereof (24–38% egg solids, 2–12% added nonegg ingredients), liquid salt whole egg, liquid sugar whole egg, and other liquid whole egg blends which are 24–38% egg solids and 12% or less of added nonegg ingredients. Terms used herein have their standard meaning in accordance with industry and regulator usage. See, e.g., 7 C.F.R.§59.570(b) (1985).

The invention having been explained in general terms above, the following examples are provided to further illustrate the invention.

EXAMPLES 1–10

Raw Egg Product. Raw liquid whole egg was obtained from a local breaking plant (Gold Kist, Durham, N.C.). The egg was taken from their raw holding tank which was agitated to thoroughly blend approximately 30,000 pounds of egg. The egg was manually filled into 13.6 kg (30 lb) metal cans and were kept refrigerated before being transported 13.2 km (20 mi) to our laboratory in an insulated truck. The egg was held overnight at 4° C. (40° F.) or allowed to stand at room temperature for up to 12 hours to achieve higher bacterial numbers.

Thermal Processes. The time-temperature processes used in this study were designed to be equal to or more severe than minimum conditions defined by the 9D line for the destruction of Salmonella in whole egg (USDA, 1969) and within predetermined limits of denaturation of egg protein defined as percent soluble protein loss (%SPL) by Hamid-Samimi et al., *J. Food Sci.* 49:132 (1984). The objectives of this design were to provide Salmonella negative whole egg with a low number of surviving spoilage organisms while retaining adequate functional properties.

The thermal processing system used is outlined in FIG. 1. It consisted of a plate-type heat exchanger for preheat, various modifications of the No-Bac Unitherm model XLV (Cherry Burrell Corporation, Cedar Rapids, Iowa) to achieve different holding times, an aseptic homogenizer operated at 10.34 mPa (1,500 p.s.i.), and an aseptic packaging system (Model AB-3-250, Tetra Pak Inc., Dallas, Tex.). The flow rate was $2.89 \times 10^{-4} m^3$/sec. (275 GPH) with heating, holding, and cooling pipe diameters of 12.45 mm ID (½" nominal) stainless steel.

Before each process the entire system was sterilized at 121° C. for 30 minutes using hot water in the product section and steam in the heating media section and then cooled. The product and heating media temperatures were recorded for evaluation of the thermal effect of the heating section and to determine the total thermal effect. Swartzel, *J. Agri. Food Chem.* 34:396 (1986). The temperatures were measured using Type T thermocouples with an electronic data logger (Model 9302, Monitor Labs., Inc., San Diego, Calif.). Each thermocouple probe was scanned every 30 seconds (one minute for process #1) and the readout sent to a computer for analyses. The specific locations of the thermocouples in the system were as described by Swartzel and Jones. Paper No. 84-6006 of the American Society of Agricultural Engineers (1984).

Approximately one hour prior to initiation of each process, 408.2 kg (900 lb) of raw egg were transferred from the metal cans to a 568.1 (150 gal) vessel (Creamery Package Mfg. Co., Chicago, Ill.) and then mixed at room temperature with the stirring propeller at ca. 30 r.p.m. This volume of egg required approximately 20 minutes to process, therefore the last liter of egg was processed not later than 80 minutes after being removed from the cooler. Nine processes designated 1, 2, 3, 4, 5, 6, 7, 8, and 9 were run. Process 6 was repeated and designated 6.1. They were conducted two days apart on egg picked up on the same day. Egg for processes 6.1 to 9 were held at room temperature for not more than 12 hours to achieve a higher initial microbial load. All egg

incubated at room temperature was chilled to 4° C. (40° F.) prior to processing.

After holding the egg at the scheduled process time and temperature and prior to packaging, the temperature was reduced to less than 10° C. (50° F.) in less than 26 seconds. Occasionally, due to technical difficulties it was not possible to cool the processed egg to below 10° C. In those instances the processed egg was moved into a freezer at −20° C. for 20 minutes after packaging. The packaging material was a low oxygen permeable laminate of polyethylene, paper, and aluminum foil formed into 250 ml containers (Tetra pak aseptic filler model AB-3). Each package was dated and coded so that egg processed in the first seven minutes, the second seven minutes, and the remaining time were numbered 1, 2, and 3, respectively. The processed and packaged egg was held overnight at 4° C. (40° F.) prior to obtaining samples and being distributed for four and 10° C. storage.

Sampling. Samples of raw egg for physical, chemical, and functional testing were aseptically removed from the mixing vat approximately 30 minutes prior to processing. The samples were then held overnight at 4° C. for evaluation with the pasteurized egg. Pasteurized samples were obtained on the day after processing or at selected times during storage at four and 10° C. Analyses were made on the combined contents of three or four individual packages representing the first, second, and third portions of each process run. When four packages were required, two packages from the middle portion of each process were used. Any sediment on the bottom of the cartons was scraped out and mixed into the egg by magnetic stirring.

Chemical Assays. The pH of the product was determined with a Fisher Accumet pH meter, model 600, equipped with a calomel reference and glass indicating electrodes. Solids were determined in triplicate by weighing two ml samples into disposable aluminum pans and drying in a forced draft oven for 24 hours. The AOAC (1985) microKjeldahl procedure was used to determine protein content of the samples. The extent of denaturation was estimated by determining the loss of soluble protein as described by Hamid-Samimi et al., supra, and the alphaamylase activity of the egg was determined as described by Shrimpton and Monsey, *J. Hyg.* 60:153 (1962).

Sponge Cakes. True sponge cakes were made by using half of the amounts of ingredients listed following the procedures given by Gorman and Ball (1986) (Chapter 15 in *Egg Science and Technology*, 3rd Ed., W. J. Stadelman and O. J. Cotterill, Eds., AVI Publishing Co., Inc. Westport, Conn.) with the omission of vanilla. Two separate batches of batter were mixed for each treatment and 340 g of batter was weighed into rectangular pans (21.5 × 11.5 × 6.5 cm, id.). Cakes were baked at 191° C. for 25 minutes, inverted on a wire rack and allowed to stand at room temperature overnight. Heights were determined from the mean of four measurements along the center line of the long axis of the cake. Cakes were then kept in plastic bags for further rheological evaluations.

Textural properties of the cakes were evaluated using an Instron Universal Testing Machine (Model 1122, Instron Engineering Corporation, Canton, Mass.). A plate was connected to a 2000-g load cell and positioned at the surface of the 5-cm cube of cake. The cross head and chart speeds were 200 mm/min and 100 mm/min, respectively. Three samples from each cake were sub-

jected to deformation-relaxation cycles. The cubed cake samples were kept in a plastic bag before and after each test. The water activity of the cake samples were determined by placing three Durotherm (Lufft, West Germany) water activity meters in the plastic bag. Each meter was calibrated daily with a solution of barium chloride (aW 0.90 at 20° C.).

Custards. Duplicate custards of the flan type were made. Ingredients were 190-ml evaporated milk, 196-g sweetened condensed milk, 125-g whole egg, 50-g water, and one teaspoon vanilla. All ingredients were blended in a Waring blender at low speed for one minute and 360-g were weighed into a rectangular pan (14.3×8.0×5.6 cm, id.) which had been sprayed with "PAM" (Boyle-Midway, Inc., New York, N.Y.). Pans were placed in a tray containing 2.5-cm water and baked at 191° C. for 40 minutes. After overnight storage at 10° C., height of the custard in the pan was determined from the mean of three measurements made and with calipers along the center line of the long axis of the custard. Custards were removed from the pan after the sides were loosened with a spatula and allowed to stand at room temperature for 45 minutes. Height was again determined and percent sag was calculated according to Gardner et al. Poultry Sci. 61:75 (1982). Custards were stored in plastic bags at 10° C. for rheological evaluation.

The flat plate described above for evaluation of cake texture was replaced with a 10.5 mm diameter rod with a semispherical tip and force-deformation curves to failure were obtained for each custard. Cross head speed was 100 mm/min and all other parameters were the same as used in evaluations of the cakes. Five values were averaged to obtain the penetration force (F1) for each custard.

Organoleptic Evaluation. Flavor of processed and stored egg was evaluated by one judge using the USDA palatability score (Laboratory Methods for Egg Products, UDSA, Agricultural Marketing Service Poultry Division, Grading Branch, Washington, D.C. 20250 (1984)).

Thermal Process. The process times and temperatures used in this study are presented in Table 2.

TABLE 2

Actual, Equivalent Times and Temperatures, Calculated Heating Value of Treatments and Predicted % SPL Based on Heating Value.[e]

Proc. No.	Actual		Equivalent		Heating Value[b] (G × 10[G])	Theoretical % SPL[c]
	Time (Sec.)	Temp. (°C.)	Time (Sec.)	Temp. (°C.)		
1	26.2	63.7	30.4	63.1	6.1	0.52
2	92.0	63.8	97.5	63.3	20.8	1.74
3	192.2	65.3	192.4	65.1	72.8	5.97
4	9.2	67.8	15.7	66.5	8.4	0.71
5	56.9	68.2	63.0	67.5	44.6	3.70
6	123.0	68.3	125.5	67.9	99.4	8.10
6.1	123.0	68.9	129.0	68.4	117.6	9.50
7	2.7	71.5	9.5	68.5	8.9	0.75
8	30.1	71.2	36.5	71.5	78.9	6.46
9	56.7	72.0	62.5	71.8	146.8	11.70

[a]See Swartzel, J. Food Sci. 47:1886 (1982), and Hamid-Samimi et al., supra (1984) for descriptions of heating value and % SPL.
[b]G values are determined based on activation energy for SPL.
[c]Based on laboratory batch data.

The 10 processes, numbers 1-9, were performed in the same chronological order as they are numbered. After gaining process experience and as the result of evaluations during the study, it was determined that longer holding times and temperatures than expected could be used. The actual temperatures reported in Table 3 are the averages of temperature readings, every 30 seconds,

of the temperature probes at the beginning and end of the holding tube.

Equivalent times and temperatures as well as holding times and temperatures are set forth in Table 2. It can be seen that equivalent times are generally longer than the corresponding holding times, and equivalent temperatures are generally lower than the corresponding holding temperatures. At longer times, the differences between corresponding holding temperatures and equivalent temperatures are smaller.

The calculated heating value, G, shown in Table 2, gives a means for making a comparison of the relatively severity of the different processes. Processes 9, 6.1, 6 and 8 had the highest G values, respectively. The percent SPL based on the heating value (G) are also shown in Table 2.

Chemical Properties of Processed Egg. The results of alpha-amylase activity assays (Table 3) confirms that the enzyme is inactivated by mild heat processes. Table 3 shows that the thermal processes used did not affect protein content or the soluble protein content.

TABLE 3

Thermal Effects on Alpha-Amylase Activity, Protein Content and % Soluble Protein.

Process No.	Alpha-Amylase[a]			MicroKjeldahl[b]			% Soluble Protein[c] (From Absorbance)
	Raw	UHT	Plant	Raw	UHT	Plant	
1	0.045	0.048	0.099	13.10	11.60	13.1	86.2
2	0.033	0.588	—	12.59	11.96	—	102.3
3	0.055	1.050	—	11.67	11.32	—	101.3
4	0.029	0.031	0.137	11.83	11.79	11.51	101.1
5	0.046	1.000	—	10.19	10.13	—	100.3
6	0.053	1.120	—	12.27	12.34	—	100.9
6.1	0.040	1.130	—	12.70	12.54	—	103.3
7	0.052	0.764	—	12.37	12.53	—	104.5
8	0.063	1.000	—	11.19	11.42	—	100.4
9	0.060	1.170	—	11.74	11.77	—	100.7

[a]Alpha-Amylase data is reported as the absorbance at 585 nm. Activity is inversely related to absorbance.
[b]MicroKjeldahl data is reported as percent protein.
[c]Absorbance at 280 nm of heated egg/control (raw) egg in solution as described by Hamid-Samimi et al., supra (1984).

The chemical data indicate that the processes did not result in extensive damage to the egg proteins. The predicted percent soluble protein losses (Table 3) were based on studies conducted with small amounts of egg (1 ml) being heated in the cup of a Brookfield viscometer (Hamid-Samimi et al., supra, 1984). The egg was heated while various shear rates were applied to simulate egg under dynamic conditions that exist in conventional heat exchangers. Thus, this work revealed that the model system resulted in prediction equations that underestimated the thermal treatments that liquid whole egg products could tolerate while still obtaining products with good functional properties. Analysis of the causes of these unexpectedly good results led to the guidelines discussed above which should be followed to obtain functionally superior ultrapasteurized products.

Function of Processed Eggs. The functional properties of the processed eggs agreed with the physical and chemical results. Based on the data presented in Tables 4 and 5 for nonstored egg, there appeared to be very little heat effect on the performance of the ultrapasteurized egg relative to raw or commercially pasteurized egg. Cake height as an indication of the leavening ability and force to deform, springiness, and relaxation parameter (Peleg and Normand, Rheologica Acta

22:108 (1983)) as indicators of textural properties were very similar for all egg examined.

TABLE 4

Functional Properties of Cakes for Control (Raw), Ultrapasteurized (UP) at Zero Day Storage, and Commercially Pasteurized Eggs (Plant).

Variable	Treatment	Mean	Minimum	Maximum	n	C.V.
Maximum Force[a] (N)	Raw	10.02	7.79	13.70	10	17.3
	UP	10.49	9.18	12.91	10	10.5
	Plant	9.73	9.56	9.91	2	2.5
Relaxation[b] Parameter	Raw	0.394	0.379	0.417	10	3.24
	UP	0.410	0.395	0.442	10	3.34
	Plant	0.402	0.402	0.403	2	0.17
Springiness[c]	Raw	0.83	0.81	0.86	10	1.94
	UP	0.83	0.81	0.87	10	2.47
	Plant	0.82	0.81	0.82	2	1.32
Cake Height (mm)	Raw	63.1	63.3	66.7	10	1.66
	UP	61.7	55.1	65.5	10	5.26
	Plant	64.8	64.7	64.8	2	0.11
Water Activity	Raw	0.873	0.832	0.891	10	2.53
	UP	0.875	0.835	0.892	10	2.37
	Plant	0.892	0.892	0.892	1	—

[a] Force required to deform the sample of cake by 26 mm.
[b] Asymptotic relaxation value as defined by Peleg and Normand, supra (1983).
[c] Ratio of the second peak force to the first peak force in the force deformation cycle.

TABLE 5

Functional Properties of Custards for Controls (Raw), Zero Day Storage Ultrapasteurized (UP) and Commercially Pasteurized Eggs (Plant).

Variable	Treatment	Mean	Minimum	Maximum	n	C.V.
Penetration Force (N)	Raw	0.82	0.76	0.96	10	8.20
	UP	0.70	0.59	0.80	10	8.56
	Plant	0.79	0.77	0.81	2	3.69
Custard Height (mm)	Raw	35.7	35.1	36.7	10	1.66
	UP	35.6	35.1	36.3	10	5.26
	Plant	34.6	34.0	35.3	2	0.11
% Sag	Raw	7.2	5.65	9.54	10	16
	UP	7.1	5.41	8.56	10	13
	Plant	4.6	2.66	6.51	2	59

The water activity of the cakes were similar indicating that the experimental handling procedures for the cakes were uniform and should not have affected the instrumental evaluation of textural properties. The custard data indicated that all egg sources evaluated had good ability to form gels. The gels had excellent integrity as indicated by the relatively low percent sag, yet the custards were relatively tender as indicated by the penetration forces. Although weep was not measured, very little syneresis was noted even after holding the custards overnight for textural evaluations. The limited organoleptic evaluation of the processed eggs indicated that the thermal processes did not affect flavor or aroma in scrambled eggs relative to scrambled egg made from a fresh shell egg. The USDA palatability scores were seven to eight (eight being the highest score).

Refrigerated Storage Effect. As long as the processed egg was not obviously spoiled, as indicated by organoleptic evaluations, storage at 4° C. maintained the chemical, functional, and organoleptic properties of the processed egg up to 24 weeks for some of the samples. The data presented in Tables 6, 7, and 8 were taken from stored egg that was judged organoleptically sound. The criteria for that judgement were: (1) that the color was normal, i.e., within the expected range of color observed for eggs immediately post-processing, and (2) that there were no objectional aromas or flavors. In this study, because of the sampling procedure where most of the samples were checked at four-week intervals, there were no borderline decisions, a sample was obviously acceptable or unacceptable. Bright yellow colors, off-aromas, and pH values below seven were typical of samples judged to be spoiled.

TABLE 6

Means for Proteins, Solids and pH for Controls (Raw), Commercially Pasteurized (Plant) and Ultrapasteurized (UP) Egg.

Variable	Treatment[a]	Mean	Minimum	Maximum	n	C.V.
% Protein	Raw	11.92	10.19	13.10	10	6.8
	Plant	12.30	11.51	13.10	2	9.1
	UP 0	11.74	10.13	12.54	10	6.0
% Solids	Raw	24.6	23.9	25.2	10	1.6
	Plant	24.8	24.4	25.2	2	2.5
	UP 0	24.5	24.0	25.0	10	1.3
	4	24.4	24.0	24.9	10	1.3
	8	24.4	24.0	24.7	9	0.9
	12	24.3	23.8	24.7	7	1.3
	18	24.9	24.4	25.5	2	3.1
	24	24.8	24.7	24.9	2	0.3
pH	Raw	7.5	7.2	7.6	10	1.7
	Plant	7.1	7.1	7.2	2	0.5
	UP 0	7.5	7.3	7.6	10	1.4
	4	7.4	7.2	7.6	10	1.4
	8	7.4	7.3	7.5	9	1.2
	12	7.3	7.2	7.4	7	1.2
	18	7.4	7.4	7.4	2	0
	24	7.4	7.4	7.4	2	0

[a] Numbers indicate storage at 4° C. in weeks for processed eggs.

TABLE 7

Functional Properties of Cakes Made from Eggs Stored at 4° C.

Variable	Storage (Weeks)	Mean	Minimum	Maximum	n	C.V.
Maximum Force[a] (N)	4	9.78	7.90	14.95	10	21.3
	8	10.37	7.82	14.53	9	20.5
	12	11.29	8.84	14.28	7	18.2
	18	11.42	10.32	12.53	2	13.6
	24	10.53	9.57	11.49	2	12.9
Relaxation Parameter[b]	4	.3937	0.3759	0.4167	10	3.7
	8	.3876	0.3634	0.4132	9	3.9
	12	.3846	0.3717	0.4032	7	3.0
	18	.3788	0.3788	0.3788	2	3.1
	24	.3745	0.3704	0.3788	2	1.5
Springiness[c]		0.829	0.799	0.853	10	1.7
	8	0.834	0.811	0.872	9	2.0
	12	0.834	0.820	0.843	7	0.9
	18	0.831	0.829	0.832	2	0.3
	24	0.815	0.787	0.843	2	4.9
Height (mm)	4	61	54	65	10	6.02
	8	64	63	67	9	2.06
	12	64	60	65	7	2.7
	18	63	62	65	2	3.0
	24	65	65	65	2	0.22
Water Activity	4	0.860	0.796	0.883	10	4.2
	8	0.884	0.868	0.900	9	1.1
	12	0.879	0.844	0.896	7	2.0
	18	0.872	0.872	0.872	1	—
	24	0.879	0.876	0.882	2	0.4

[a][b][c] See Table 4 for definition of terms.

TABLE 8

Functional Properties of Custards Made from Eggs Stored at 4° C.

Variable	Storage (Weeks)	Mean	Minimum	Maximum	n	C.V.
Penetration Force (N)	4	0.68	0.47	0.77	10	12.7
	8	0.70	0.64	0.76	9	9.1
	12	0.75	0.57	0.83	7	20.3
	18	0.94	0.85	1.02	2	12.6
	24	0.82	0.76	0.88	2	10.5
Custard	4	35	34	36	10	2.4

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TABLE 8-continued

		Functional Properties of Custards Made from Eggs Stored at 4° C.				
Variable	Storage (Weeks)	Mean	Minimum	Maximum	n	C.V.
Height (mm)	1	35	34	36	9	1.6
	12	35	35	36	7	1.2
	18	36	36	36	2	0.4
	24	35	35	35	2	1.0
% Seg	4	7.1	3.0	11.6	10	38.1
	8	5.9	3.5	7.5	9	20.5
	12	6.5	4.6	8.0	7	19.5
	18	7.2	6.4	8.1	2	15.9
	24	6.6	4.9	8.2	2	36.0

Visual observations of the interiors of opened packages revealed very little sedimentation during storage. A very thin layer of a fine, light yellow, granular-like material was observed on the bottom of cartons after four weeks of refrigerated storage.

Shelf Life. The times of spoilage of egg from each trial are presented in Table 9.

TABLE 9

Shelf Life for Liquid Whole Egg Stored at 4° C.	
Process	Shelf Life (Weeks)
1	4-8
2	8-12
3	>12
4	8-12
5	>18
6	18-24
6.1	>24
7	12-18
8	20-24
9	18-20

These data were used to generate the time and temperature guidelines set forth in FIG. 5.

The invention has been discussed with a degree of specificity above. This discussion has been provided for illustrative purposes only, with the scope of the invention being defined by the following claims.

That which is claimed is:

1. A method of ultrapasteurizing a liquid whole egg product, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is heated to a predetermined real temperature, by contacting said liquid whole egg product to a heated surface wherein the total thermal treatment received by the liquid whole egg product is described by an equivalent temperature and an equivalent time defining a point above the 5% SPL (BATCH) line of FIG. 3, but insufficient to cause coagulation of the liquid whole egg product.

2. A method according to claim 1, wherein said liquid whole egg product is homogenized after it is heated.

3. A method according to claim 1, followed by the step of aseptically packaging said liquid whole egg product.

4. A method of ultrapasteurizing a liquid whole egg product, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is
(a) heated to a predetermined holding temperature by contacting said liquid whole egg product to a heated surface, then

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(b) maintained at said predetermined holding temperature for a predetermined holding time, and then
(c) cooled, wherein the total thermal treatment received by the liquid whole egg product is defined by an equivalent temperature and an equivalent time defining a point above the 5% SPL (BATCH) line of FIG. 3, but insufficient to cause coagulation of the liquid whole egg product.

5. A method of ultrapasteurizing a liquid whole egg product, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is heated to a predetermined real temperature by contacting said liquid whole egg product to a heated surface while at least periodically subjecting said continuous stream of liquid whole egg product to turbulence, wherein the total thermal treatment received by the liquid whole egg product is described by an equivalent time and an equivalent temperature defining a point above the 5% SPL (BATCH) line of FIG. 3, but insufficient to cause said liquid whole egg product to coagulate.

6. A method according to claim 5, wherein said liquid whole egg product is subjected to turbulence for a major portion of the time said liquid whole egg product is heated.

7. A method according to claim 5, wherein said liquid whole egg product is dispersed before said liquid whole egg product is heated.

8. A method according to claim 5, wherein every particle of liquid whole egg product in said continuous stream of liquid whole egg product is in contact with said heated surface for a total time less than the average residence time of each particle in the heating unit.

9. A method of ultrapasteurizing a liquid whole egg product, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is
(a) heated to a predetermined holding temperature by contacting said liquid whole egg product to a heated surface while at least periodically subjecting said continuous stream of liquid whole egg product to turbulence, then
(b) maintained at said predetermined holding temperature for a predetermined holding time, and then
(c) cooled, wherein the total thermal treatment received by the liquid whole egg product is defined by an equivalent time and an equivalent temperature above the 5% SPL (BATCH) line of FIG. 3, but insufficient to cause said liquid whole egg product to coagulate.

10. A method of ultrapasteurizing a liquid whole egg product, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is
(a) heated to a predetermined holding temperature, then
(b) maintained at said predetermined holding temperature for a predetermined holding time, then
(c) homogenized, and then
(d) cooled, wherein the total thermal treatment received by the liquid whole egg product is defined by an equivalent temperature and an equivalent time defining a point above the (9D) Salmonella line of FIG. 3, but insufficient to cause coagulation of the liquid whole egg product, and wherein the liquid whole egg product which is homogenized

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consists essentially of the liquid whole egg product which is heated.

11. A method according to claim 10, wherein said liquid whole egg product is dispersed before said liquid whole egg product is heated.

12. A method according to claim 10, wherein the total thermal treatment received by the liquid whole egg product is insufficient to cause more than a 5% soluble protein loss from said liquid whole egg product.

13. A method according to claim 10, wherein said liquid whole egg product is heated while at least periodically subjecting said continuous stream of liquid whole egg product to turbulence.

14. A method according to claim 10, wherein said homogenization step is carried out at a pressure of about 1,000 p.s.i. or more.

15. A method of making a packaged liquid whole egg product characterized by a preselected refrigerated shelf life of about four weeks to about 36 weeks, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is heated by contacting said liquid whole egg product to a heated surface for a predetermined time and to a predetermined temperature while at least periodically subjecting said continuous stream of liquid whole egg product to turbulence, wherein the liquid whole egg product is heated for a predetermined time and to a predetermined temperature insufficient to cause more than a 5% soluble protein loss from said product, and wherein said predetermined temperature and said predetermined time are chosen to impart said preselected shelf life to said liquid whole egg product, followed by aseptically packaging the liquid whole egg product.

16. A method according to claim 15, wherein said pasteurizing apparatus is sterilized before said liquid whole egg product is passed therethrough, and wherein said packaged liquid whole egg product is characterized by a preselected shelf life of about eight weeks to about 36 weeks.

17. A method according to claim 15, wherein said liquid whole egg product is subjected to turbulence for a major portion of the time said liquid whole egg product is heated.

18. A method of making a packaged liquid whole egg product characterized by a preselected refrigerated shelf life of about four weeks to about 36 weeks, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is

(a) heated by contacting said liquid whole egg product to a heated surface for a time sufficient to raise said liquid whole egg product to a predetermined holding temperature while at least periodically subjecting said continuous stream of liquid whole egg product to turbulence, then

(b) maintained at said predetermined holding temperature for a predetermined holding time, wherein said holding temperature and holding time are selected to cause a soluble protein loss of not more than 5% from said product, and wherein said holding temperature and holding time are selected to impart said preselected shelf life to said liquid whole egg product, and then

(c) cooled, followed by

(d) aseptically packaging the liquid whole egg product.

19. A method according to claim 18, wherein said pasteurizing apparatus is sterilized before said liquid

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whole egg product is passed therethrough, and wherein said packaged liquid whole egg product is characterized by a preselected shelf life of about eight weeks to about 36 weeks.

20. A method according to claim 18, wherein said liquid whole egg product is subjected to turbulence for a major portion of the time said liquid whole egg product is heated.

21. A method of ultrapasteurizing a liquid whole egg product, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is heated to a predetermined real temperature, wherein the total thermal treatment received by the liquid whole egg product is described by an equivalent temperature and an equivalent time defining a point above the 15% SPL (BATCH) line of FIG. 3, but insufficient to cause coagulation of the liquid whole egg product.

22. A method according to claim 21, wherein said step of heating the liquid whole egg product is carried out by contacting said liquid whole egg product to a heated surface.

23. A method according to claim 1, 5, 15, 18, 21 or 10, wherein said equivalent temperature and equivalent time additionally define a point above the S. faecalis (7D) line of FIG. 3.

24. A method of ultrapasteurizing a liquid whole egg product, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is

(a) heated to a predetermined holding temperature, then

(b) maintained at said predetermined holding temperature for a predetermined holding time, and then

(c) cooled, wherein the total thermal treatment received by the liquid whole egg product is defined by an equivalent temperature and an equivalent time defining a point above the 15% SPL (BATCH) line of FIG. 3, but insufficient to cause coagulation of the liquid whole egg product.

25. A method of ultrapasteurizing a liquid whole egg product, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is heated to a predetermined real temperature by contacting said liquid whole egg product to a heated surface, wherein the total thermal treatment received by the liquid whole egg product is described by an equivalent temperaturer and an equivalent time defining a point above the 5% SPL (BATCH) line of FIG. 3, but insufficient to cause coagulation of the liquid whole egg product, and wherein the total thermal treatment received by the product is insufficient to cause more than a 5% soluble protein loss from the product.

26. A method of ultrapasteurizing a liquid whole egg product, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is heated to a predetermined real temperature, wherein the total thermal treatment received by the liquid whole egg product is described by an equivalent temperature and an equivalent time defining a point above the 15% SPL (BATCH) line of FIG. 3, but insufficient to cause coagulation of the liquid whole egg product, and wherein the total thermal treatment received by the product is insufficient to cause more than a 5% soluble protein loss from the product.

* * * * *

United States Patent [19]

Swartzel et al.

[11] Patent Number: 4,957,759

[45] Date of Patent: * Sep. 18, 1990

[54] **METHOD FOR THE ULTRAPASTEURIZATION OF LIQUID WHOLE EGG PRODUCTS**

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[73] Assignee: North Carolina State University, Raleigh, N.C.

[*] Notice: The portion of the term of this patent subsequent to Feb. 28, 2006 has been disclaimed.

[21] Appl. No.: 311,594

[22] Filed: Feb. 16, 1989

Related U.S. Application Data

[63] Continuation of Ser. No. 904,744, Sep. 8, 1986, Pat. No. 4,808,425.

[51] Int. Cl.⁵ A23L 3/00
[52] U.S. Cl. 426/399; 426/521; 426/614
[58] Field of Search 426/399, 521, 614

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[57] **ABSTRACT**

Methods of ultrapasteurizing liquid whole egg products in continuous flow, high temperature, short time pasteurization equipment are provided. The equivalent point method is preferably used to evaluate the total thermal treatment received by the product in this equipment. Also disclosed is a method of making liquid whole egg products having preselected, extended, refrigerated shelf lives.

6 Claims, 4 Drawing Sheets

HEATING SECTION

HOLDING SECTION

TIMING PUMP

COOLING SECTION

HOMOGENIZATION

PRE-HEATING

ASEPTIC PACKAGING

Fig. 1.

CONTINUOUS FLOW PASTEURIZING APPARATUS

LWE IN

HEATER | HOLDING | COOLER

SECTION

LWE OUT

t_H

HEATING STAGE | HOLDING STAGE | COOLING STAGE

T_H

T_E

TEMPERATURE

t_E

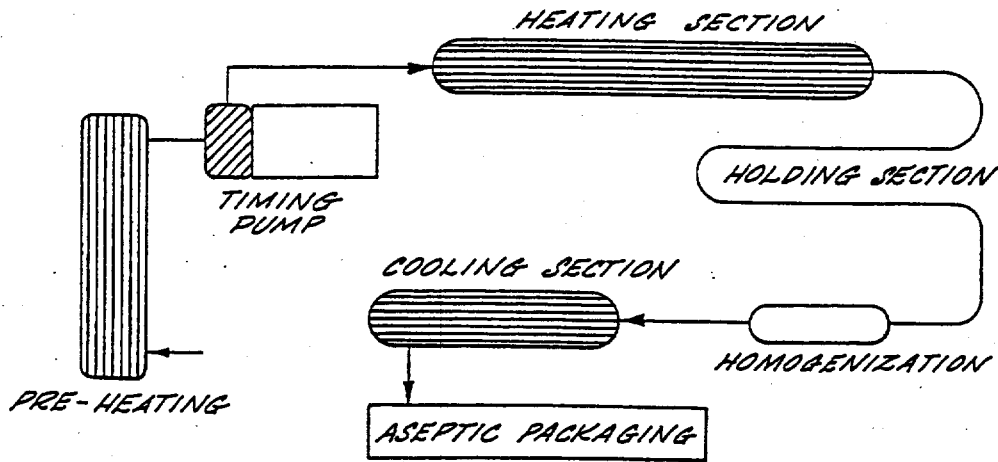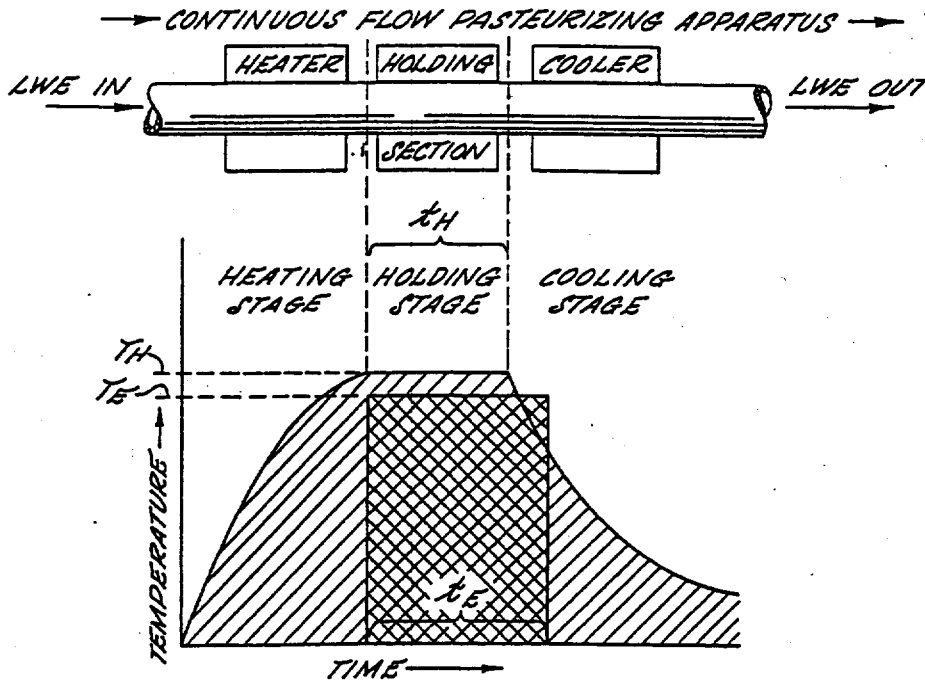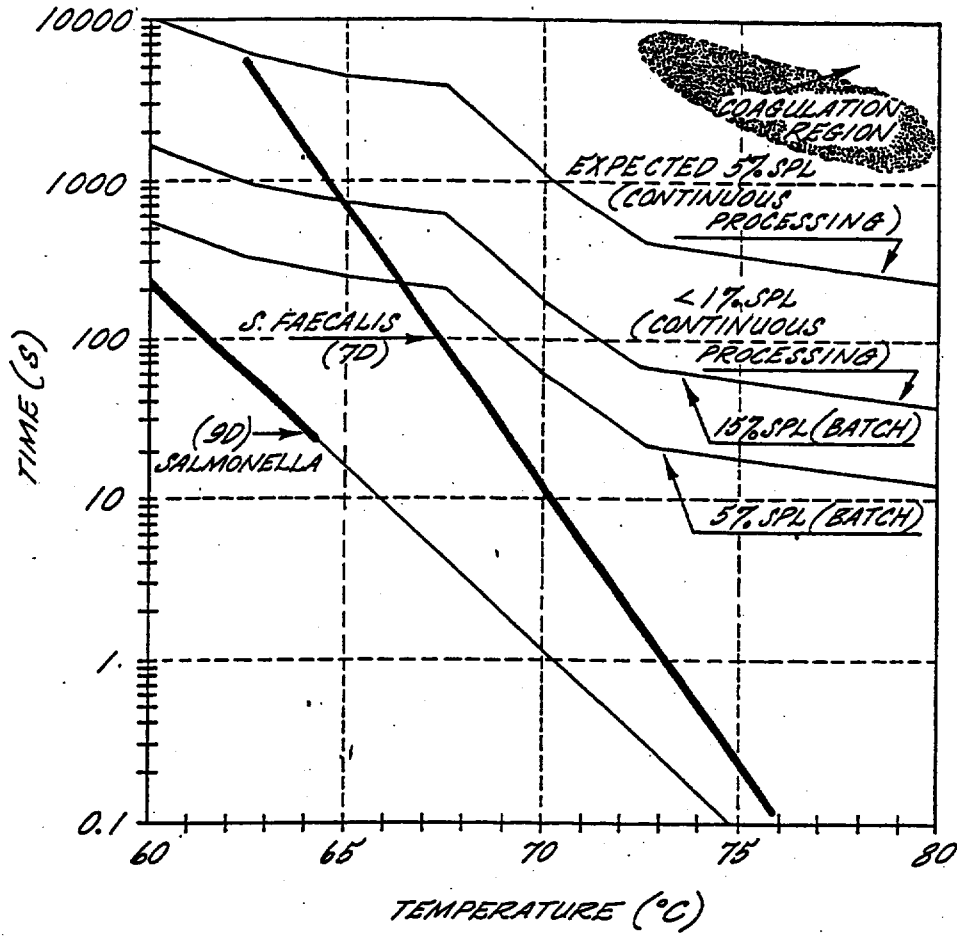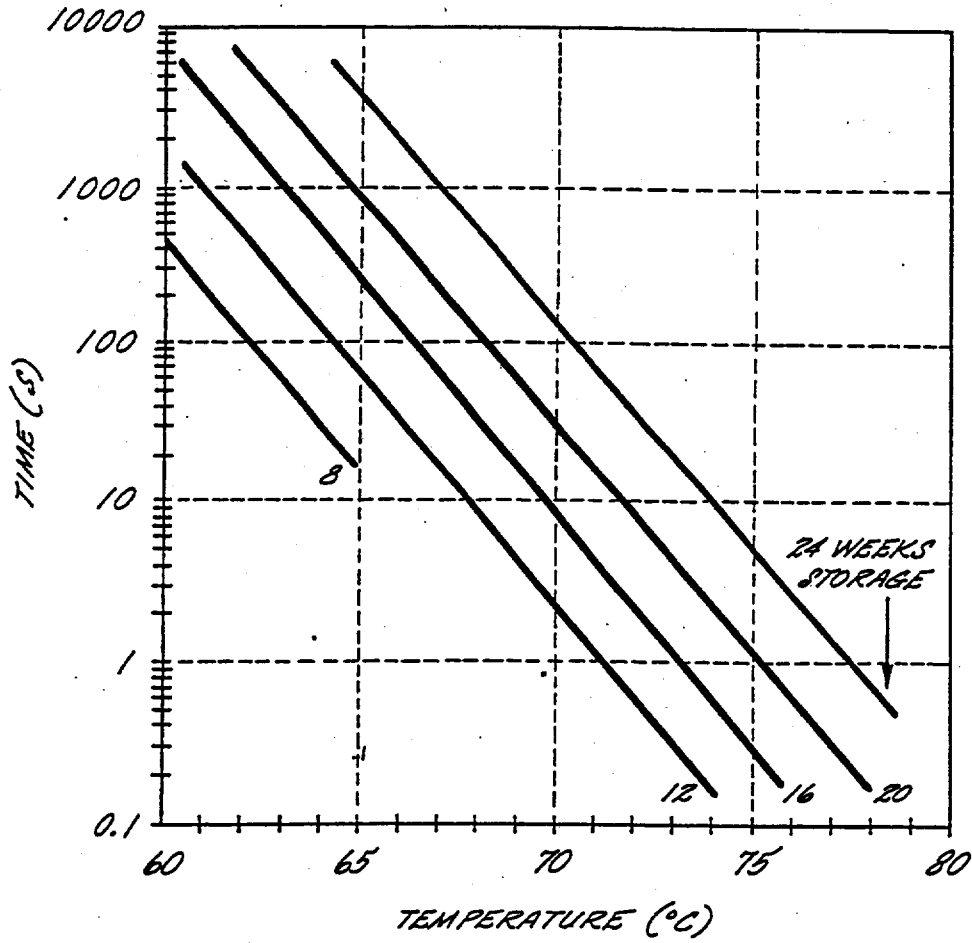TIME
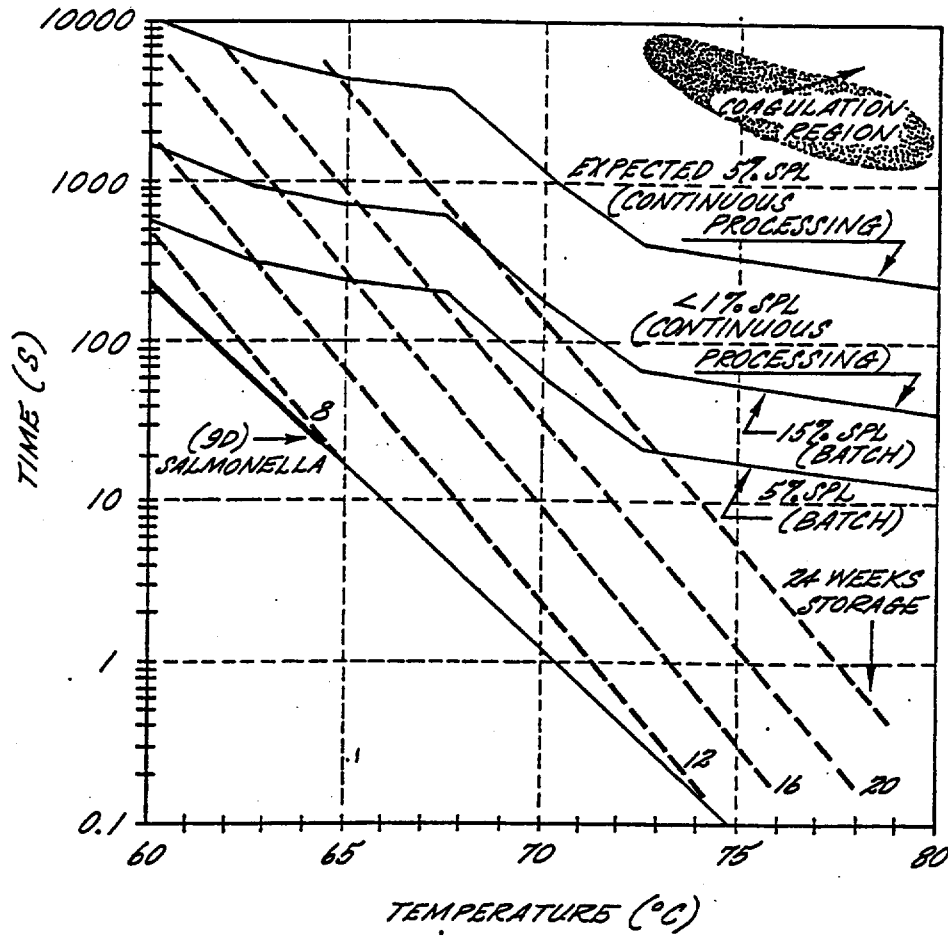
Fig. 2.

Fig. 3.

Fig. 4.

Fig.5.

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METHOD FOR THE ULTRAPASTEURIZATION OF LIQUID WHOLE EGG PRODUCTS

This is a continuation of Ser. No. 904,744, filed Sept. 8, 1986 now U.S. Pat. No. 4,808,425.

DESCRIPTION OF THE INVENTION

The present invention relates to the pasteurization of liquid whole egg products generally, and particularly relates to ultrapasteurization methods which can be used to produce liquid whole egg products which have good functional properties and which have extended refrigerated shelf lives.

BACKGROUND OF THE INVENTION

The U.S. egg industry produced more than 300 million pounds of frozen pasteurized egg products in 1985. The relatively mild pasteurization processes used are designed to eliminate Salmonella from eggs for all practical purposes, but do not destroy organisms capable of spoiling egg products held under refrigerated temperatures above freezing. The survival of spoilage organisms in pasteurized egg, coupled with conventional packaging technology, results in products with limited shelf life (7–14 days at 40° F.) that require freezing and frozen distribution systems for preservation Freezing is cost intensive, lowers the functional quality (flavor, performance, etc.) of the egg product, and results in an inconvenient product that requires thawing prior to use.

Standard pasteurization practices for liquid whole egg products are generally discussed in the *Egg Pasteurization Manual* (USDA Agricultural Research Service 1969). See also U.S. Pat. No. 3,949,099 to Kaufman, at column 1, lines 46–58 (summarizing pasteurization processes). The *Egg Pasteurization Manual* notes that experiments conducted in England to establish treatment conditions used there, which were carried out in a high temperature, short time pasteurization unit, included trials with holding times of two and one-half minutes and temperatures up to 151 degrees Fahrenheit (66.1 degrees Centigrade). The functional quality of these eggs is not discussed; however, it is noted that England adopted a lower temperature of 148 degrees Fahrenheit as a treatment condition The Manual observes that such "severe" treatments help increase the stability of egg products in liquid form, but does not teach how this can be accomplished without sacrificing desirable functional properties of the products. For other types of egg products which are more heat stable, pasteurization temperatures as high as 152 degrees Fahrenheit (66.67 degrees Centigrade) have been reported. Again, little is known about how to ultrapasteurize (decrease the number of spoilage microorganisms to levels lower than obtained with a pasteurization procedure) these products by heating without sacrificing functional performance.

Higher temperatures than those investigated in England have been explored. See e.g., Essary, E. O. Rony, P. R., and Collins, W. F., *New uses of heated aseptically packaged fluid egg products*, Report to the American Egg Board (1983). This work suggested that merging techniques of ultrapasteurization with aseptic packaging can be accomplished to yield safe, stable, and functional liquid whole egg. This research suggested and used a heat exchanger operated in laminar flow to process whole egg at elevated temperatures, and used an ethylene oxide-flushed glove box to aseptically package

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the product (neither device approved for the commercial production of a salable product). Holding temperatures of up to 154 degrees Fahrenheit (67.8 degrees Centigrade) were reported. The results of this pioneering work demonstrated the possibility of extending the refrigerated shelf life of liquid whole egg products, but did not enable the commercial production of a refrigerated product which could be sold to consumers.

To carry out ultrapasteurization of liquid whole egg products on commercial equipment, the time and temperature parameters of the thermal treatment must be selected with care. Arbitrary increases in thermal treatment will likely produce a functionally unacceptable product, or—even worse—coagulation of the product and blockage of the pasteurizing equipment. Because such pasteurizing equipment operates at high pressures (e.g., 1,500 p.s.i. and more) the consequences of blockage are serious. For these reasons, it is essential to know how liquid whole egg products respond to various thermal treatments before experimenting with the production of these products on commercial equipment.

Because this essential information was not available, Hamid-Samimi investigated the time and temperature parameters which should be used in commercial equipment to obtain a functionally acceptable, ultra-pasteurized, liquid whole egg product. M. H. Hamid-Samimi, Criteria Development for Extended Shelf-Life Pasteurized Liquid Whole Egg. Ph.D. Thesis, North Carolina State University (1984). This research was carried out at the laboratory bench, with a Brookfield viscometer, which processed the product in small batches rather than continuously. Processing times and temperatures defining thermal treatments producing a soluble protein loss (SPL) of up to 5% from the product, as an upper limit, were suggested as producing a functionally acceptable product. The suggested 5% SPL limit was defined by a graph line in the thesis: this line is reproduced herein in FIG. 3 as the 5% SPL (Batch) line. Time and temperature values tested by other investigators which were believed to be the limits of pasteurization are summarized in M. H. Hamid-Samimi and K. R. Swartzel, *J. Food Processing and Preservation* 8: 219, 221 FIG. 1 (1984). All are below the 5% SPL (Batch) line.

The present inventors sought to test the predictions of Hamid-Samimi by ultrapasteurizing liquid whole egg on continuous flow, high temperature, short time pasteurization equipment. It was unexpectedly found that functionally acceptable liquid whole egg can be produced at times and temperatures greater than previously believed. These findings, which will be explained in detail below, enable the commercial production of functionally acceptable products with longer refrigerated shelf lives than heretofore available. As will also be explained below, discovery of these unexpected results has led to the identification of several steps which should be taken to produce ultra-pasteurized liquid whole egg products that have superior functional properties.

The object of the present invention, in short, is to provide liquid whole egg products for refrigerated distribution which have greatly reduced levels of spoilage microorganisms, while still having good functional properties.

SUMMARY OF THE INVENTION

This object is achieved by a method for ultra-pasteurizing liquid whole egg products. The method comprises passing the liquid whole egg product as a continu-

ous stream through a pasteurizing apparatus, during which the liquid whole egg product is heated to a predetermined real temperature. The method is practiced so that the total thermal treatment received by the liquid whole egg product is described by an equivalent temperature and an equivalent time (these terms are explained in detail below) defining a point above the 5% SPL (Batch) line of FIG. 3, but insufficient to cause coagulation of the product.

Also disclosed herein is a method of making a packaged liquid whole egg product characterized by a preselected refrigerated shelf life of from about four weeks to about 36 weeks. This method comprises passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is heated for a predetermined time and to a predetermined temperature. The predetermined time and the predetermined temperature are chosen to impart the preselected shelf life to the liquid whole egg product. After it is heated, the liquid whole egg product is aseptically packaged.

Preferably, the continuous stream of liquid whole egg product referred to in each of the methods above is at least periodically subjected to turbulence while it is heated. The liquid whole egg products are also, preferably, homogenized after they have been heated. In addition, the methods described above are more narrowly described as methods in which the liquid whole egg product is heated to a predetermined holding temperature, then maintained at said predetermined holding temperature for a predetermined holding time, and then cooled.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of a continuous flow pasteurizing apparatus suitable for carrying out the present invention.

FIG. 2 is a diagram illustrating the differences and relations between real holding times and holding temperatures, and equivalent times and equivalent temperatures for describing total thermal treatments, in continuous flow pasteurizing equipment.

FIG. 3 is a graph showing time and temperature regions for the ultrapasteurization of liquid whole egg products.

FIG. 4 is a graph showing equivalent times and equivalent temperatures that give particular refrigerated shelf lives for liquid whole egg.

FIG. 5 is a combination graph in which FIGS. 3 and 4 are superimposed, with the S. faecalis line removed.

DETAILED DESCRIPTION OF THE INVENTION

Thermal treatments simultaneously produce beneficial and undesirable changes in food products. Knowledge of kinetic methods, and how they can be applied to the mechanics of designing a thermal process, aids in attaining food quality retention and process efficiency. Determining the time and temperature requirement for a thermal process depends upon destruction of spoilage and disease causing microbial spores while minimizing undesirable physical, chemical and biological transformations that occur within the product.

As schematically shown in FIG. 1, with arrowheads indicating direction of flow, continuous flow thermal processing equipment comprises heating, holding, and cooling sections. The thermal treatment received by the product in the heating and cooling stage, (illustrated in

FIG. 2), is oftentimes not considered: instead, only the holding time (t_H) and holding temperature (TH) are considered. However, when products are pasteurized in such equipment at higher temperatures and shorter times, as is taught herein, the contribution of the heating stage, and perhaps the cooling stage, to the total thermal treatment of the product becomes significant, and must be accounted for if a product with good functional qualities is to be obtained and coagulation during pasteurization is to be avoided. It is accordingly recommended that the equivalent point method for evaluating thermal treatments be applied in practicing the present invention. As explained in detail below, this method describes the total thermal treatment received by a product in continuous flow equipment with one equivalent time (t_E) and one equivalent temperature (T_E) (see FIG. 2).

Procedures for use of the equivalent point method for analyzing the thermal effects on products during continuous flow heating have been previously outlined (Swartzel, 1982, J. Food Sci. 47:1886 and Swartzel, 1986, J. Agric. Food Chem. 34:397) and are known to those skilled in the art. This method differs substantially from previous methods in that all other methods define the thermal treatment based upon a single factor such as enzyme inactivation, microbial destruction, protein denaturation, nutrient loss, etc. The problem with these other methods is that a physical and/or chemical effect (flavor, color, product separation and gelation during storage if thermally related) may actually be the shelf life limiting factor.

The unique feature of the equivalent point method lies in the fact that, for any thermal curve, one equivalent time and equivalent temperature combination exists (see FIG. 2). This equivalent time and temperature combination will yield the exact thermal effect on all constituents within the product as would the original thermal curve. This unique time and temperature combination is not dependent on individual constituent kinetics, as are all previous thermal evaluation procedures (it is independent of constituent activation energy).

To determine the equivalent point of a thermal system, a complete thermal history of the treatment must be available. This is obtained by measuring mixed mean product temperatures at various locations (entrance to the heat exchanger, exit of the heat exchanger and at least two locations inside the heat exchanger). Time is calculated by correlating mean residence time with location of the temperature probe. With heat exchangers into which it is difficult or impractical to insert thermal probes, time-temperature curves are calculated based on knowledge of the product's physical characteristics and on the geometry of the processing equipment.

With available time-temperature curves and a basic knowledge of kinetic relationships, equivalent points can routinely be calculated. The log of a product constituent concentration ratio (initial concentration divided by concentration after treatment) is set equivalent to the integration of that constituent's Arrhenius equation (or any other appropriate function describing the temperature dependency of the rate of the reaction associated with the constituent change) for the particular time-temperature interval (thermal history previously defined). For a given activation energy each section of a thermal treatment (heating, holding, and cooling) will produce a unique thermal constituent concentration ratio. For the different sections the effect may be

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summed. For the original activation energy selected, a linear infinite log (time)-temperature relationship exists. Any and all of these infinite time and temperature combinations would produce the same thermal effect on a constituent (with the same activation energy) as during the original thermal treatment. By reexamining the original thermal curves with different activation energies a series of infinite linear log (time)-temperature relationships are developed (one line in a log (time)-temperature plot per activation energy). Uniquely all lines intersect at one point. This unique time-temperature is the equivalent point for the original thermal curve. It accounts for all thermal treatment and is used to accurately predict constituent change, or product characteristic.

FIG. 3 sets forth thermal treatments which should be used to ultrapasteurize liquid whole egg products. Thermal treatments defined by points above the 5% SPL (Batch) line have not heretofore been suggested. For practicing the present invention in continuous flow processing equipment, the thermal treatment is described by a point on FIG. 3 defining an equivalent time and an equivalent temperature, as explained above. The thermal treatment should be more than sufficient to pasteurize the liquid whole egg product. "Pasteurize" means to cause a nine log cycle (9D) or 99.9999999% reduction in Salmonella in the product being treated. The thermal treatment should be insufficient to cause the liquid whole egg product to coagulate. The thermal treatment should more particularly cause not more than a 15% soluble protein loss (SPL) in the liquid whole egg product being treated, and will preferably cause not more than a 5% soluble protein loss in the product being treated. The expected 5% SPL (continuous processing) line on FIG. 3 indicates approximately the upper limit on thermal treatments which can be tolerated without sustaining more than a 5% soluble protein loss (the exact location of this line for any one process will depend on the physical factors discussed below). More preferably, the thermal treatment will be designed to produce not more than about a 1% soluble protein loss from the product. As shown in FIG. 3, equivalent times and equivalent temperatures defining points along the line previously believed to represent the line at which a 15% soluble protein loss would be obtained (the 15% SPL (Batch) line), are now known to represent thermal treatments which produce ultra-pasteurized products having less than a 1% soluble protein loss under continuous flow.

The line defining thermal treatments causing a seven log cycle reduction in the spoilage bacteria *Streptococcus faecalis* is labeled in FIG. 3 as the *S. faecalis* (7D) line. The *S. faecalis* line has a steeper slope than the several SPL lines. This illustrates that thermal treatments employing higher temperatures and shorter times are preferred for practicing the present invention. Thus, holding soluble protein loss constant (so that treatment time must be decreased as treatment temperature is increased), thermal treatments in which the product is subjected to treatment temperatures of about 67.0 degrees Centigrade or more are preferred to thermal treatments in which the product is subjected to treatment temperatures of 65° C.; treatment temperatures of about 69.0° C. or more are preferred to treatment temperatures of 67° C.; treatment temperatures of about 71.0° C. or more are preferred to treatment temperatures of 69° C.; treatment temperatures of about 73.0° C. or more are preferred to 71° C.; and so on. The foregoing statement

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is true whether the real temperatures (or holding temperatures) of the processes are being compared, or equivalent temperatures are being compared (thus the term "treatment temperature" is used to encompass both).

Treatment temperatures are primarily limited by the ability to accurately time the duration of the thermal treatment: as temperature is increased the treatment time must be decreased, and shorter treatment times are more difficult to administer with precision. Generally, equivalent temperatures not more than about 90° C. are preferred, and equivalent temperatures not more than about 80° C. are more preferred.

Desirable thermal treatments for practicing the present invention can also be described with reference to the *S. faecalis* lines. Preferably, the thermal treatment will define a point above the *S. faecalis* (7D) line, and more preferably the thermal treatment will define a point above the *S. faecalis* (9D) line. While this latter line is not plotted in FIG. 3, it can be plotted in accordance with the equations given below.

Equations for lines in the figures are as follows, where t=time in seconds, T=temperature in degrees Centigrade, and n=number of decimal reductions. *Salmonella* line: $\log(t)=15.96-0.227(T)$. *S. faecalis* lines: $\log(t)=24.62+\log(n)-0.346(T)$. % SPL lines: $\log(t)=\log(\%SPL)+a-b(t)$, where a and b are given in Table 1 below:

TABLE 1

T range °C.	a (for Batch lines)	b	a (Expected) (for continuous flow lines)
60–62.5	7.494	0.091	8.761
62.5–67.5	4.103	0.037	5.370
67.5–72.5	14.68	0.194	15.942
72.5 and above	3.014	0.033	4.281

These equations can be used to extend the teaching of the figures beyond their depicted scope.

The liquid whole egg product is preferably heated by contacting the product to a heated surface. The heated surface is comprised of a corrosion-resistant, non-toxic and nonabsorbent material such as stainless steel. Standards for evaluating the acceptability of such product contact surfaces (the 3-A Sanitary Standards) are known and established. See, e.g., *Egg Pasteurization Manual, supra,* at 27.

To obtain a product with reduced amounts of spoilage microorganisms, the pasteurizing apparatus should be sterilized before the liquid whole egg product is passed therethrough. Sterilizing is preferably accomplished by passing hot water under pressure through the pasteurizing apparatus, as is known in the art, so that, among other things, hot water is contacted to the heating surface at a temperature and pressure and for a time sufficient to sterilize the heating surface.

In addition, the product, after ultrapasteurization, should be aseptically packaged. Aseptically packaged means packaged to the exclusion of microorganisms other than those carried by the liquid whole egg product. Equipment suitable for aseptically packaging liquid whole egg products is commercially available.

FIG. 4 illustrates the refrigerated shelf life of liquid whole egg after it is ultra-pasteurized and aseptically packaged, as explained above. The term "refrigerated," as used herein, means stored at a temperature of 4° C. Time and temperatures for points on each line represent

equivalent times and temperatures, as also explained above. A liquid whole egg product having a preselected shelf life of from about 4–36 weeks is made by selecting a point on a line or in a region which will provide the desired shelf life, determining the equivalent time and equivalent temperature which correspond to the point selected, and—preferably through the use of the equivalent point method—establishing the operating conditions on the particular pasteurizing apparatus being used that will provide the selected thermal treatment. Products having shelf lives not depicted in FIG. 4 are made by extrapolating the teachings of the figure, in light of the teachings above. Preferably, this process is carried out in pasteurizing apparatus which has been sterilized before the liquid whole egg product is passed therethrough, as explained above, to produce products having shelf lives of about eight weeks or more. In addition, it will be appreciated that longer shelf lives are generally obtained at the expense of greater levels of soluble protein loss. Thus, if product distribution systems do not require otherwise, products with shelf lives of up to about 32 weeks are preferred, and products with shelf lives up to about 24 weeks are more preferred.

FIG. 5 combines portions of FIGS. 3 and 4. It shows how the thermal treatments selected to provide a desired shelf life can at the same time be selected to provide products with good functional properties. More particularly, thermal treatments can be selected which produce liquid whole egg products having the desired shelf life and a soluble protein loss not greater than 5%.

The foregoing graphs have been presented to aid the understanding of the present invention. Some variation about the plotted lines is to be expected when the present invention is practiced on different equipment, or with different products. These graphs are accordingly not to be taken as limiting the present invention, as departures could be made therefrom while still capturing and benefiting from the teachings of the invention.

To obtain a superior ultra-pasteurized liquid whole egg product, the contact time of the liquid product to heated surfaces during pasteurization should be reduced. More particularly, every particle of liquid whole egg product should be in contact with the heated surface or surfaces of the unit in which the product is heated for a total time less than the residence time of the particle in the heating unit. (The term "particle" as used herein has its standard meaning in the egg pasteurization field See, e.g., 7 C.F.R. § 59.570(b) (1985)). This is accomplished by mixing the product at least periodically while it is being heated. In a continuous flow pasteurizing apparatus, such mixing is accomplished by introducing turbulence into the stream of the product at least periodically while it is being heated, as discussed below. Other steps which are preferably employed to reduce fluid element contact time to heated surfaces include providing portions of the thermal treatment in which fluid elements are not in contact with heated surfaces, such as by providing a portion of the thermal treatment in a holding section, and by providing heated contact surface area to product volume ratios of less than 18 cm²/cm³ (Thus the surface area to volume ratio is preferably less than about 10, and is more preferably in the area of about 2).

It is also desirable to induce physical forces to make the product more homogeneous prior to thermal treatment, such as by inducing shear forces capable of reducing protein and fat unit size. This is preferably accomplished by dispersing the product prior to heating. Dispersing may be carried out with a dispersing valve or with a timing pump, as is known in the art. Such treatment advantageously reduces fouling, and serves to reduce any tendency of the product to coagulate. Such a dispersing step may be carried out by conducting a more rigorous homogenization step, but it is recommended that such more expensive homogenizing equipment be used as described below.

It is preferable that a homogenization step after heating be included. The term "homogenized," as used herein, means to subject the product to physical forces to reduce particle size. Such procedures are known in the art, and may be carried out on different types of equipment. It is preferable to carry out this homogenizing step with homogenizing equipment at total pressures of about 1,000 p.s.i. or more. Pressures of about 1,500 p.s.i. or more are more preferred, and pressures of 2,000 p.s.i. or more still more preferred.

Of these steps, it is particularly desirable to mix the liquid whole egg product at least periodically while it is heated. As noted above, in continuous flow equipment mixing is carried out by at least periodically subjecting the stream of liquid whole egg product to turbulence while it is heated. Turbulence, which is the mixing of particles over the cross-section of the product stream, is discussed in the *Egg Pasteurization Manual* at pages 6–8. Such turbulence is characterized by a Reynolds number greater than about 2,300, and preferably greater than about 4,600. Commercial high temperature, short time pasteurizing units are available which at least periodically impart turbulence to the stream of product being pasteurized while the product is being heated. For the purposes of the present invention, greater levels of turbulence are preferred. Thus the liquid whole egg product is preferably subjected to turbulence for a major portion of the time it is heated. Plate heat exchangers, trombone heat exchangers, spiral heat exchangers, and scrape surface heat exchangers are illustrative of the types of known heat exchangers which can be used to subject liquid whole egg products to turbulence while they are heated. The physical forces induced in scrape surface heat exchangers are generally thought of as "mixing," but these exchangers induce turbulence at least in regions of the product stream, and are therefore considered to induce turbulence for purposes of the present invention.

Examples of whole egg products which can be pasteurized in liquid form by the method of the present invention include whole egg, fortified whole egg (whole egg with added yolk), salt whole egg (e.g., salt 10%), sugar whole egg (e.g., sugar 10%), blends of whole egg with syrup solids, syrups, dextrose and dextrins and/or gums and thickening agents, blends of whole eggs with less than 1% sugar and/or salt, scrambled egg mixes (for example, a mix of about 51% egg solids, 30% skim milk solids, 15% vegetable oil and 1.5% salt), reduced cholesterol egg products and blends thereof, custard blends, and the like. Products which are extremely sensitive to thermal processing and which are particularly suitable for ultrapasteurization by the present invention include, for example, liquid whole egg and blends thereof (less than 2% added nonegg ingredients), fortified whole egg and blends thereof (24–38% egg solids, 2–12% added nonegg ingredients), liquid salt whole egg, liquid sugar whole egg, and other liquid whole egg blends which are 24–38% egg solids and 12% or less of added nonegg ingredients. Terms used herein have their standard meaning in accordance

with industry and regulatory usage. See, e.g., 7 C.F.R. § 59.570(b) (1985).

The invention having been explained in general terms above, the following examples are provided to further illustrate the invention.

EXAMPLES 1-10

Raw Egg Product. Raw liquid whole egg was obtained from a local breaking plant (Gold Kist, Durham, N.C.). The egg was taken from their raw holding tank which was agitated to thoroughly blend approximately 30,000 pounds of egg. The egg was manually filled into 13.6 kg (30 lb) metal cans and were kept refrigerated before being transported 13.2 km (20 mi) to our laboratory in an insulated truck. The egg was held overnight at 4° C. (40° F.) or allowed to stand at room temperature for up to 12 hours to achieve higher bacterial numbers.

Thermal Processes. The time-temperature processes used in this study were designed to be equal to or more severe than minimum conditions defined by the 9D line for the destruction of Salmonella in whole egg (USDA, 1969) and within predetermined limits of denaturation of egg protein defined as percent soluble protein loss (%SPL) by Hamid-Samimi et al., *J. Food Sci.* 49:132 (1984). The objectives of this design were to provide Salmonella negative whole egg with a low number of surviving spoilage organisms while retaining adequate functional properties.

The thermal processing system used is outlined in FIG. 1. It consisted of a plate-type heat exchanger for preheat, various modifications of the No-Bac Unitherm model XLV (Cherry Burrell Corporation, Cedar Rapids, Iowa) to achieve different holding times, an aseptic homogenizer operated at 10.34 mPa (1,500 p.s.i.), and an aseptic packaging system (Model AB-3-250, Tetra Pak Inc., Dallas, Tex.). The flow rate was $2.89 \times 10^{-4} m/^3$ sec (275 GPH) with heating, holding, and cooling pipe diameters of 12.45 mm ID (½" nominal) stainless steel.

Before each process the entire system was sterilized at 121° C. for 30 minutes using hot water in the product section and steam in the heating media section and then cooled. The product and heating media temperatures were recorded for evaluation of the thermal effect of the heating section and to determine the total thermal effect. Swartzel, *J. Agri. Food Chem.* 34:396 (1986). The temperatures were measured using Type T thermocouples with an electronic data logger (Model 9302, Monitor Labs., Inc., San Diego, Calif.). Each thermocouple probe was scanned every 30 seconds (one minute for process #1) and the readout sent to a computer for analyses. The specific locations of the thermocouples in the system were as described by Swartzel and Jones. Paper No. 84-6006 of the American Society of Agricultural Engineers (1984).

Approximately one hour prior to initiation of each process, 408.2 kg (900 lb) of raw egg were transferred from the metal cans to a 568 1 (150 gal) vessel (Creamery Package Mfg. Co., Chicago, Ill.) and then mixed at room temperature with the stirring propeller at ca. 30 r.p.m. This volume of egg required approximately 20 minutes to process, therefore the last liter of egg was processed not later than 80 minutes after being removed from the cooler. Nine processes designated 1, 2, 3, 4, 5, 6, 7, 8, and 9 were run. Process 6 was repeated and designated 6.1. They were conducted two days apart on egg picked up on the same day. Egg for processes 6.1 to 9 were held at room temperature for not more than 12 hours to achieve a higher initial microbial load. All egg incubated at room temperature was chilled to 4° C. (40° F.) prior to processing.

After holding the egg at the scheduled process time and temperature and prior to packaging, the temperature was reduced to less than 10° C. (50° F.) in less than 26 seconds. Occasionally, due to technical difficulties it was not possible to cool the processed egg to below 10° C. In those instances the processed egg was moved into a freezer at −20° C. for 20 minutes after packaging. The packaging material was a low oxygen permeable laminate of polyethylene, paper, and aluminum foil formed into 250 ml containers (Tetra Pak aseptic filler model AB-3). Each package was dated and coded so that egg processed in the first seven minutes, the second seven minutes, and the remaining time were numbered 1, 2, and 3, respectively. The processed and packaged egg was held overnight at 4° C. (40° F.) prior to obtaining samples and being distributed for four and 10° C. storage.

Sampling Samples of raw egg for physical, chemical, and functional testing were aseptically removed from the mixing vat approximately 30 minutes prior to processing. The samples were then held overnight at 4° C. for evaluation with the pasteurized egg. Pasteurized samples were obtained on the day after processing or at selected times during storage at four and 10° C. Analyses were made on the combined contents of three or four individual packages representing the first, second, and third portions of each process run. When four packages were required, two packages from the middle portion of each process were used. Any sediment on the bottom of the cartons was scraped out and mixed into the egg by magnetic stirring.

Chemical Assays. The pH of the product was determined with a Fisher Accumet pH meter, model 600, equipped with a calomel reference and glass indicating electrodes. Solids were determined in triplicate by weighing two ml samples into disposable aluminum pans and drying in a forced draft oven for 24 hours. The AOAC (1985) microKjeldahl procedure was used to determine protein content of the samples. The extent of denaturation was estimated by determining the loss of soluble protein as described by Hamid-Samimi et al., supra, and the alphaamylase activity of the egg was determined as described by Shrimpton and Mousey, *J. Hyg.* 60:153 (1962).

Sponge Cakes. True sponge cakes were made by using half of the amounts of ingredients listed following the procedures given by Gorman and Ball (1986) (Chapter 15 in *Egg Science and Technology*, 3rd Ed., W. J. Stadelman and O. J. Cotterill, Eds., AVI Publishing Co., Inc. Westport, Conn.) with the omission of vanilla. Two separate batches of batter were mixed for each treatment and 340 g of batter was weighed into rectangular pans (21.5×11.5×6.5 cm, id.). Cakes were baked at 191° C. for 25 minutes, inverted on a wire rack and allowed to stand at room temperature overnight. Heights were determined from the mean of four measurements along the center line of the long axis of the cake. Cakes were then kept in plastic bags for further rheological evaluations.

Textural properties of the cakes were evaluated using an Instron Universal Testing Machine (Model 1122, Instron Engineering Corporation, Canton, Mass.). A plate was connected to a 2000-g load cell and positioned at the surface of the 5-cm cube of cake. The cross head and chart speeds were 200 mm/min and 100 mm/min,

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respectively. Three samples from each cake were subjected to deformation-relaxation cycles. The cubed cake samples were kept in a plastic bag before and after each test. The water activity of the cake samples were determined by placing three Durotherm (Lufft, West Germany) water activity meters in the plastic bag. Each meter was calibrated daily with a solution of barium chloride (aW 0.90 at 20° C.).

Custards. Duplicate custards of the flan type were made. Ingredients were 190-ml evaporated milk, 196-g sweetened condensed milk, 125-g whole egg, 50-g water, and one teaspoon vanilla. All ingredients were blended in a Waring blender at low speed for one minute and 360-g were weighed into a rectangular pan (14.3×8.0×5.6 cm, id.) which had been sprayed with "PAM" (Boyle-Midway, Inc., New York, N.Y.). Pans were placed in a tray containing 2.5-cm water and baked at 191° C. for 40 minutes. After overnight storage at 10° C., height of the custard in the pan was determined from the mean of three measurements made and with calipers along the center line of the long axis of the custard. Custards were removed from the pan after the sides were loosened with a spatula and allowed to stand at room temperature for 45 minutes. Height was again determined and percent sag was calculated according to Gardner et al. *Poultry Sci.* 61:75 (1982). Custards were stored in plastic bags at 10° C. for rheological evaluation.

The flat plate described above for evaluation of cake texture was replaced with a 10.5 mm diameter rod with a semispherical tip and force-deformation curves to failure were obtained for each custard. Cross head speed was 100 mm/min and all other parameters were the same as used in evaluations of the cakes. Five values were averaged to obtain the penetration force (FI) for each custard.

Organoleptic Evaluation. Flavor of processed and stored egg was evaluated by one judge using the USDA palatability score (Laboratory Methods for Egg Products, USDA, Agricultural Marketing Service Poultry Division, Grading Branch, Washington, D.C. 20250 (1984)).

Thermal Process. The process times and temperatures used in this study are presented in Table 2.

TABLE 2

Actual, Equivalent Times and Temperatures.
Calculated Heating Value of Treatments and
Predicted % SPL Based on Heating Value.[a]

Proc. No.	Actual		Equivalent		Heating Value[b] (G × 10⁴²)	Theoretical % SPL[c]
	Time (Sec.)	Temp. (°C.)	Time (Sec.)	Temp. (°C.)		
1	26.2	63.7	30.4	63.1	6.1	0.52
2	92.0	63.8	97.5	63.3	20.8	1.74
3	192.2	65.3	192.4	65.1	72.8	5.97
4	9.2	67.8	15.7	66.5	8.4	0.71
5	56.9	68.2	63.0	67.5	44.6	3.70
6	123.0	68.3	125.5	67.9	99.4	8.10
6.1	123.0	68.9	129.0	68.4	117.6	9.50
7	2.7	71.5	9.5	68.5	8.9	0.75
8	30.1	72.2	36.5	71.5	78.9	6.46
9	56.7	72.0	62.5	71.8	146.8	11.70

[a]See Swartzel, J. Food Sci. 47:1886 (1982), and Hamid-Samimi et al., supra (1984) for descriptions of heating value and % SPL.
[b]G values are determined based on activation energy for SPL.
[c]Based on laboratory batch data.

The 10 processes, numbers 1–9, were performed in the same chronological order as they are numbered. After gaining process experience and as the result of evaluations during the study, it was determined that longer holding times and temperatures than expected could be

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used. The actual temperatures reported in Table 3 are the averages of temperature readings, every 30 seconds, of the temperature probes at the beginning and end of the holding tube.

Equivalent times and temperatures as well as holding times and temperatures are set forth in Table 2. It can be seen that equivalent times are generally longer than the corresponding holding times, and equivalent temperatures are generally lower than the corresponding holding temperatures. At longer times, the differences between corresponding holding temperatures and equivalent temperatures are smaller.

The calculated heating value, G, shown in Table 2, gives a means for making a comparison of the relatively severity of the different processes. Processes 9, 6.1, 6 and 8 had the highest G values, respectively. The percent SPL based on the heating value (G) are also shown in Table 2.

Chemical Properties of Processed Egg. The results of alpha-amylase activity assays (Table 3) confirms that the enzyme is inactivated by mild heat processes. Table 3 shows that the thermal processes used did not affect protein content or the soluble protein content.

TABLE 3

Thermal Effects on Alpha-Amylase Activity,
Protein Content and % Soluble Protein.

Process No.	Alpha-Amylase[a]			MicroKjeldahl[b]			% Soluble Protein[c] (From Absorbance)
	Raw	UHT	Plant	Raw	UHT	Plant	
1	0.045	0.048	0.099	13.10	11.60	13.1	86.2
2	0.033	0.588	—	12.59	11.96	—	102.3
3	0.055	1.050	—	11.67	11.32	—	101.3
4	0.029	0.031	0.137	11.83	11.79	11.51	101.1
5	0.046	1.000	—	10.19	10.13	—	100.3
6	0.053	1.120	—	12.27	12.34	—	100.9
6.1	0.040	1.130	—	12.70	12.54	—	103.3
7	0.052	0.764	—	12.37	12.53	—	104.5
8	0.063	1.000	—	11.19	11.42	—	100.4
9	0.060	1.170	—	11.74	11.77	—	100.7

[a]Alpha-Amylase data is reported as the absorbance at 585 nm. Activity is inversely related in absorbance.
[b]MicroKjeldahl data is reported as percent protein.
[c]Absorbance at 280 nm of heated egg/control (raw) egg in solution as described by Hamid-Samimi et al. supra (1984).

The chemical data indicate that the processes did not result in extensive damage to the egg proteins. The predicted percent soluble protein losses (Table 3) were based on studies conducted with small amounts of egg (1 ml) being heated in the cup of a Brookfield viscometer (Hamid-Samimi et al., supra, 1984). The egg was heated while various shear rates were applied to simulate egg under dynamic conditions that exist in conventional heat exchangers. Thus, this work revealed that the model system resulted in prediction equations that underestimated the thermal treatments that liquid whole egg products could tolerate while still obtaining products with good functional properties. Analysis of the causes of these unexpectedly good results led to the guidelines discussed above which should be followed to obtain functionally superior ultra-pasteurized products.

Function of Processed Eggs. The functional properties of the processed eggs agreed with the physical and chemical results. Based on the data presented in Tables 4 and 5 for nonstored egg, there appeared to be very little heat effect on the performance of the ultra-pasteurized egg relative to raw or commercially pasteurized egg. Cake height as an indication of the leavening ability and force to deform, springiness, and relaxation

parameter (Peleg and Normand, *Rheologica Acta* 22:108 (1983)) as indicators of textural properties were very similar for all egg examined.

TABLE 4

Functional Properties of Cakes for Control (Raw), Ultrapasteurized (UP) at Zero Day Storage, and Commercially Pasteurized Eggs (Plant).

Variable	Treat-ment	Mean	Minimum	Maximum	n	C.V.
Maximum	Raw	10.02	7.79	13.70	10	17.3
Force[a]	UP	10.49	9.18	12.91	10	10.5
(N)	Plant	9.73	9.56	9.91	2	2.5
Relaxa-	Raw	0.394	0.379	0.417	10	3.24
tion[b]	UP	0.410	0.395	0.442	10	3.34
Para-	Plant	0.402	0.402	0.403	2	0.17
meter						
Spring-	Raw	0.83	0.81	0.86	10	1.94
iness[c]	UP	0.83	0.81	0.87	10	2.47
	Plant	0.82	0.81	0.82	2	1.32
Cake	Raw	65.1	63.3	66.7	10	1.66
Height	UP	61.7	55.1	65.5	10	5.26
(mm)	Plant	64.8	64.7	64.8	2	0.11
Water	Raw	0.873	0.832	0.891	10	2.53
Activity	UP	0.875	0.835	0.892	10	2.37
	Plant	0.892	0.892	0.892	1	—

[a]Force required to deform the sample of cake by 26 mm.
[b]Asymptotic relaxation value as defined by Peleg and Normand, supra (1983).
[c]Ratio of the second peak force to the first peak force in the force deformation cycle.

TABLE 5

Functional Properties of Custards for Controls (Raw), Zero Day Storage Ultrapasteurized (UP) and Commercially Pasteurized Eggs (Plant).

Variable	Treat-ment	Mean	Minimum	Maximum	n	C.V.
Penetra-	Raw	0.82	0.76	0.96	10	8.20
tion	UP	0.70	0.59	0.80	10	8.56
Force	Plant	0.79	0.77	0.81	2	3.69
(N)						
Custard	Raw	35.7	35.1	36.7	10	1.66
Height	UP	35.6	35.1	36.3	10	5.26
(mm)	Plant	34.6	34.0	35.3	2	0.11
% Sag	Raw	7.2	5.65	9.54	10	16
	UP	7.1	5.41	8.56	10	13
	Plant	4.6	2.66	6.51	2	59

The water activity of the cakes were similar indicating that the experimental handling procedures for the cakes were uniform and should not have affected the instrumental evaluation of textural properties. The custard data indicated that all egg sources evaluated had good ability to form gels. The gels had excellent integrity as indicated by the relatively low percent sag, yet the custards were relatively tender as indicated by the penetration forces. Although weep was not measured, very little syneresis was noted even after holding the custards overnight for textural evaluations. The limited organoleptic evaluation of the processed eggs indicated that the thermal processes did not affect flavor or aroma in scrambled eggs relative to scrambled egg made from a fresh shell egg. The USDA palatability scores were seven to eight (eight being the highest score).

Refrigerated Storage Effect. As long as the processed egg was not obviously spoiled, as indicated by organoleptic evaluations, storage at 4° C. maintained the chemical, functional, and organoleptic properties of the processed egg up to 24 weeks for some of the samples. The data presented in Tables 6, 7, and 8 were taken from stored egg that was judged organoleptically sound. The criteria for that judgment were: (1) that the color was normal, i.e., within the expected range of color observed for eggs immediately post-processing, and (2) that there were no objectional aromas or flavors. In this

study, because of the sampling procedure where most of the samples were checked at four-week intervals, there were no borderline decisions, a sample was obviously acceptable or unacceptable. Bright yellow colors, off-aromas, and pH values below seven were typical of samples judged to be spoiled.

TABLE 6

Means for Proteins, Solids and pH for Controls (Raw), Commercially Pasteurized (Plant) and Ultrapasteurized (UP) Egg.

Variable	Treat-ment[a]		Mean	Minimum	Maximum	n	C.V.
%	Raw		11.92	10.19	13.10	10	6.8
Protein	Plant		12.30	11.51	13.10	2	9.1
	UP	0	11.74	10.13	12.54	10	6.0
%	Raw		24.6	23.9	25.2	10	1.6
Solids	Plant		24.8	24.4	25.2	2	2.5
		0	24.5	24.0	25.0	10	1.3
		4	24.4	24.0	24.9	10	1.3
	UP	8	24.4	24.0	24.7	9	0.9
		12	24.3	23.8	24.7	7	1.3
		18	24.9	24.4	25.5	2	3.1
		24	24.8	24.7	24.9	2	0.3
pH	Raw		7.5	7.2	7.6	10	1.7
	Plant		7.1	7.1	7.2	2	0.5
		0	7.5	7.3	7.6	10	1.4
		4	7.4	7.2	7.6	10	1.4
	UP	8	7.4	7.3	7.5	9	1.2
		12	7.3	7.2	7.4	7	1.2
		18	7.4	7.4	7.4	2	0
		24	7.4	7.4	7.4	2	0

[a]Numbers indicate storage at 4° C. in weeks for processed eggs.

TABLE 7

Functional Properties of Cakes Made from Eggs Stored at 4° C.

Variable	Storage (Weeks)	Mean	Minimum	Maximum	n	C.V.
Maxi-	4	9.78	7.90	14.95	10	21.3
mum	8	10.37	7.82	14.53	9	20.5
Force[a]	12	11.29	8.84	14.28	7	18.2
(N)	18	11.42	10.32	12.53	2	13.6
	24	10.53	9.57	11.49	2	12.9
Relaxa-	4	.3937	0.3759	0.4167	10	3.7
tion	8	.3876	0.3636	0.4132	9	3.9
Para-	12	.3846	0.3717	0.4032	7	3.0
meter[b]	18	.3788	0.3788	0.3788	2	3.1
	24	.3745	0.3704	0.3788	2	1.5
Spring-		0.829	0.799	0.853	10	1.7
iness[c]	8	0.834	0.811	0.872	9	2.0
	12	0.834	0.820	0.843	7	0.9
	18	0.831	0.829	0.832	2	0.3
	24	0.815	0.787	0.843	2	4.9
Height	4	61	54	65	10	6.02
(mm)	8	64	63	67	9	2.06
	12	64	60	65	7	2.7
	18	63	62	65	2	3.0
	24	65	65	65	2	0.22
Water	4	0.860	0.796	0.888	10	4.2
Activity	8	0.884	0.868	0.900	9	1.1
	12	0.879	0.844	0.896	7	2.0
	18	0.872	0.872	0.872	1	—
	24	0.879	0.876	0.882	2	0.4

[a,b,c]See Table 4 for definition of terms.

TABLE 8

Functional Properties of Custards Made from Eggs Stored at 4° C.

Variable	Storage (Weeks)	Mean	Minimum	Maximum	n	C.V.
Pene-	4	0.68	0.47	0.77	10	12.7
tration	8	0.70	0.64	0.76	9	9.1
Force	12	0.75	0.57	0.83	7	20.3
(N)	18	0.94	0.85	1.02	2	12.6
	24	0.82	0.76	0.88	2	10.5

TABLE 8-continued

		Functional Properties of Custards Made from Eggs Stored at 4° C.				
Variable	Storage (Weeks)	Mean	Minimum	Maximum	n	C.V.
Custard	4	35	34	36	10	2.4
Height	8	35	34	36	9	1.6
(mm)	12	35	35	36	7	1.2
	18	36	36	36	2	0.4
	24	35	35	35	2	1.0
% Sag	4	7.1	3.0	11.6	10	38.1
	8	5.9	3.5	7.5	9	20.5
	12	6.5	4.6	8.0	7	19.5
	18	7.2	6.4	8.1	2	15.9
	24	6.6	4.9	8.2	2	36.0

Visual observations of the interiors of opened packages revealed very little sedimentation during storage. A very thin layer of a fine, light yellow, granular-like material was observed on the bottom of cartons after four weeks of refrigerated storage.

Shelf Life. The times of spoilage of egg from each trial are presented in Table 9.

TABLE 9

	Shelf Life for Liquid Whole Egg Stored at 4° C.
Process	Shelf Life (Weeks)
1	4-8
2	8-12
3	>12
4	8-12
5	>18
6	18-24
6.1	>24
7	12-18
8	20-24
9	18-20

These data were used to generate the time and temperature guidelines set forth in FIG. 5.

The invention has been discussed with a degree of specificty above. This discussion has been provided for illustrative purposes only, with the scope of the invention being defined by the following claims.

That which is claimed is:

1. A method of making a packaged liquid whole egg product characterized by a preselected refrigerated shelf life of about four weeks to about 36 weeks, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is heated by contacting said liquid whole egg product to a heated surface for a predetermined time and to a predetermined temperature while at least periodically subjecting said continuous stream of liquid whole egg product to turbulence, wherein the liquid while egg product is heated for a predetermined time and to a predetermined temperature insufficient to cause more than a 5% soluble protein loss from said product, wherein the total thermal treatment received by the liquid whole egg product is described by an equivalent temperature and an equivalent time defining a point above the 5% SPL (BATCH) line of FIG. 3, and wherein said predetermined temperature and said predetermined time are chosen to impart said preselected shelf life to said liquid whole egg product, followed by aseptically packaging the liquid whole egg product.

2. A method according to claim 1, wherein said pasteurizing apparatus is sterilized before said liquid whole egg product is passed therethrough, and wherein said packaged liquid whole egg product is characterized by a preselected shelf life of about eight weeks to about 36 weeks.

3. A method according to claim 1, wherein said liquid whole egg product is subjected to turbulence for a major portion of the time said liquid whole egg product is heated.

4. A method of making a packaged liquid whole egg product characterized by a preselected refrigerated shelf life of about four weeks to about 36 weeks, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is
   (a) heated by contacting said liquid whole egg product to a heated surface for a time sufficient to raise said liquid whole egg product to a predetermined holding temperature while at least periodically subjecting said continuous stream of liquid whole egg product to turbulence, then
   (b) maintained at said preselected holding temperature for a predetermined holding time, wherein said holding temperature and holding time are selected to cause a soluble protein loss of not more than 5% from said product, and wherein said holding temperature and holding time are selected to impart said preselected shelf life to said liquid whole egg product, and then
   (c) cooled, wherein the total thermal treatment received by the liquid whole egg product is described by an equivalent temperature and an equivalent time defining a point above the 5% SPL (BATCH) line of FIG. 3, followed by
   (d) aseptically packaging the liquid whole egg product.

5. A method according to claim 4, wherein said pasteurizing apparatus is sterilized before said liquid whole egg product is passed therethrough, and wherein said packaged liquid whole egg product is characterized by a preselected shelf life of about eight weeks to about 36 weeks.

6. A method according to claim 4, wherein said liquid whole egg product s subjected to turbulence for a major portion of the time said liquid whole egg product is heated.

* * * * *

United States Patent [19]

Swartzel et al.

[11] Patent Number: 4,994,291

[45] Date of Patent: * Feb. 19, 1991

[54] **METHOD FOR THE ULTRAPASTEURIZATION OF LIQUID WHOLE EGG**

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[*] Notice: The portion of the term of this patent subsequent to Feb. 28, 2006 has been disclaimed.

[21] Appl. No.: 535,718

[22] Filed: **Jun. 11, 1990**

Related U.S. Application Data

[63] Continuation of Ser. No. 311,594, Feb. 16, 1989, which is a continuation of Ser. No. 904,744, Sep. 8, 1986, Pat. No. 4,808,425.

[51] Int. Cl.⁵ A23L 3/00

[52] U.S. Cl. 426/399; 426/521; 426/614

[58] Field of Search 426/399, 521, 614

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[57]   **ABSTRACT**

Methods of ultrapasteurizing liquid whole egg products in continuous flow, high temperature, short time pasteurization equipment are provided. The equivalent point method is preferably used to evaluate the total thermal treatment received by the product in this equipment. Also disclosed is a method of making liquid whole egg products having preselected, extended, refrigerated shelf lives.
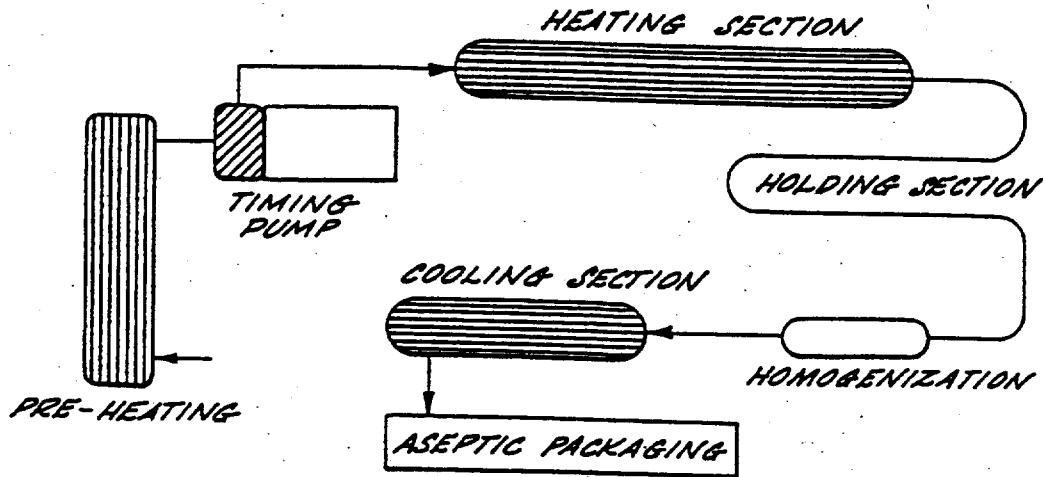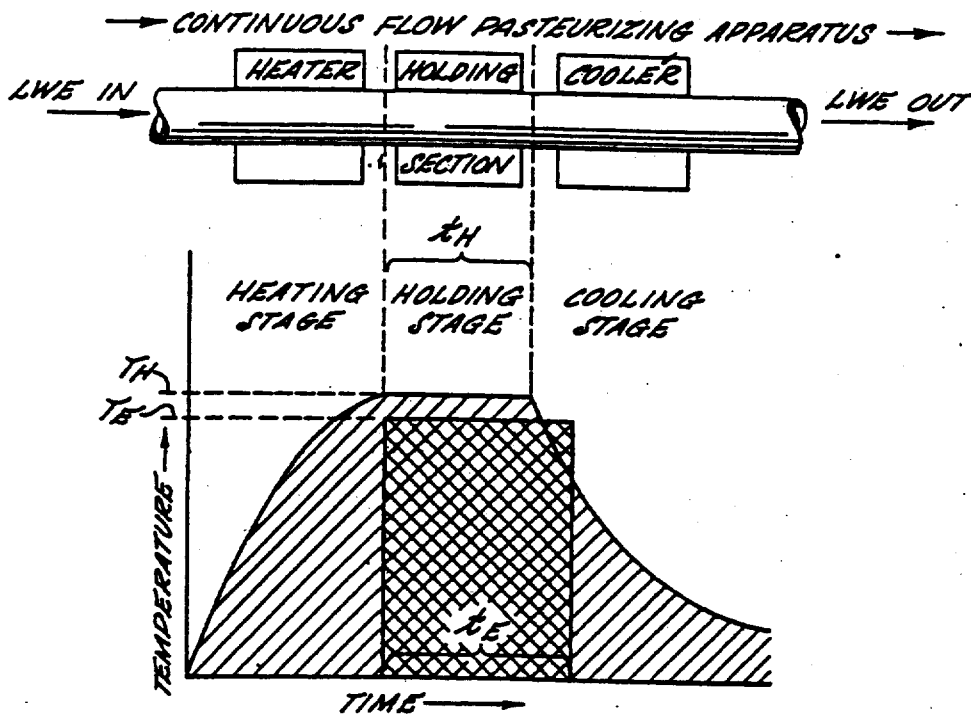
21 Claims, 4 Drawing Sheets

HEATING SECTION

HOLDING SECTION

TIMING PUMP

COOLING SECTION

HOMOGENIZATION

PRE-HEATING

ASEPTIC PACKAGING

$$-\text{fig. 1.}$$

CONTINUOUS FLOW PASTEURIZING APPARATUS

HEATER | HOLDING | COOLER

LWE IN

SECTION

LWE OUT

t_H

HEATING STAGE | HOLDING STAGE | COOLING STAGE

T_H
T_E
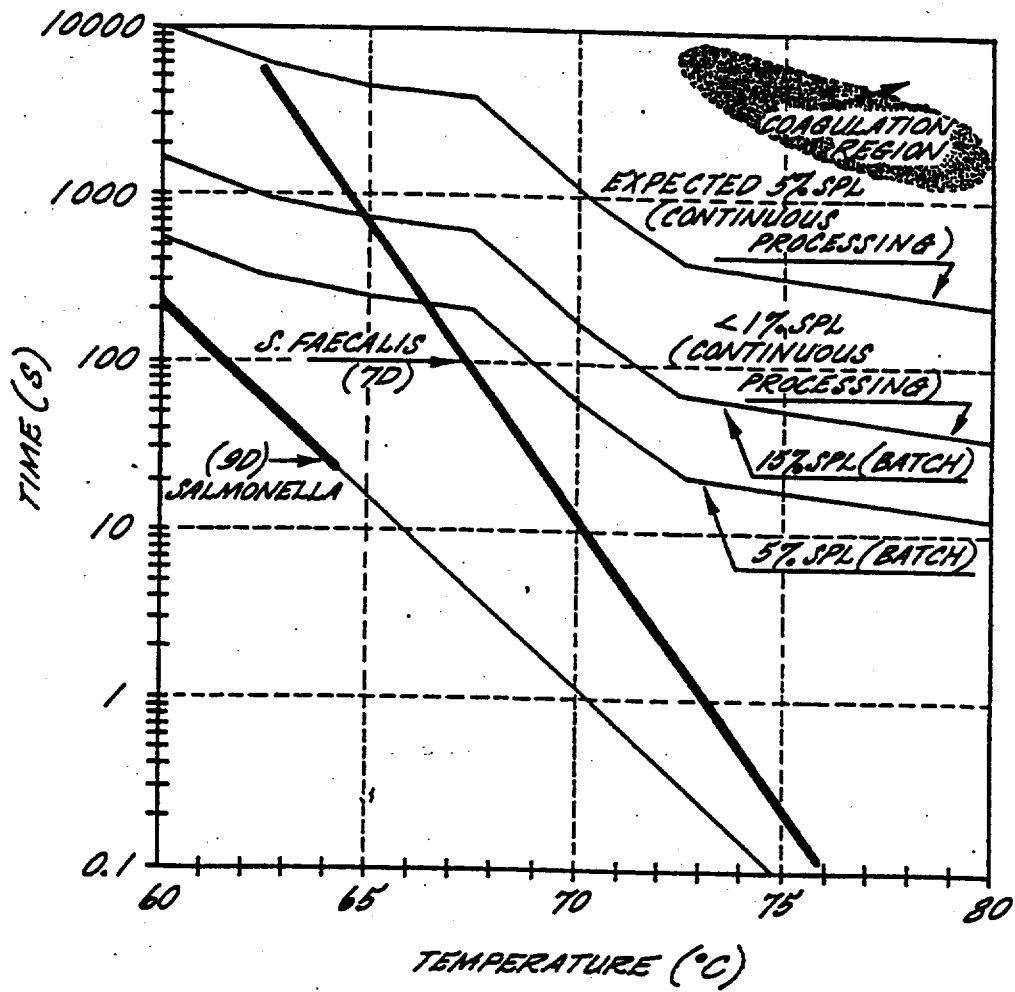
TEMPERATURE

t_E

TIME

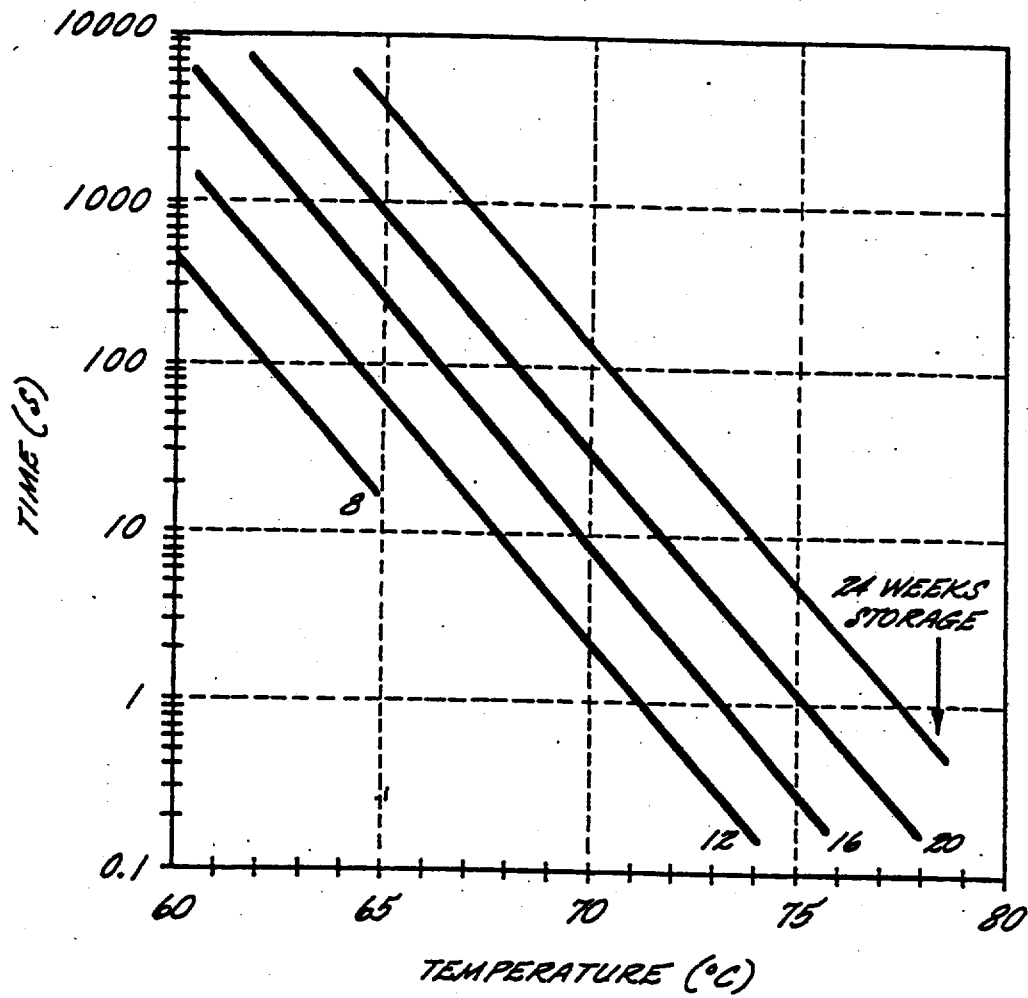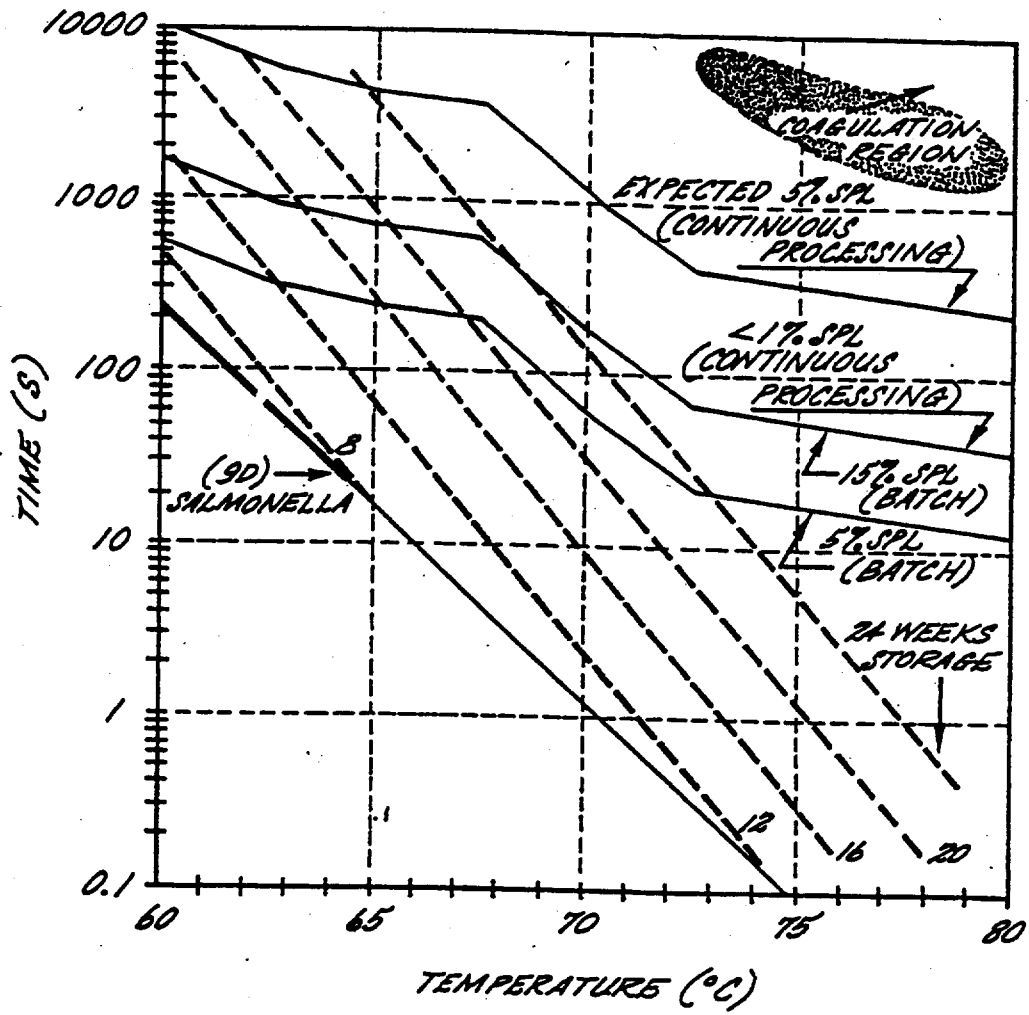$$-\text{fig. 2.}$$

FIG. 3.

FIG. 4.

FIG.5.

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METHOD FOR THE ULTRAPASTEURIZATION OF LIQUID WHOLE EGG

This application is a continuation of application Ser. No. 07,311,594, filed Feb. 16, 1989, which is a continuation of application Ser. No. 06/904,744, filed Sept. 8, 1986, now U.S. Pat. No. 4,808,425.

DESCRIPTION OF THE INVENTION

The present invention relates to the pasteurization of liquid whole egg products generally, and particularly relates to ultrapasteurization methods which can be used to produce liquid whole egg products which have good functional properties and which have extended refrigerated shelf lives.

BACKGROUND OF THE INVENTION

The U.S. egg industry produced more than 300 million pounds of frozen pasteurized egg products in 1985. The relatively mild pasteurization processes used are designed to eliminate Salmonella from eggs for all practical purposes, but do not destroy organisms capable of spoiling egg products held under refrigerated temperatures above freezing. The survival of spoilage organisms in pasteurized egg, coupled with conventional packaging technology, results in products with limited shelf life (7–14 days at 40° F.) that require freezing and frozen distribution systems for preservation. Freezing is cost intensive, lowers the functional quality (flavor, performance, etc.) of the egg product, and results in an inconvenient product that requires thawing prior to use.

Standard pasteurization practices for liquid whole egg products are generally discussed in the *Egg Pasteurization Manual* (USDA Agricultural Research Service 1969). See also U.S. Pat. No. 3,949,099 to Kaufman, at column 1, lines 46–58 (summarizing pasteurization processes). The *Egg Pasteurization Manual* notes that experiments conducted in England to establish treatment conditions used there, which were carried out in a high temperature, short time pasteurization unit, included trials with holding times of two and one-half minutes and temperatures up to 151 degrees Fahrenheit (66.1 degrees Centigrade). The functional quality of these eggs is not discussed; however, it is noted that England adopted a lower temperature of 148 degrees Fahrenheit as a treatment condition The Manual observes that such "severe" treatments help increase the stability of egg products in liquid form, but does not teach how this can be accomplished without sacrificing desirable functional properties of the products For other types of egg products which are more heat stable, pasteurization temperatures as high as 152 degrees Fahrenheit (66.67 degrees Centigrade) have been reported. Again, little is known about how to ultrapasteurize (decrease the number of spoilage microorganisms to levels lower than obtained with a pasteurization procedure) these products by heating without sacrificing functional performance.

Higher temperatures than those investigated in England have been explored See e.g., Essary, E. O., Rony, P. R., and Collins, W. F., *New uses of heated aseptically packaged fluid egg products*, Report to the American Egg Board (1983). This work suggested that merging techniques of ultrapasteurization with aseptic packaging can be accomplished to yield safe, stable, and functional liquid whole egg. This research suggested and used a heat exchanger operated in laminar flow to pro-

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cess whole egg at elevated temperatures, and used an ethylene oxide-flushed glove box to aseptically package the product (neither device approved for the commercial production of a salable product). Holding temperatures of up to 154 degrees Fahrenheit (67.8 degrees Centigrade) were reported. The results of this pioneering work demonstrated the possibility of extending the refrigerated shelf life of liquid whole egg products, but did not enable the commercial production of a refrigerated product which could be sold to consumers.

To carry out ultrapasteurization of liquid whole egg products on commercial equipment, the time and temperature parameters of the thermal treatment must be selected with care. Arbitrary increases in thermal treatment will likely produce a functionally unacceptable product, or—even worse—coagulation of the product and blockage of the pasteurizing equipment. Because such pasteurizing equipment operates at high pressures (e.g., 1,500 p.s.i. and more) the consequences of blockage are serious. For these reasons, it is essential to know how liquid whole egg products respond to various thermal treatments before experimenting with the production of these products on commercial equipment.

Because this essential information was not available, Hamid-Samimi investigated the time and temperature parameters which should be used in commercial equipment to obtain a functionally acceptable, ultrapasteurized, liquid whole egg product. M. H. Hamid-Samimi, Criteria Development for Extended Shelf-Life Pasteurized Liquid Whole Egg. Ph.D. Thesis, North Carolina State University (1984). This research was carried out at the laboratory bench, with a Brookfield viscometer, which processed the product in small batches rather than continuously. Processing times and temperatures defining thermal treatments producing a soluble protein loss (SPL) of up to 5% from the product, as an upper limit, were suggested as producing a functionally acceptable product. The suggested 5% SPL limit was defined by a graph line in the thesis this line is reproduced herein in FIG. 3 as the 5% SPL (Batch) line. Time and temperature values tested by other investigators which were believed to be the limits of pasteurization are summarized in M. H. Hamid-Samimi and K. R. Swartzel, *J. Food Processing and Preservation* 8: 219, 221 FIG. 1 (1984). All are below the 5% SPL (Batch) line.

The present inventors sought to test the predictions of Hamid-Samimi by ultrapasteurizing liquid whole egg on continuous flow, high temperature, short time pasteurization equipment. It was unexpectedly found that functionally acceptable liquid whole egg can be produced at times and temperatures greater than previously believed. These findings, which will be explained in detail below, enable the commercial production of functionally acceptable products with longer refrigerated shelf lives than heretofore available. As will also be explained below, discovery of these unexpected results has led to the identification of several steps which should be taken to produce ultrapasteurized liquid whole egg products that have superior functional properties.

The object of the present invention, in short, is to provide liquid whole egg products for refrigerated distribution which have greatly reduced levels of spoilage microorganisms, while still having good functional properties.

SUMMARY OF THE INVENTION

This object is achieved by a method for ultrapasteurizing liquid whole egg products. The method comprises passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is heated to a predetermined real temperature. The method is practiced so that the total thermal treatment received by the liquid whole egg product is described by an equivalent temperature and an equivalent time (these terms are explained in detail below) defining a point above the 5% SPL (Batch) line of FIG. 3, but insufficient to cause coagulation of the product.

Also disclosed herein is a method of making a packaged liquid whole egg product characterized by a preselected refrigerated shelf life of from about four weeks to about 36 weeks. This method comprises passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is heated for a predetermined time and to a predetermined temperature. The predetermined time and the predetermined temperature are chosen to impart the preselected shelf life to the liquid whole egg product. After it is heated, the liquid whole egg product is aseptically packaged.

Preferably, the continuous stream of liquid whole egg product referred to in each of the methods above is at least periodically subjected to turbulence while it is heated. The liquid whole egg products are also, preferably, homogenized after they have been heated In addition, the methods described above are more narrowly described as methods in which the liquid whole egg product is heated to a predetermined holding temperature, then maintained at said predetermined holding temperature for a predetermined holding time, and then cooled.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of a continuous flow pasteurizing apparatus suitable for carrying out the present invention.

FIG. 2 is a diagram illustrating the differences and relations between real holding times and holding temperatures, and equivalent times and equivalent temperatures for describing total thermal treatments, in continuous flow pasteurizing equipment.

FIG. 3 is a graph showing time and temperature regions for the ultrapasteurization of liquid whole egg products.

FIG. 4 is a graph showing equivalent times and equivalent temperatures that give particular refrigerated shelf lives for liquid whole egg.

FIG. 5 is a combination graph in which FIGS. 3 and 4 are superimposed, with the *S. faecalis* line removed.

DETAILED DESCRIPTION OF THE INVENTION

Thermal treatments simultaneously produce beneficial and undesirable changes in food products. Knowledge of kinetic methods, and how they can be applied to the mechanics of designing a thermal process, aids in attaining food quality retention and process efficiency. Determining the time and temperature requirement for a thermal process depends upon destruction of spoilage and disease causing microbial spores while minimizing undesirable physical, chemical and biological transformations that occur within the product.

As schematically shown in FIG. 1, with arrowheads indicating direction of flow, continuous flow thermal processing equipment comprises heating, holding, and cooling sections. The thermal treatment received by the product in the heating and cooling stage, (illustrated in FIG. 2), is oftentimes not considered instead, only the holding time (t_H) and holding temperature (T_H) are considered. However, when products are pasteurized in such equipment at higher temperatures and shorter times, as is taught herein, the contribution of the heating stage, and perhaps the cooling stage, to the total thermal treatment of the product becomes significant, and must be accounted for if a product with good functional qualities is to be obtained and coagulation during pasteurization is to be avoided. It is accordingly recommended that the equivalent point method for evaluating thermal treatments be applied in practicing the present invention. As explained in detail below, this method describes the total thermal treatment received by a product in continuous flow equipment with one equivalent time (t_E) and one equivalent temperature (T_E) (see FIG. 2).

Procedures for use of the equivalent point method for analyzing the thermal effects on products during continuous flow heating have been previously outlined (Swartzel, 1982, *J. Food Sci.* 47:1886 and Swartzel, 1986, *J. Agric. Food Chem.* 34:397) and are known to those skilled in the art. This method differs substantially from previous methods in that all other methods define the thermal treatment based upon a single factor such as enzyme inactivation, microbial destruction, protein denaturation, nutrient loss, etc. The problem with these other methods is that a physical and/or chemical effect (flavor, color, product separation and gelation during storage if thermally related) may actually be the shelf life limiting factor.

The unique feature of the equivalent point method lies in the fact that, for any thermal curve, one equivalent time and equivalent temperature combination exists (see FIG. 2). This equivalent time and temperature combination will yield the exact thermal effect on *all* constituents within the product as would the original thermal curve. This unique time and temperature combination is not dependent on *individual* constituent kinetics, as are all previous thermal evaluation procedures (it is independent of constituent activation energy).

To determine the equivalent point of a thermal system, a complete thermal history of the treatment must be available. This is obtained by measuring mixed mean product temperatures at various locations (entrance to the heat exchanger, exit of the heat exchanger and at least two locations inside the heat exchanger). Time is calculated by correlating mean residence time with location of the temperature probe. With heat exchangers into which it is difficult or impractical to insert thermal probes, time-temperature curves are calculated based on knowledge of the product's physical characteristics and on the geometry of the processing equipment.

With available time-temperature curves and a basic knowledge of kinetic relationships, equivalent points can routinely be calculated. The log of a product constituent concentration ratio (initial concentration divided by concentration after treatment) is set equivalent to the integration of that constituent's Arrhenius equation (or any other appropriate function describing the temperature dependency of the rate of the reaction associated with the constituent change) for the particu-

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lar time-temperature interval (thermal history previously defined). For a given activation energy each section of a thermal treatment (heating, holding, and cooling) will produce a unique thermal constituent concentration ratio For the different sections the effect may be summed. For the original activation energy selected, a linear infinite log (time)temperature relationship exists Any and all of these infinite time and temperature combinations would produce the same thermal effect on a constituent (with the same activation energy) as during the original thermal treatment. By reexamining the original thermal curves with different activation energies a series of infinite linear log (time)-temperature relationships are developed (one line in a log (time)-temperature plot per activation energy). Uniquely all lines intersect at one point. This unique time-temperature is the equivalent point for the original thermal curve. It accounts for all thermal treatment and is used to accurately predict constituent change, or product characteristic.

FIG. 3 sets forth thermal treatments which should be used to ultrapasteurize liquid whole egg products. Thermal treatments defined by points above the 5% SPL (Batch) line have not heretofore been suggested. For practicing the present invention in continuous flow processing equipment, the thermal treatment is described by a point on FIG. 3 defining an equivalent time and an equivalent temperature, as explained above. The thermal treatment should be more than sufficient to pasteurize the liquid whole egg product. "Pasteurize" means to cause a nine log cycle (9D) or 99.9999999% reduction in Salmonella in the product being treated. The thermal treatment should be insufficient to cause the liquid whole egg product to coagulate. The thermal treatment should more particularly cause not more than a 15% soluble protein loss (SPL) in the liquid whole egg product being treated, and will preferably cause not more than a 5% soluble protein loss in the product being treated. The expected 5% SPL (continuous processing) line on FIG. 3 indicates approximately the upper limit on thermal treatments which can be tolerated without sustaining more than a 5% soluble protein loss (the exact location of this line for any one process will depend on the physical factors discussed below). More preferably, the thermal treatment will be designed to produce not more than about a 1% soluble protein loss from the product. As shown in FIG. 3, equivalent times and equivalent temperatures defining points along the line previously believed to represent the line at which a 15% soluble protein loss would be obtained (the 15% SPL (Batch) line), are now known to represent thermal treatments which produce ultrapasteurized products having less than a 1% soluble protein loss under continuous flow.

The line defining thermal treatments causing a seven log cycle reduction in the spoilage bacteria *Streptococcus faecalis* is labeled in FIG. 3 as the *S. faecalis* (7D) line. The *S. faecalis* line has a steeper slope than the several SPL lines. This illustrates that thermal treatments employing higher temperatures and shorter times are preferred for practicing the present invention. Thus, holding soluble protein loss constant (so that treatment time must be decreased as treatment temperature is increased), thermal treatments in which the product is subjected to treatment temperatures of about 67.0 degrees Centigrade or more are preferred to thermal treatments in which the product is subjected to treatment temperatures of 65° C.; treatment temperatures of about

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69.0° C. or more are preferred to treatment temperatures of 67° C.; treatment temperatures of about 71.0° C. or more are preferred to treatment temperatures of 69° C.; treatment temperatures of about 73.0° C. or more are preferred to 71° C.; and so on. The foregoing statement is true whether the real temperatures (or holding temperatures) of the processes are being compared, or equivalent temperatures are being compared (thus the term "treatment temperature" is used to encompass both).

Treatment temperatures are primarily limited by the ability to accurately time the duration of the thermal treatment: as temperature is increased the treatment time must be decreased, and shorter treatment times are more difficult to administer with precision. Generally, equivalent temperatures not more than about 90° C. are preferred, and equivalent temperatures not more than about 80° C. are more preferred.

Desirable thermal treatments for practicing the present invention can also be described with reference to the *S. faecalis* lines. Preferably, the thermal treatment will define a point above the *S. faecalis* (7D) line, and more preferably the thermal treatment will define a point above the *S. faecalis* (9D) line. While this latter line is not plotted in FIG. 3, it can be plotted in accordance with the equations given below.

Equations for lines in the figures are as follows, where t=time in seconds, T=temperature in degrees Centigrade, and n=number of decimal reductions. Salmonella line: $\log(t)=15.96-0.227(T)$. *S. faecalis* lines: $\log(t)=24.62+\log(n)-0.346(T)$. % SPL lines: $\log(t)=\log(\%SPL)+a-b(t)$, where a and b are given in TABLE 1 below:

TABLE 1

T range °C.	a (for Batch lines)	b	a (Expected) (for continuous flow lines)
60–62.5	7.494	0.091	1.761
62.5–67.5	4.103	0.037	5.370
67.5–72.5	14.68	0.194	15.942
72.5 and above	3.014	0.033	4.281

These equations can be used to extend the teaching of the figures beyond their depicted scope.

The liquid whole egg product is preferably heated by contacting the product to a heated surface. The heated surface is comprised of a corrosion-resistant, non-toxic and nonabsorbent material such as stainless steel. Standards for evaluating the acceptability of such product contact surfaces (the 3-A Sanitary Standards) are known and established. See, e.g., *Egg Pasteurization Manual*, supra, at 27.

To obtain a product with reduced amounts of spoilage microorganisms, the pasteurizing apparatus should be sterilized before the liquid whole egg product is passed therethrough. Sterilizing is preferably accomplished by passing hot water under pressure through the pasteurizing apparatus, as is known in the art, so that, among other things, hot water is contacted to the heating surface at a temperature and pressure and for a time sufficient to sterilize the heating surface.

In addition, the product, after ultrapasteurization, should be aseptically packaged. Aseptically packaged means packaged to the exclusion of microorganisms other than those carried by the liquid whole egg product. Equipment suitable for aseptically packaging liquid whole egg products is commercially available.

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FIG. 4 illustrates the refrigerated shelf life of liquid whole egg after it is ultrapasteurized and aseptically packaged, as explained above. The term "refrigerated," as used herein, means stored at a temperature of 4° C. Time and temperatures for points on each line represent equivalent times and temperatures, as also explained above. A liquid whole egg product having a preselected shelf life of from about 4–36 weeks is made by selecting a point on a line or in a region which will provide the desired shelf life, determining the equivalent time and equivalent temperature which correspond to the point selected, and—preferably through the use of the equivalent point method—establishing the operating conditions on the particular pasteurizing apparatus being used that will provide the selected thermal treatment. Products having shelf lives not depicted in FIG. 4 are made by extrapolating the teachings of the figure, in light of the teachings above. Preferably, this process is carried out in pasteurizing apparatus which has been sterilized before the liquid whole egg product is passed therethrough, as explained above, to produce products having shelf lives of about eight weeks or more. In addition, it will be appreciated that longer shelf lives are generally obtained at the expense of greater levels of soluble protein loss. Thus, if product distribution systems do not require otherwise, products with shelf lives of up to about 32 weeks are preferred, and products with shelf lives up to about 24 weeks are more preferred.

FIG. 5 combines portions of FIGS. 3 and 4. It shows how the thermal treatments selected to provide a desired shelf life can at the same time be selected to provide products with good functional properties. More particularly, thermal treatments can be selected which produce liquid whole egg products having the desired shelf life and a soluble protein loss not greater than 5%.

The foregoing graphs have been presented to aid the understanding of the present invention. Some variation about the plotted lines is to be expected when the present invention is practiced on different equipment, or with different products. These graphs are accordingly not to be taken as limiting the present invention, as departures could be made therefrom while still capturing and benefitting from the teachings of the invention.

To obtain a superior ultrapasteurized liquid whole egg product, the contact time of the liquid product to heated surfaces during pasteurization should be reduced. More particularly, every particle of liquid whole egg product should be in contact with the heated surface or surfaces of the unit in which the product is heated for a total time less than the residence time of the particle in the heating unit. (The term "particle" as used herein has its standard meaning in the egg pasteurization field. See, e.g., 7 C.F.R. § 59.570(b) (1985)). This is accomplished by mixing the product at least periodically while it is being heated. In a continuous flow pasteurizing apparatus, such mixing is accomplished by introducing turbulence into the stream of the product at least periodically while it is being heated, as discussed below. Other steps which are preferably employed to reduce fluid element contact time to heated surfaces include providing portions of the thermal treatment in which fluid elements are not in contact with heated surfaces, such as by providing a portion of the thermal treatment in a holding section, and by providing heated contact surface area to product volume ratios of less than 18 cm²/cm³ (Thus the surface area to volume ratio is preferably less than about 10, and is more preferably in the area of about 2).

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It is also desirable to induce physical forces to make the product more homogeneous prior to thermal treatment, such as by inducing shear forces capable of reducing protein and fat unit size This is preferably accomplished by dispersing the product prior to heating. Dispersing may be carried out with a dispersing valve or with a timing pump, as is known in the art. Such treatment advantageously reduces fouling, and serves to reduce any tendency of the product to coagulate. Such a dispersing step may be carried out by conducting a more rigorous homogenization step, but it is recommended that such more expensive homogenizing equipment be used as described below.

It is preferable that a homogenization step after heating be included. The term "homogenized," as used herein, means to subject the product to physical forces to reduce particle size. Such procedures are known in the art, and may be carried out on different types of equipment. It is preferable to carry out this homogenizing step with homogenizing equipment at total pressures of about 1,000 p.s.i. or more. Pressures of about 1,500 p.s.i. or more are more preferred, and pressures of 2,000 p.s.i. or more still more preferred.

Of these steps, it is particularly desirable to mix the liquid whole egg product at least periodically while it is heated. As noted above, in continuous flow equipment mixing is carried out by at least periodically subjecting the stream of liquid whole egg product to turbulence while it is heated. Turbulence, which is the mixing of particles over the cross-section of the product stream, is discussed in the *Egg Pasteurization Manual* at pages 6–8. Such turbulence is characterized by a Reynolds number greater than about 2,300, and preferably greater than about 4,600. Commercial high temperature, short time pasteurizing units are available which at least periodically impart turbulence to the stream of product being pasteurized while the product is being heated. For the purposes of the present invention, greater levels of turbulence are preferred. Thus the liquid whole egg product is preferably subjected to turbulence for a major portion of the time it is heated Plate heat exchangers, trombone heat exchangers, spiral heat exchangers, and scrape surface heat exchangers are illustrative of the types of known heat exchangers which can be used to subject liquid whole egg products to turbulence while they are heated. The physical forces induced in scrape surface heat exchangers are generally thought of as "mixing," but these exchangers induce turbulence at least in regions of the product stream, and are therefore considered to induce turbulence for purposes of the present invention.

Examples of whole egg products which can be pasteurized in liquid form by the method of the present invention include whole egg, fortified whole egg (whole egg with added yolk), salt whole egg (e.g., salt 10%), sugar whole egg (e.g., sugar 10%), blends of whole egg with syrup solids, syrups, dextrose and dextrins and/or gums and thickening agents, blends of whole eggs with less than 1% sugar and/or salt, scrambled egg mixes (for example, a mix of about 51% egg solids, 30% skim milk solids, 15% vegetable oil and 1.5% salt), reduced cholesterol egg products and blends thereof, custard blends, and the like. Products which are extremely sensitive to thermal processing and which are particularly suitable for ultrapasteurization by the present invention include, for example, liquid whole egg and blends thereof (less than 2% added nonegg ingredients), fortified whole egg and blends thereof

(24–38% egg solids, 2–12% added nonegg ingredients), liquid salt whole egg, liquid sugar whole egg, and other liquid whole egg blends which are 24–38% egg solids and 12% or less of added nonegg ingredients. Terms used herein have their standard meaning in accordance with industry and regulatory usage. See, e.g., 7 C.F.R. § 59.570(b) (1985).

The invention having been explained in general terms above, the following examples are provided to further illustrate the invention.

EXAMPLES 1–10

Raw Egg Product. Raw liquid whole egg was obtained from a local breaking plant (Gold Kist, Durham, N.C.). The egg was taken from their raw holding tank which was agitated to thoroughly blend approximately 30,000 pounds of egg. The egg was manually filled into 13.6 kg (30 lb) metal cans and were kept refrigerated before being transported 13.2 km (20 mi) to our laboratory in an insulated truck. The egg was held overnight at 4° C. (40° F.) or allowed to stand at room temperature for up to 12 hours to achieve higher bacterial numbers

Thermal Processes. The time-temperature processes used in this study were designed to be equal to or more severe than minimum conditions defined by the 9D line for the destruction of Salmonella in whole egg (USDA, 1969) and within predetermined limits of denaturation of egg protein defined as percent soluble protein loss (%SPL) by Hamid-Samimi et al., *J. Food Sci.* 49:132 (1984). The objectives of this design were to provide Salmonella negative whole egg with a low number of surviving spoilage organisms while retaining adequate functional properties.

The thermal processing system used is outlined in FIG. 1. It consisted of a plate-type heat exchanger for preheat, various modifications of the No-Bac Unitherm model XLV (Cherry Burrell Corporation, Cedar Rapids, Iowa) to achieve different holding times, an aseptic homogenizer operated at 10.34 mPa (1,500 p.s.i.), and an aseptic packaging system (Model AB-3-250, Tetra Pak Inc., Dallas, Tex.) The flow rate was $2.89 \times 10^{-4} m^3/sec$ (275 GPH) with heating, holding, and cooling pipe diameters of 12.45 mm ID (5/8" nominal) stainless steel.

Before each process the entire system was sterilized at 121° C. for 30 minutes using hot water in the product section and steam in the heating media section and then cooled. The product and heating media temperatures were recorded for evaluation of the thermal effect of the heating section and to determine the total thermal effect Swartzel, *J. Agri. Food Chem.* 34:396 (1986). The temperatures were measured using Type T thermocouples with an electronic data logger (Model 9302, Monitor Labs., Inc., San Diego, Calif.). Each thermocouple probe was scanned every 30 seconds (one minute for process #1) and the readout sent to a computer for analyses The specific locations of the thermocouples in the system were as described by Swartzel and Jones. Paper No. 84-6006 of the American Society of Agricultural Engineers (1984).

Approximately one hour prior to initiation of each process, 408.2 kg (900 lb) of raw egg were transferred from the metal cans to a 568 l (150 gal) vessel (Creamery Package Mfg. Co., Chicago, Ill.) and then mixed at room temperature with the stirring propeller at ca. 30 r.p.m. This volume of egg required approximately 20 minutes to process, therefore the last liter of egg was processed not later than 80 minutes after being removed

from the cooler. Nine processes designated 1, 2, 3, 4, 5, 6, 7, 8, and 9 were run. Process 6 was repeated and designated 6.1. They were conducted two days apart on egg picked up on the same day. Egg for processes 6.1 to 9 were held at room temperature for not more than 12 hours to achieve a higher initial microbial load. All egg incubated at room temperature was chilled to 4° C. (40° F.) prior to processing.

After holding the egg at the scheduled process time and temperature and prior to packaging, the temperature was reduced to less than 10° C. (50° F.) in less than 26 seconds. Occasionally, due to technical difficulties it was not possible to cool the processed egg to below 10° C. In those instances the processed egg was moved into a freezer at −20° C. for 20 minutes after packaging. The packaging material was a low oxygen permeable laminate of polyethylene, paper, and aluminum foil formed into 250 ml containers (Tetra Pak aseptic filler model AB-3) Each package was dated and coded so that egg processed in the first seven minutes, the second seven minutes, and the remaining time were numbered 1, 2, and 3, respectively. The processed and packaged egg was held overnight at 4° C. (40° F.) prior to obtaining samples and being distributed for four and 10° C. storage.

Sampling. Samples of raw egg for physical, chemical, and functional testing were aseptically removed from the mixing vat approximately 30 minutes prior to processing. The samples were then held overnight at 4° C. for evaluation with the pasteurized egg. Pasteurized samples were obtained on the day after processing or at selected times during storage at four and 10° C. Analyses were made on the combined contents of three or four individual packages representing the first, second, and third portions of each process run. When four packages were required, two packages from the middle portion of each process were used. Any sediment on the bottom of the cartons was scraped out and mixed into the egg by magnetic stirring.

Chemical Assays. The pH of the product was determined with a Fisher Accumet pH meter, model 600, equipped with a calomel reference and glass indicating electrodes. Solids were determined in triplicate by weighing two ml samples into disposable aluminum pans and drying in a forced draft oven for 24 hours. The AOAC (1985) microKjeldahl procedure was used to determine protein content of the samples. The extent of denaturation was estimated by determining the loss of soluble protein as described by Hamid-Samimi et al., supra, and the alphaamylase activity of the egg was determined as described by Shrimpton and Monsey, *J. Hyg.* 60:153 (1962).

Sponge Cakes. True sponge cakes were made by using half of the amounts of ingredients listed following the procedures given by Gorman and Ball (1986) (Chapter 15 in *Egg Science and Technology*, 3rd Ed., W. J. Stadelman and O.J. Cotterill, Eds., AVI Publishing Co., Inc. Westport, Conn.) with the omission of vanilla. Two separate batches of batter were mixed for each treatment and 340 g of batter was weighed into rectangular pans (21.5 × 11.5 × 6.5 cm, id.). Cakes were baked at 191° C. for 25 minutes, inverted on a wire rack and allowed to stand at room temperature overnight. Heights were determined from the mean of four measurements along the center line of the long axis of the cake. Cakes were then kept in plastic bags for further rheological evaluations.

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Textural properties of the cakes were evaluated using an Instron Universal Testing Machine (Model 1122, Instron Engineering Corporation, Canton, Mass.). A plate was connected to a 2000-g load cell and positioned at the surface of the 5-cm cube of cake. The cross head and chart speeds were 200 mm/min and 100 mm/min, respectively. Three samples from each cake were subjected to deformation-relaxation cycles. The cubed cake samples were kept in a plastic bag before and after each test. The water activity of the cake samples were determined by placing three Durotherm (Lufft, West Germany) water activity meters in the plastic bag. Each meter was calibrated daily with a solution of barium chloride (aW 0.90 at 20° C.).

Custards. Duplicate custards of the flan type were made. Ingredients were 190-ml evaporated milk, 196-g sweetened condensed milk, 125-g whole egg, 50-g water, and one teaspoon vanilla. All ingredients were blended in a Waring blender at low speed for one minute and 360-g were weighed into a rectangular pan (14.3×8.0×5.6 cm, id.) which had been sprayed with "PAM" (Boyle-Midway, Inc., New York, N.Y.). Pans were placed in a tray containing 2.5-cm water and baked at 191° C. for 40 minutes. After overnight storage at 10° C., height of the custard in the pan was determined from the mean of three measurements made and with calipers along the center line of the long axis of the custard. Custards were removed from the pan after the sides were loosened with a spatula and allowed to stand at room temperature for 45 minutes. Height was again determined and percent sag was calculated according to Gardner et al. *Poultry Sci.* 61:75 (1982). Custards were stored in plastic bags at 10° C. for rheological evaluation.

The flat plate described above for evaluation of cake texture was replaced with a 10.5 mm diameter rod with a semispherical tip and force-deformation curves to failure were obtained for each custard. Cross head speed was 100 mm/min and all other parameters were the same as used in evaluations of the cakes. Five values were averaged to obtain the penetration force (F1) for each custard.

Organoleptic Evaluation. Flavor of processed and stored egg was evaluated by one judge using the USDA palatability score (Laboratory Methods for Egg Products, USDA, Agricultural Marketing Service Poultry Division, Grading Branch, Washington, D.C. 20250 (1984)).

Thermal Process. The process times and temperatures used in this study are presented in Table 2.

TABLE 2

	Actual, Equivalent Times and Temperatures, Calculated Heating Value of Treatments and Predicted % SPL Based on Heating Value.[a]					
	Actual		Equivalent		Heating	The-
Proc. No.	Time (Sec.)	Temp. (°C.)	Time (Sec.)	Temp. (°C.)	Value (G × 10^{42})	oretical % SPL[c]
1	26.2	63.7	30.4	63.1	6.1	0.52
2	92.0	63.8	97.5	63.3	20.8	1.74
3	192.2	65.3	192.4	65.1	72.8	5.97
4	9.2	67.8	15.7	66.5	8.4	0.71
5	56.9	68.2	63.0	67.5	44.6	3.70
6	123.0	68.3	125.5	67.9	99.4	8.10
6.1	123.0	68.9	129.0	68.4	117.6	9.50
7	2.7	71.5	9.5	68.5	8.9	0.75
8	30.1	72.2	36.5	71.5	78.9	6.46

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TABLE 2-continued

	Actual, Equivalent Times and Temperatures, Calculated Heating Value of Treatments and Predicted % SPL Based on Heating Value.[a]					
	Actual		Equivalent		Heating	The-
Proc. No.	Time (Sec.)	Temp. (°C.)	Time (Sec.)	Temp. (°C.)	Value (G × 10^{42})	oretical % SPL[c]
9	56.7	72.0	62.5	71.8	146.8	11.70

[a]—See Swartzel, J. Food Sci. 47:1886 (1982), and Hamid-Samimi et al., supra (1984) for descriptions of heating value and % SPL.
[b]—G values are determined based on activation energy for SPL.
[c]—Based on laboratory bench data.

The 10 processes, numbers 1–9, were performed in the same chronological order as they are numbered. After gaining process experience and as the result of evaluations during the study, it was determined that longer holding times and temperatures than expected could be used. The actual temperatures reported in Table 3 are the averages of temperature readings, every 30 seconds, of the temperature probes at the beginning and end of the holding tube.

Equivalent times and temperatures as well as holding times and temperatures are set forth in Table 2. It can be seen that equivalent times are generally longer than the corresponding holding times, and equivalent temperatures are generally lower than the corresponding holding temperatures. At longer times, the differences between corresponding holding temperatures and equivalent temperatures are smaller.

The calculated heating value, G, shown in Table 2, gives a means for making a comparison of the relatively severity of the different processes. Processes 9, 6.1, 6 and 8 had the highest G values, respectively. The percent SPL based on the heating value (G) are also shown in Table 2.

Chemical Properties of Processed Egg. The results of alpha-amylase activity assays (Table 3) confirms that the enzyme is inactivated by mild heat processes. Table 3 shows that the thermal processes used did not affect protein content or the soluble protein content.

TABLE 3

	Thermal Effects on Alpha-Amylase Activity, Protein Content and % Soluble Protein.						
Process No.	Alpha-Amylase[a]			MicroKjeldahl[b]			% Soluble Protein[c] (From Absorbance)
	Raw	UHT	Plant	Raw	UHT	Plant	
1	0.045	0.048	0.099	13.10	11.60	13.1	86.2
2	0.033	0.588	—	12.59	11.96	—	102.3
3	0.055	1.050	—	11.67	11.32	—	101.3
4	0.029	0.031	0.137	11.83	11.79	11.51	101.1
5	0.046	1.000	—	10.19	10.13	—	100.3
6	0.053	1.120	—	12.27	12.34	—	100.9
6.1	0.040	1.130	—	12.70	12.54	—	101.3
7	0.052	0.764	—	12.37	12.53	—	104.5
8	0.063	1.000	—	11.19	11.42	—	100.4
9	0.060	1.170	—	11.74	11.77	—	100.7

[a]—Alpha-Amylase data is reported as the absorbance at 585 nm. Activity is inversely related to absorbance.
[b]—MicroKjeldahl data is reported as percent protein.
[c]—Absorbance at 280 nm of heated egg/control (raw) egg in solution as described by Hamid-Samimi et al., supra (1984).

The chemical data indicate that the processes did not result in extensive damage to the egg proteins. The predicted percent soluble protein losses (Table 3) were based on studies conducted with small amounts of egg (1 ml) being heated in the cup of a Brookfield viscometer (Hamid-Samimi et al., supra, 1984). The egg was heated while various shear rates were applied to simu-

late egg under dynamic conditions that exist in conventional heat exchangers. Thus, this work revealed that the model system resulted in prediction equations that underestimated the thermal treatments that liquid whole egg products could tolerate while still obtaining products with good functional properties. Analysis of the causes of these unexpectedly good results led to the guidelines discussed above which should be followed to obtain functionally superior ultrapasteurized products.

Function of Processed Eggs. The functional properties of the processed eggs agreed with the physical and chemical results. Based on the data presented in Tables 4 and 5 for nonstored egg, there appeared to be very little heat effect on the performance of the ultrapasteurized egg relative to raw or commercially pasteurized egg. Cake height as an indication of the leavening ability and force to deform, springiness, and relaxation parameter (Peleg and Normand, *Rheologica Acta* 22:108 (1983)) as indicators of textural properties were very similar for all egg examined.

TABLE 4

Functional Properties of Cakes for Control (Raw), Ultrapasteurized (UP) at Zero Day Storage, and Commercially Pasteurized Eggs (Plant).

Variable	Treat-ment	Mean	Minimum	Maximum	n	C.V.
Maximum	Raw	10.02	7.79	13.70	10	17.3
Force[a]	UP	10.49	9.18	12.91	10	10.5
(N)	Plant	9.73	9.56	9.91	2	2.5
Relaxa-	Raw	0.394	0.379	0.417	10	3.24
tion[b]	UP	0.410	0.395	0.442	10	3.34
Para-	Plant	0.402	0.402	0.403	2	0.17
meter						
Spring-	Raw	0.83	0.81	0.86	10	1.94
iness[c]	UP	0.83	0.81	0.87	10	2.47
	Plant	0.82	0.81	0.82	2	1.32
Cake	Raw	65.1	63.3	66.7	10	1.66
Height	UP	61.7	55.1	65.5	10	5.26
(mm)	Plant	64.8	64.7	64.8	2	0.11
Water	Raw	0.873	0.832	0.891	10	2.53
Activity	UP	0.875	0.835	0.892	10	2.37
	Plant	0.892	0.892	0.892	1	—

[a]—Force required to deform the sample of cake by 26 mm.
[b]—Asymptotic relaxation value as defined by Peleg and Normand, supra (1983).
[c]—Ratio of the second peak force to the first peak force in the force deformation cycle.

TABLE 5

Functional Properties of Custards for Controls (Raw), Zero Day Storage Ultrapasteurized (UP) and Commercially Pasteurized Eggs (Plant).

Variable	Treat-ment	Mean	Minimum	Maximum	n	C.V.
Penetra-	Raw	0.82	0.76	0.96	10	8.20
tion	UP	0.70	0.59	0.80	10	8.56
Force	Plant	0.79	0.77	0.81	2	3.69
(N)						
Custard	Raw	35.7	35.1	36.7	10	1.66
Height	UP	35.6	35.1	36.3	10	5.26
(mm)	Plant	34.6	34.0	35.3	2	0.11
% Sag	Raw	7.2	5.65	9.54	10	16
	UP	7.1	5.41	8.56	10	13
	Plant	4.6	2.66	6.51	2	59

The water activity of the cakes were similar indicating that the experimental handling procedures for the cakes were uniform and should not have affected the instrumental evaluation of textural properties. The custard data indicated that all egg sources evaluated had good ability to form gels. The gels had excellent integrity as indicated by the relatively low percent sag, yet the custards were relatively tender as indicated by the penetration forces. Although weep was not measured, very

little syneresis was noted even after holding the custards overnight for textural evaluations. The limited organoleptic evaluation of the processed eggs indicated that the thermal processes did not affect flavor or aroma in scrambled eggs relative to scrambled egg made from a fresh shell egg. The USDA palatability scores were seven to eight (eight being the highest score).

Refrigerated Storage Effect. As long as the processed egg was not obviously spoiled, as indicated by organoleptic evaluations, storage at 4° C. maintained the chemical, functional, and organoleptic properties of the processed egg up to 24 weeks for some of the samples. The data presented in Tables 6, 7, and 8 were taken from stored egg that was judged organoleptically sound. The criteria for that judgment were (1) that the color was normal, i.e., within the expected range of color observed for eggs immediately post-processing, and (2) that there were no objectional aromas or flavors. In this study, because of the sampling procedure where most of the samples were checked at four-week intervals, there were no borderline decisions, a sample was obviously acceptable or unacceptable. Bright yellow colors, off-aromas, and pH values below seven were typical of samples judged to be spoiled.

TABLE 6

Means for Proteins, Solids and pH for Controls (Raw), Commercially Pasteurized (Plant) and Ultrapasteurized (UP) Egg.

Variable	Treat-ment[a]	Mean	Minimum	Maximum	n	C.V.
%.	Raw	11.92	10.19	13.10	10	6.8
Protein	Plant	12.30	11.51	13.10	2	9.1
	UP 0	11.74	10.13	12.54	10	6.0
%	Raw	24.6	23.9	25.2	10	1.6
Solids	Plant	24.8	24.4	25.2	2	2.5
	0	24.5	24.0	25.0	10	1.3
	4	24.4	24.0	24.9	10	1.3
	UP 8	24.4	24.0	24.7	9	0.9
	12	24.3	23.8	24.7	7	1.3
	18	24.9	24.4	25.5	2	3.1
	24	24.8	24.7	24.9	2	0.3
pH	Raw	7.5	7.2	7.6	10	1.7
	Plant	7.1	7.1	7.2	2	0.5
	0	7.5	7.3	7.6	10	1.4
	4	7.4	7.2	7.6	10	1.4
	UP 8	7.4	7.3	7.5	9	1.2
	12	7.3	7.2	7.4	7	1.2
	18	7.4	7.4	7.4	2	0
	24	7.4	7.4	7.4	2	0

[a]—Numbers indicate storage at 4° C. in weeks for processed eggs.

TABLE 7

Functional Properties of Cakes Made from Eggs Stored at 4° C.

Variable	Storage (Weeks)	Mean	Minimum	Maxi-mum	n	C.V.
Maximum	4	9.78	7.90	14.95	10	21.3
Force[a]	8	10.37	7.82	14.53	9	20.5
(N)	12	11.29	8.84	14.28	7	18.2
	18	11.42	10.32	12.53	2	13.6
	24	10.53	9.57	11.49	2	12.9
Relaxa-	4	.3937	0.3759	0.4167	10	3.7
tion	8	.3876	0.3636	0.4132	9	3.9
Para-	12	.3846	0.3717	0.4032	7	3.0
meter[b]	18	.3788	0.3788	0.3788	2	3.1
	24	.3745	0.3704	0.3788	2	1.5
Spring-		0.829	0.799	0.853	10	1.7
iness[c]	8	0.834	0.811	0.872	9	2.0
	12	0.834	0.820	0.843	7	0.9
	18	0.831	0.829	0.832	2	0.3
	24	0.815	0.787	0.843	2	4.9
Height	4	61	54	65	10	6.02
(mm)	8	64	63	67	9	2.06
	12	64	60	65	7	2.7

TABLE 7-continued

Variable	Storage (Weeks)	Mean	Minimum	Maximum	n	C.V.
	18	63	62	65	2	1.0
	24	65	65	65	2	0.22
Water Activity	4	0.860	0.796	0.883	10	4.2
	8	0.884	0.868	0.900	9	1.1
	12	0.879	0.844	0.896	7	2.0
	18	0.872	0.872	0.872	1	—
	24	0.879	0.876	0.882	2	0.4

a,b,c—See Table 4 for definition of terms.

TABLE 8

Functional Properties of Custards Made from Eggs Stored at 4°C.

Variable	Storage (Weeks)	Mean	Minimum	Maximum	n	C.V.
Penetration Force (N)	4	0.68	0.47	0.77	10	12.7
	8	0.70	0.64	0.76	9	9.1
	12	0.75	0.57	0.83	7	20.3
	18	0.94	0.85	1.02	2	12.6
	24	0.82	0.76	0.88	2	10.5
Custard Height (mm)	4	35	34	36	10	2.4
	8	35	34	36	9	1.6
	12	35	35	36	7	1.2
	18	36	36	36	2	0.4
	24	35	35	35	2	1.0
% Sag	4	7.1	3.0	11.6	10	38.1
	8	5.9	3.5	7.5	9	20.5
	12	6.5	4.6	8.0	7	19.5
	18	7.2	6.4	8.1	2	15.9
	24	6.6	4.9	8.2	2	36.0

Visual observations of the interiors of opened packages revealed very little sedimentation during storage. A very thin layer of a fine, light yellow, granular-like material was observed on the bottom of cartons after four weeks of refrigerated storage.

Shelf Life. The times of spoilage of egg from each trial are presented in Table 9.

TABLE 9

Shelf Life for Liquid Whole Egg Stored at 4°C.

Process	Shelf Life (Weeks)
1	4-8
2	8-12
3	>12
4	8-12
5	>18
6	18-24
6.1	>24
7	12-18
8	20-24
9	18-20

These data were used to generate the time and temperature guidelines set forth in FIG. 5.

The invention has been discussed with a degree of specificity above. This discussion has been provided for illustrative purposes only, with the scope of the invention being defined by the following claims.

That which is claimed is:

1. A method of ultrapasteurizing liquid whole egg, comprising passing the liquid whole egg as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg is heated to a predetermined real temperature, by contacting said liquid whole egg to a heated surface wherein the total thermal treatment received by the liquid whole egg is described by an equivalent temperature and an equivalent time defining a

point above the 5% SPL (BATCH) line of FIG. 3, but insufficient to cause coagulation of the liquid whole egg.

2. A method according to claim 1, wherein said liquid whole egg is homogenized after it is heated.

3. A method according to claim 1, followed by the step of aseptically packaging said liquid whole egg.

4. A method of ultrapasteurizing liquid whole egg, comprising passing the liquid whole egg as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg is

(a) heated to a predetermined holding temperature by contacting said liquid whole egg to a heated surface, then

(b) maintained at said predetermined holding temperature for a predetermined holding time, and then

(c) cooled, wherein the total thermal treatment received by the liquid whole egg is defined by an equivalent temperature and an equivalent time defining a point above the 5% SPL (BATCH) line of FIG. 3, but insufficient to cause coagulation of the liquid whole egg.

5. A method of ultrapasteurizing liquid whole egg, comprising passing the liquid whole egg as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg is heated to a predetermined real temperature by contacting said liquid whole egg to a heated surface while at least periodically subjecting said continuous stream of liquid whole egg to turbulence, wherein the total thermal treatment received by the liquid whole egg is described by an equivalent time and an equivalent temperature defining a point above the 5% SPL (BATCH) line of FIG. 3, but insufficient to cause said liquid whole egg to coagulate.

6. A method according to claim 5, wherein said liquid whole egg is subjected to turbulence for a major portion of the time said liquid whole egg is heated.

7. A method according to claim 5, wherein said liquid whole egg is dispersed before said liquid whole egg is heated.

8. A method according to claim 5, wherein every particle of liquid whole egg in said continuous stream of liquid whole egg is in contact with said heated surface for a total time less than the average residence time of each particle in the heating unit.

9. A method of ultrapasteurizing liquid whole egg, comprising passing the liquid whole egg as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg is

(a) heated to a predetermined holding temperature by contacting said liquid whole egg to a heated surface while at least periodically subjecting said continuous stream of liquid whole egg to turbulence, then

(b) maintained at said predetermined holding temperature for a predetermined holding time, and then

(c) cooled, wherein the total thermal treatment received by the liquid whole egg is defined by an equivalent time and an equivalent temperature above the 5% SPL (BATCH) line of FIG. 3, but insufficient to cause said liquid whole egg to coagulate.

10. A method of making packaged liquid whole egg characterized by a preselected refrigerated shelf life of about four weeks to about 36 weeks, comprising passing the liquid whole egg as a continuous stream through a pasteurizing apparatus to produce non-sterile pasteur-

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ized liquid whole egg, during which the liquid whole egg is heated by contacting said liquid whole egg to a heated surface for a predetermined time and to a predetermined temperature while at least periodically subjecting said continuous stream of liquid whole egg product to turbulence, wherein the liquid whole egg is heated for a predetermined time and to a predetermined temperature insufficient to cause more than a 5% soluble protein loss therefrom, and wherein said predetermined temperature and said predetermined time are chosen to impart said preselected shelf life to said liquid whole egg, followed by aseptically packaging the non-sterile pasteurized liquid whole egg.

11. A method according to claim 10, wherein said pasteurizing apparatus is sterilized before said liquid whole egg is passed therethrough, and wherein said packaged liquid whole egg is characterized by a preselected shelf life of about eight weeks to about 36 weeks.

12. A method according to claim 10, wherein said liquid whole egg is subjected to turbulence for a major portion of the time said liquid whole egg is heated.

13. A method of making packaged liquid whole egg characterized by a preselected refrigerated shelf life of about four weeks to about 36 weeks, comprising passing the liquid whole egg as a continuous stream through a pasteurizing apparatus to produce non-sterile pasteurized liquid whole egg, during which the liquid whole egg is

(a) heated by contacting said liquid whole egg to a heated surface for a time sufficient to raise said liquid whole egg to a predetermined holding temperature while at least periodically subjecting said continuous stream of liquid whole egg to turbulence, then

(b) maintained at said predetermined holding temperature for a predetermined holding time, wherein said holding temperature and holding time are selected to cause a soluble protein loss of not more than 5% therefrom, and wherein said holding temperature and holding time are selected to impart said preselected shelf life to said liquid whole egg, and then

(c) cooled, followed by

(d) aseptically packaging the non-sterile pasteurized liquid whole egg.

14. A method according to claim 13, wherein said pasteurizing apparatus is sterilized before said liquid whole egg is passed therethrough, and wherein said packaged liquid whole egg is characterized by a preselected shelf life of about eight weeks to about 36 weeks.

15. A method according to claim 13, wherein said liquid whole egg is subjected to turbulence for a major portion of the time said liquid whole egg is heated.

16. A method of making packaged liquid whole egg characterized by a preselected refrigerated shelf life of about four weeks to about 36 weeks, comprising passing the liquid whole egg as a continuous stream through a pasteurizing apparatus to produce non-sterile pasteurized liquid whole egg, during which the liquid whole egg is heated by contacting said liquid whole egg to a

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heated surface for a predetermined time and to a predetermined temperature while at least periodically subjecting said continuous stream of liquid whole egg to turbulence, wherein the liquid whole egg is heated for a predetermined time and to a predetermined temperature insufficient to cause more than a 5% soluble protein loss therefrom, wherein the total thermal treatment received by the liquid whole egg product is described by an equivalent temperature and an equivalent time defining a point above the 5% (SPL) (BATCH) line of FIG. 3, and wherein said predetermined temperature and said predetermined time are chosen to impart said preselected shelf life to said liquid whole egg, followed by aseptically packaging the non-sterile pasteurized liquid whole egg.

17. A method according to claim 16, wherein said pasteurizing apparatus is sterilized before said liquid whole egg is passed therethrough, and wherein said packaged liquid whole egg is characterized by a preselected shelf life of about eight weeks to about 36 weeks.

18. A method according to claim 16, wherein said liquid whole egg is subjected to turbulence for a major portion of the time said liquid whole egg is heated.

19. A method of making packaged liquid whole egg characterized by a preselected refrigerated shelf life of about four weeks to about 36 weeks, comprising passing the liquid whole egg as a continuous stream through a pasteurizing apparatus to produce non-sterile pasteurized liquid whole egg during which the liquid whole egg is

(a) heated by contacting said liquid whole egg to a heated surface for a time sufficient to raise said liquid hole egg to a predetermined holding temperature while at least periodically subjecting said continuous stream of liquid whole egg to turbulence, then

(b) maintained at said predetermined holding temperature for a predetermined holding time, wherein said holding temperature and holding time are selected to cause a soluble protein loss of not more than 5% therefrom, and wherein said holding temperature and holding time are selected to impart said preselected shelf life to said liquid whole egg, and then

(c) cooled, wherein the total thermal treatment received by the liquid whole egg is described by an equivalent temperature and an equivalent time defining a point above the 5% SPL (BATCH) line of FIG. 3, followed by

(d) aseptically packaging the non-sterile pasteurized liquid whole egg.

20. A method according to claim 19, wherein said pasturing apparatus is sterilized before said liquid whole egg is passed therethrough, and wherein said packaged liquid whole egg is characterized by a preselected shelf life of about eight weeks to about 36 weeks.

21. A method according to claim 19, wherein said liquid whole egg is subjected to turbulence for a major portion of the time said liquid whole egg is heated.

* * * * *

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United States Patent [19]

Swartzel et al.

[11] Patent Number: 5,019,408

[45] Date of Patent: * May 28, 1991

[54] METHOD FOR THE ULTRAPASTEURIZATION OF LIQUID WHOLE EGG PRODUCTS

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[*] Notice: The portion of the term of this patent subsequent to Feb. 28, 2006 has been disclaimed.

[21] Appl. No.: 628,716

[22] Filed: Dec. 17, 1990

Related U.S. Application Data

[63] Continuation of Ser. No. 535,718, Jun. 11, 1990, Pat. No. 4,994,291, which is a continuation of Ser. No. 311,594, Feb. 16, 1989, Pat. No. 4,957,759, which is a continuation of Ser. No. 904,744, Sep. 8, 1986, Pat. No. 4,808,425.

[51] Int. Cl.^{5} A23L 3/00
[52] U.S. Cl. 426/399; 426/521; 426/614
[58] Field of Search 426/399, 521, 614

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Mohammad-Hossein Hamid-Samimi, Thesis: Criteria Development for Extended Shelf-Life Pasteurized Liquid Whole Egg (1984).

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Attorney, Agent, or Firm—Bell, Seltzer, Park & Gibson

[57] ABSTRACT

Methods of ultrapasteurizing liquid whole egg products in continuous flow, high temperature, short time pasteurization equipment are provided. The equivalent point method is preferably used to evaluate the total thermal treatment received by the product in this equipment. Also disclosed is a method of making liquid whole egg products having preselected, extended, refrigerated shelf lives.
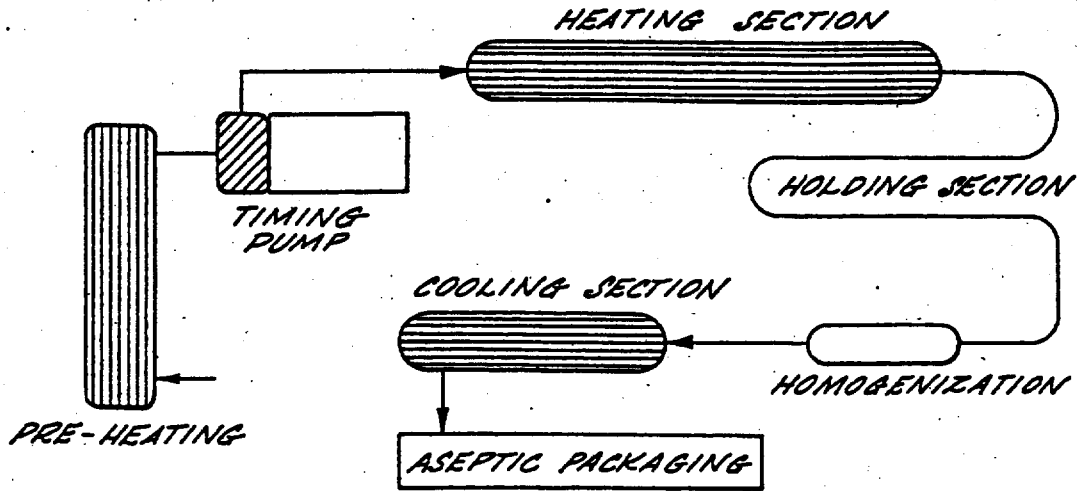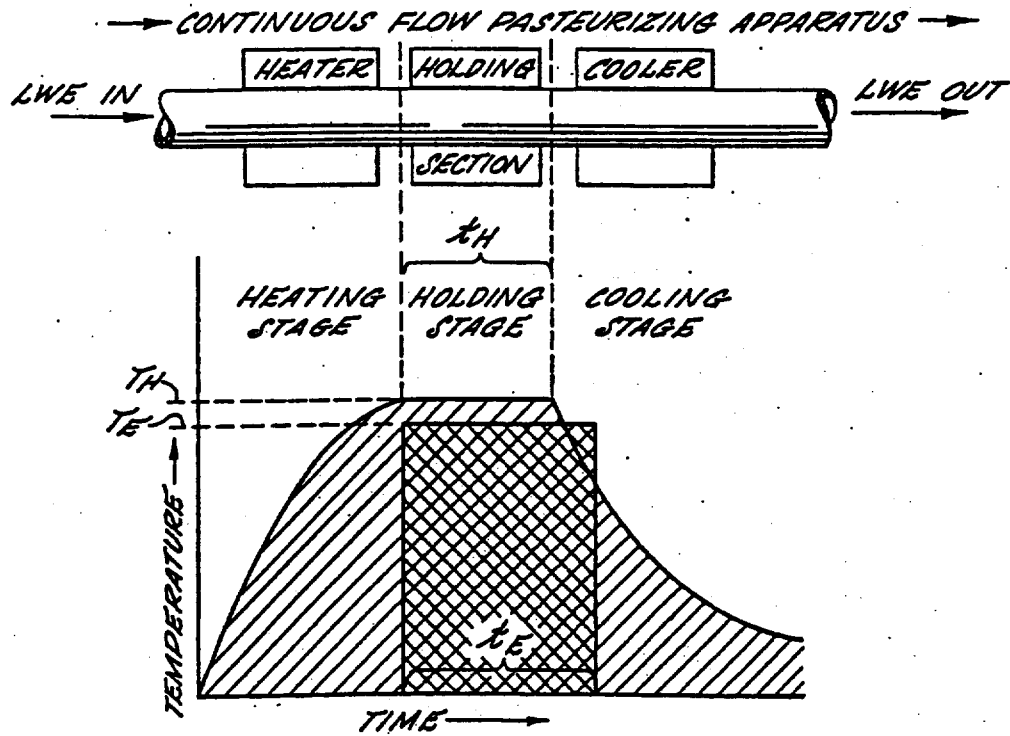
19 Claims, 4 Drawing Sheets

HEATING SECTION
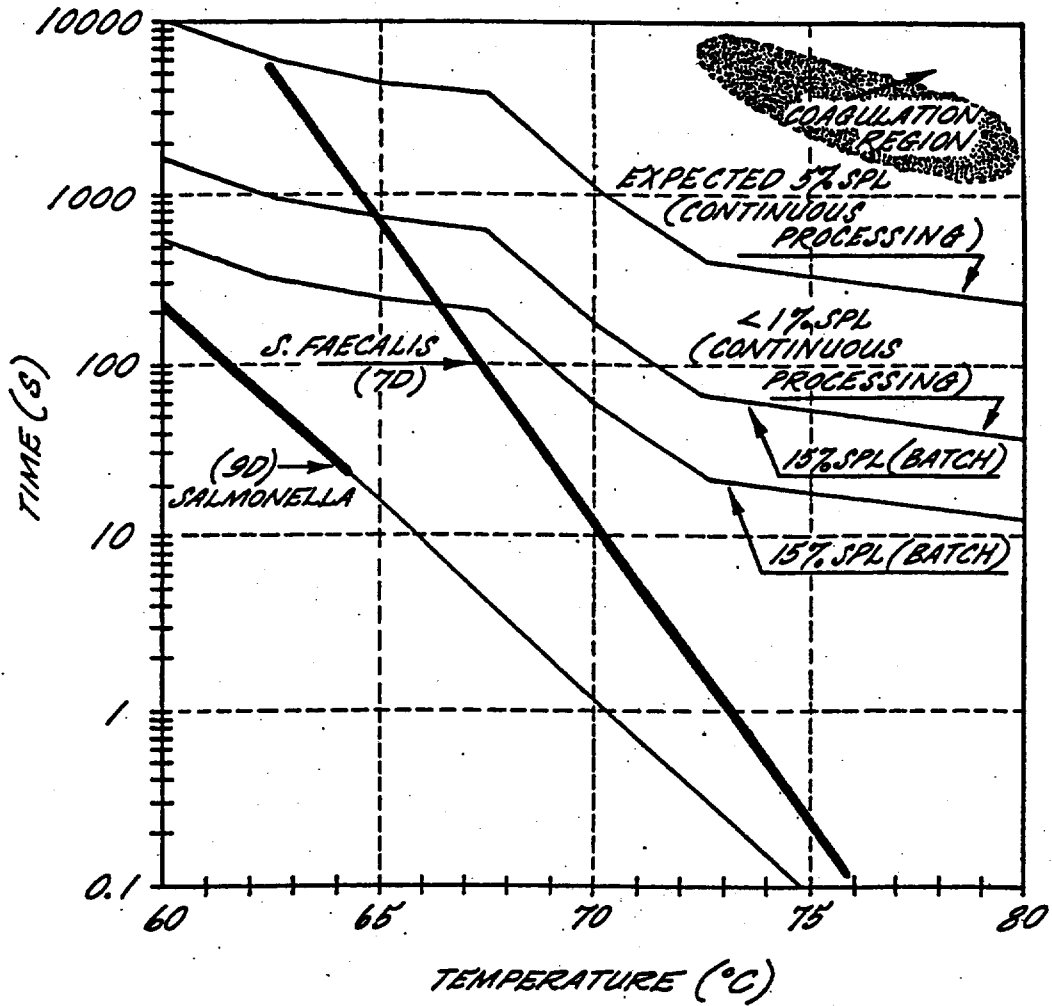
HOLDING SECTION

COOLING SECTION

HOMOGENIZATION

ASEPTIC PACKAGING

TIMING PUMP

PRE-HEATING

fig. 1.

CONTINUOUS FLOW PASTEURIZING APPARATUS

HEATER   HOLDING   COOLER

LWE IN   LWE OUT

SECTION

t_H

HEATING STAGE   HOLDING STAGE   COOLING STAGE
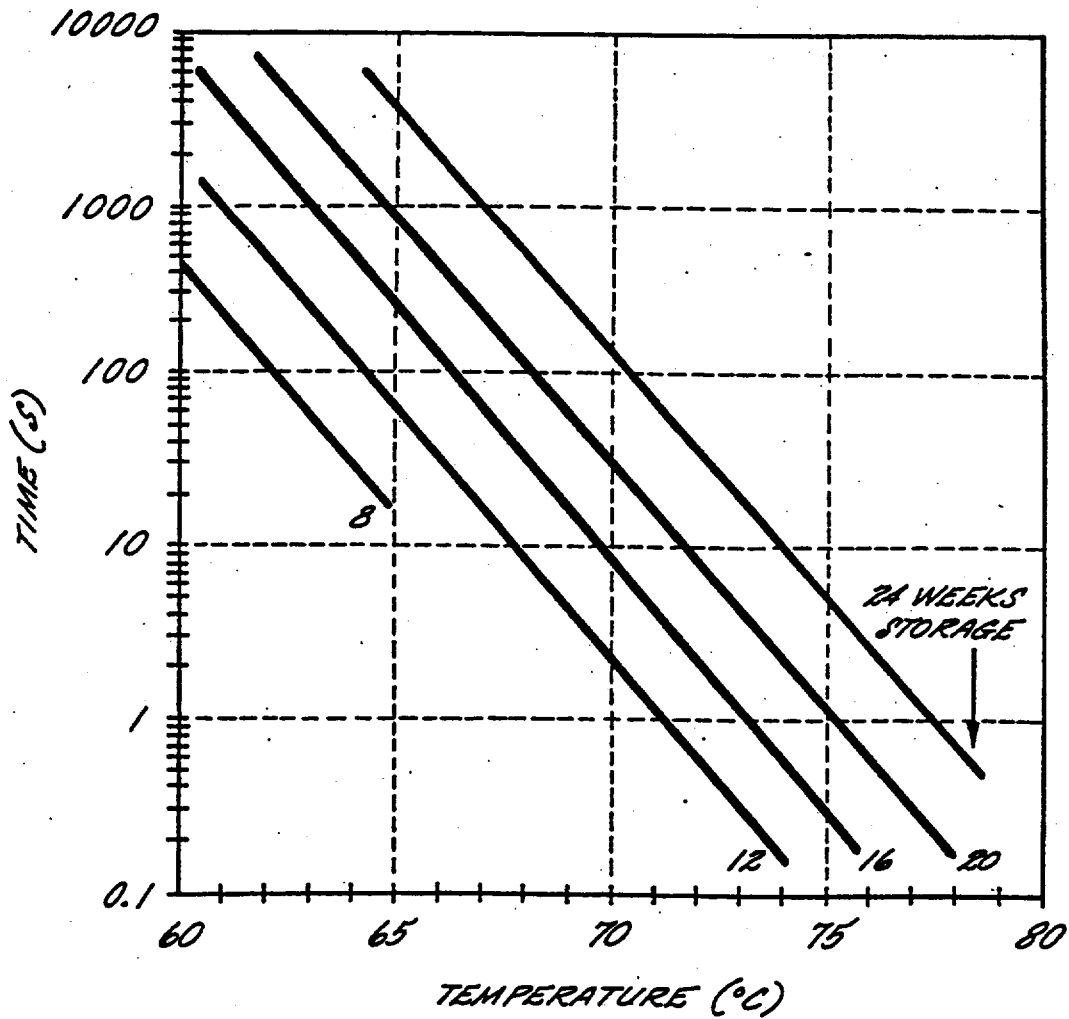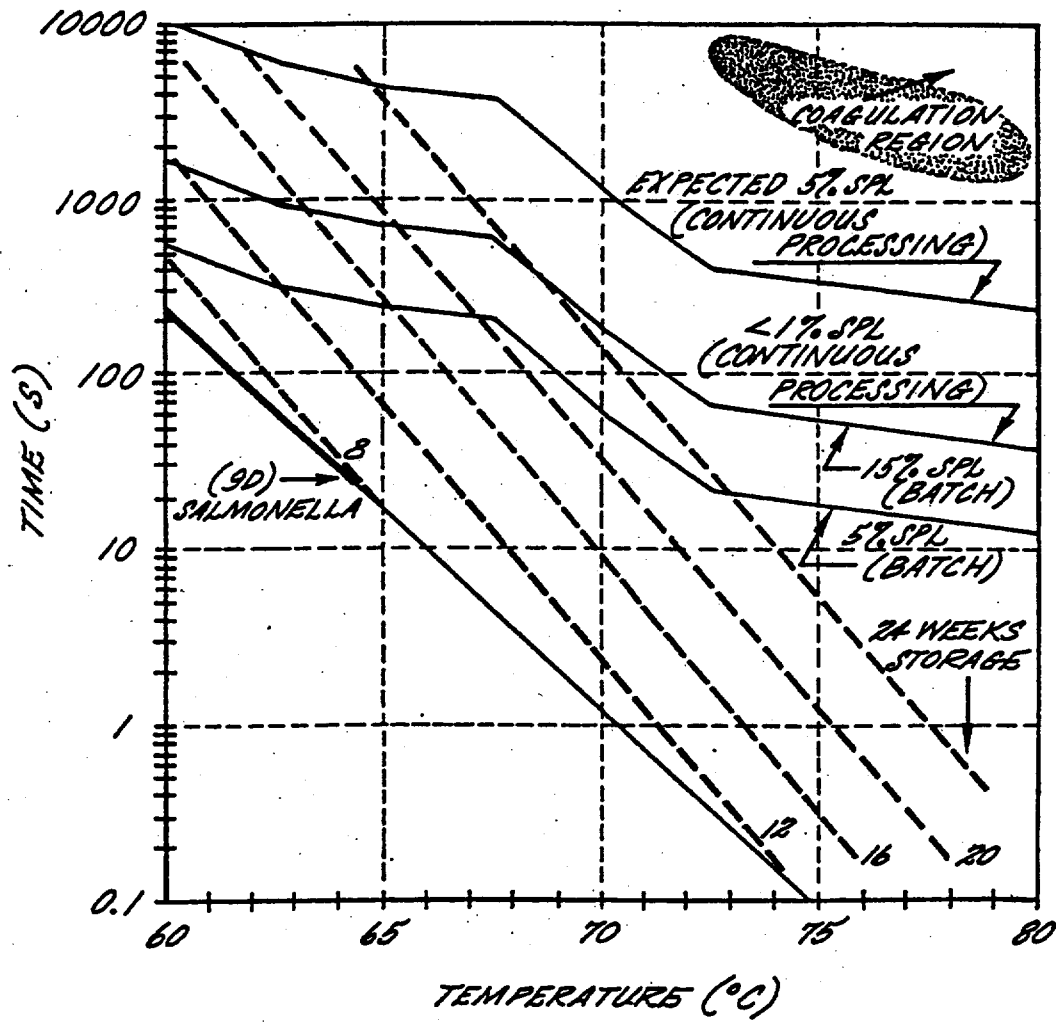
T_H
T_E

TEMPERATURE

t_E

TIME

fig. 2.

Fig. 3.

F ι ɡ. 4.

FIG.5.

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METHOD FOR THE ULTRAPASTEURIZATION OF LIQUID WHOLE EGG PRODUCTS

This application is a continuation of pending prior U.S. application Ser. No. 07/535,718, filed June 11, 1990 now U.S. Pat. No. 4,994,291, which is a continuation of prior U.S. application Ser. No. 07/311,594, filed Feb. 16, 1989, now U.S. Pat. No. 4,957,759, which is a continuation of prior U.S. application Ser. No. 06/904,744, filed Sept. 8, 1986, now U.S. Pat. No. 4,808,425, issued Feb. 28, 1989.

DESCRIPTION OF THE INVENTION

The present invention relates to the pasteurization of liquid whole egg products generally, and particularly relates to ultrapasteurization methods which can be used to produce liquid whole egg products which have good functional properties and which have extended refrigerated shelf lives.

BACKGROUND OF THE INVENTION

The U.S. egg industry produced more than 300 million pounds of frozen pasteurized egg products in 1985. The relatively mild pasteurization processes used are designed to eliminate Salmonella from eggs for all practical purposes, but do not destroy organisms capable of spoiling egg products held under refrigerated temperatures above freezing The survival of spoilage organisms in pasteurized egg, coupled with conventional packaging technology, results in products with limited shelf life (7-14 days at 40° F.) that require freezing and frozen distribution systems for preservation. Freezing is cost intensive, lowers the functional quality (flavor, performance, etc.) of the egg product, and results in an inconvenient product that requires thawing prior to use.

Standard pasteurization practices for liquid whole egg products are generally discussed in the *Egg Pasteurization Manual* (USDA Agricultural Research Service 1969). See also U.S. Pat. No. 3,949,099 to Kaufman, at column 1, lines 46-58 (summarizing pasteurization processes). The *Egg Pasteurization Manual* notes that experiments conducted in England to establish treatment conditions used there, which were carried out in a high temperature, short time pasteurization unit, included trials with holding times of two and one-half minutes and temperatures up to 151 degrees Fahrenheit (66.1 degrees Centigrade). The functional quality of these eggs is not discussed; however, it is noted that England adopted a lower temperature of 148 degrees Fahrenheit as a treatment condition. The Manual observes that such "severe" treatments help increase the stability of egg products in liquid form, but does not teach how this can be accomplished without sacrificing desirable functional properties of the products. For other types of egg products which are more heat stable, pasteurization temperatures as high as 152 degrees Fahrenheit (66.67 degrees Centigrade) have been reported. Again, little is known about how to ultrapasteurize (decrease the number of spoilage microorganisms to levels lower than obtained with a pasteurization procedure) these products by heating without sacrificing functional performance.

Higher temperatures than those investigated in England have been explored. See e.g., Essary, E. O., Rony, P. R., and Collins, W. F., *New uses of heated aseptically packaged fluid egg products*, Report to the American Egg Board (1983). This work suggested that merging

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techniques of ultrapasteurization with aseptic packaging can be accomplished to yield safe, stable, and functional liquid whole egg. This research suggested and used a heat exchanger operated in laminar flow to process whole egg at elevated temperatures, and used an ethylene oxide-flushed glove box to aseptically package the product (neither device approved for the commercial production of a salable product). Holding temperatures of up to 154 degrees Fahrenheit (67.8 degrees Centigrade) were reported. The results of this pioneering work demonstrated the possibility of extending the refrigerated shelf life of liquid whole egg products, but did not enable the commercial production of a refrigerated product which could be sold to consumers.

To carry out ultrapasteurization of liquid whole egg products on commercial equipment, the time and temperature parameters of the thermal treatment must be selected with care. Arbitrary increases in thermal treatment will likely produce a functionally unacceptable product, or--even worse--coagulation of the product and blockage of the pasteurizing equipment. Because such pasteurizing equipment operates at high pressures (e.g., 1,500 p.s.i. and more) the consequences of blockage are serious. For these reasons, it is essential to know how liquid whole egg products respond to various thermal treatments before experimenting with the production of these products on commercial equipment.

Because this essential information was not available, Hamid-Samimi investigated the time and temperature parameters which should be used in commercial equipment to obtain a functionally acceptable, ultrapasteurized, liquid whole egg product M. H. Hamid-Samimi, *Criteria Development for Extended Shelf-Life Pasteurized Liquid Whole Egg*. Ph.D. Thesis, North Carolina State University (1984). This research was carried out at the laboratory bench, with a Brookfield viscometer, which processed the product in small batches rather than continuously. Processing times and temperatures defining thermal treatments producing a soluble protein loss (SPL) of up to 5% from the product, as an upper limit, were suggested as producing a functionally acceptable product. The suggested 5% SPL limit was defined by a graph line in the thesis: this line is reproduced herein in FIG. 3 as the 5% SPL (Batch) line. Time and temperature values tested by other investigators which were believed to be the limits of pasteurization are summarized in M. H. Hamid-Samimi and K. R. Swartzel, *J. Food Processing and Preservation* 8: 219, 221 FIG. 1 (1984). All are below the 5% SPL (Batch) line.

The present inventors sought to test the predictions of Hamid-Samimi by ultrapasteurizing liquid whole egg on continuous flow, high temperature, short time pasteurization equipment. It was unexpectedly found that functionally acceptable liquid whole egg can be produced at times and temperatures greater than previously believed. These findings, which will be explained in detail below, enable the commercial production of functionally acceptable products with longer refrigerated shelf lives than heretofore available. As will also be explained below, discovery of these unexpected results has led to the identification of several steps which should be taken to produce ultrapasteurized liquid whole egg products that have superior functional properties.

The object of the present invention, in short, is to provide liquid whole egg products for refrigerated distribution which have greatly reduced levels of spoilage

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microorganisms, while still having good functional properties.

SUMMARY OF THE INVENTION

This object is achieved by a method for ultrapasteurizing liquid whole egg products. The method comprises passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is heated to a predetermined real temperature. The method is practiced so that the total thermal treatment received by the liquid whole egg product is described by an equivalent temperature and an equivalent time (these terms are explained in detail below) defining a point above the 5% SPL (Batch) line of FIG. 3, but insufficient to cause coagulation of the product.

Also disclosed herein is a method of making a packaged liquid whole egg product characterized by a preselected refrigerated shelf life of from about four weeks to about 36 weeks. This method comprises passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is heated for a predetermined time and to a predetermined temperature. The predetermined time and the predetermined temperature are chosen to impart the preselected shelf life to the liquid whole egg product. After it is heated, the liquid whole egg product is aseptically packaged.

Preferably, the continuous stream of liquid whole egg product referred to in each of the methods above is at least periodically subjected to turbulence while it is heated. The liquid whole egg products are also, preferably, homogenized after they have been heated. In addition, the methods described above are more narrowly described as methods in which the liquid whole egg product is heated to a predetermined holding temperature, then maintained at said predetermined holding temperature for a predetermined holding time, and then cooled.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of a continuous flow pasteurizing apparatus suitable for carrying out the present invention.

FIG. 2 is a diagram illustrating the differences and relations between real holding times and holding temperatures, and equivalent times and equivalent temperatures for describing total thermal treatments, in continuous flow pasteurizing equipment.

FIG. 3 is a graph showing time and temperature regions for the ultrapasteurization of liquid whole egg products.

FIG. 4 is a graph showing equivalent times and equivalent temperatures that give particular refrigerated shelf lives for liquid whole egg.

FIG. 5 is a combination graph in which FIGS. 3 and 4 are superimposed, with the *S. faecalis* line removed

DETAILED DESCRIPTION OF THE INVENTION

Thermal treatments simultaneously produce beneficial and undesirable changes in food products. Knowledge of kinetic methods, and how they can be applied to the mechanics of designing a thermal process, aids in attaining food quality retention and process efficiency. Determining the time and temperature requirement for a thermal process depends upon destruction of spoilage and disease causing microbial spores while minimizing

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undesirable physical, chemical and biological transformations that occur within the product.

As schematically shown in FIG. 1, with arrowheads indicating direction of flow, continuous flow thermal processing equipment comprises heating, holding, and cooling sections The thermal treatment received by the product in the heating and cooling stage, (illustrated in FIG. 2), is oftentimes not considered instead, only the holding time (t_H) and holding temperature (T_H) are considered. However, when products are pasteurized in such equipment at higher temperatures and shorter times, as is taught herein, the contribution of the heating stage, and perhaps the cooling stage, to the total thermal treatment of the product becomes significant, and must be accounted for if a product with good functional qualities is to be obtained and coagulation during pasteurization is to be avoided. It is accordingly recommended that the equivalent point method for evaluating thermal treatments be applied in practicing the present invention. As explained in detail below, this method describes the total thermal treatment received by a product in continuous flow equipment with one equivalent time (t_E) and one equivalent temperature (T_E) (see FIG. 2).

Procedures for use of the equivalent point method for analyzing the thermal effects on products during continuous flow heating have been previously outlined (Swartzel, 1982, *J. Food Sci.* 47:1886 and Swartzel, 1986, *J. Agric. Food Chem.* 34:397) and are known to those skilled in the art This method differs substantially from previous methods in that all other methods define the thermal treatment based upon a single factor such as enzyme inactivation, microbial destruction, protein denaturation, nutrient loss, etc. The problem with these other methods is that a physical and/or chemical effect (flavor, color, product separation and gelation during storage if thermally related) may actually be the shelf life limiting factor.

The unique feature of the equivalent point method lies in the fact that, for any thermal curve, one equivalent time and equivalent temperature combination exists (see FIG. 2). This equivalent time and temperature combination will yield the exact thermal effect on all constituents within the product as would the original thermal curve. This unique time and temperature combination is not dependent on individual constituent kinetics, as are all previous thermal evaluation procedures (it is independent of constituent activation energy).

To determine the equivalent point of a thermal system, a complete thermal history of the treatment must be available. This is obtained by measuring mixed mean product temperatures at various locations (entrance to the heat exchanger, exit of the heat exchanger and at least two locations inside the heat exchanger). Time is calculated by correlating mean residence time with location of the temperature probe. With heat exchangers into which it is difficult or impractical to insert thermal probes, time-temperature curves are calculated based on knowledge of the product's physical characteristics and on the geometry of the processing equipment.

With available time-temperature curves and a basic knowledge of kinetic relationships, equivalent points can routinely be calculated. The log of a product constituent concentration ratio (initial concentration divided by concentration after treatment) is set equivalent to the integration of that constituent's Arrhenius equation (or any other appropriate function describing the

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temperature dependency of the rate of the reaction associated with the constituent change) for the particular time-temperature interval (thermal history previously defined) For a given activation energy each section of a thermal treatment (heating, holding, and cooling) will produce a unique thermal constituent concentration ratio For the different sections the effect may be summed For the original activation energy selected, a linear infinite log (time)-temperature relationship exists. Any and all of these infinite time and temperature combinations would produce the same thermal effect on a constituent (with the same activation energy) as during the original thermal treatment. By reexamining the original thermal curves with different activation energies a series of infinite linear log (time)-temperature relationships are developed (one line in a log (time)-temperature plot per activation energy). Uniquely all lines intersect at one point. This unique time-temperature is the equivalent point for the original thermal curve. It accounts for all thermal treatment and is used to accurately predict constituent change, or product characteristic.

FIG. 3 sets forth thermal treatments which should be used to ultrapasteurize liquid whole egg products. Thermal treatments defined by points above the 5% SPL (Batch) line have not heretofore been suggested. For practicing the present invention in continuous flow processing equipment, the thermal treatment is described by a point on FIG. 3 defining an equivalent time and an equivalent temperature, as explained above. The thermal treatment should be more than sufficient to pasteurize the liquid whole egg product "Pasteurize" means to cause a nine log cycle (9D) or 99.9999999% reduction in Salmonella in the product being treated. The thermal treatment should be insufficient to cause the liquid whole egg product to coagulate. The thermal treatment should more particularly cause not more than a 15% soluble protein loss (SPL) in the liquid whole egg product being treated, and will preferably cause not more than a 5% soluble protein loss in the product being treated. The expected 5% SPL (continuous processing) line on FIG. 3 indicates approximately the upper limit on thermal treatments which can be tolerated without sustaining more than a 5% soluble protein loss (the exact location of this line for any one process will depend on the physical factors discussed below). More preferably, the thermal treatment will be designed to produce not more than about a 1% soluble protein loss from the product. As shown in FIG. 3, equivalent times and equivalent temperatures defining points along the line previously believed to represent the line at which a 15% soluble protein loss would be obtained (the 15% SPL (Batch) line), are now known to represent thermal treatments which produce ultrapasteurized products having less than a 1% soluble protein loss under continuous flow.

The line defining thermal treatments causing a seven log cycle reduction in the spoilage bacteria *Streptococcus faecalis* is labeled in FIG. 3 as the *S. faecalis* (7D) line. The *S. faecalis* line has a steeper slope than the several SPL lines. This illustrates that thermal treatments employing higher temperatures and shorter times are preferred for practicing the present invention. Thus, holding soluble protein loss constant (so that treatment time must be decreased as treatment temperature is increased), thermal treatments in which the product is subjected to treatment temperatures of about 67.0 degrees Centigrade or more are preferred to thermal treat-

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ments in which the product is subjected to treatment temperatures of 65° C.; treatment temperatures of about 69.0° C. or more are preferred to treatment temperatures of 67° C; treatment temperatures of about 71.0° C. or more are preferred to treatment temperatures of 69° C.; treatment temperatures of about 73.0° C. or more are preferred to 71° C.; and so on. The foregoing statement is true whether the real temperatures (or holding temperatures) of the processes are being compared, or equivalent temperatures are being compared (thus the term "treatment temperature" is used to encompass both).

Treatment temperatures are primarily limited by the ability to accurately time the duration of the thermal treatment: as temperature is increased the treatment time must be decreased, and shorter treatment times are more difficult to administer with precision. Generally, equivalent temperatures not more than about 90° C. are preferred, and equivalent temperatures not more than about 80° C. are more preferred.

Desirable thermal treatments for practicing the present invention can also be described with reference to the *S. faecalis* lines. Preferably, the thermal treatment will define a point above the *S. faecalis* (7D) line, and more preferably the thermal treatment will define a point above the *S. faecalis* (9D) line. While this latter line is not plotted in FIG. 3, it can be plotted in accordance with the equations given below.

Equations for lines in the figures are as follows, where t = time in seconds, T = temperature in degrees Centigrade, and n = number of decimal reductions. Salmonella line: $\log(t) = 15.96 - 0.227(T)$. *S. faecalis* lines: $\log(t) = 24.62 + \log(n) - 0.346(T)$. % SPL lines: $\log(t) = 10$ g(% SPL) = 9 − b, where a and b are given in Table 1 below:

TABLE 1

T range °C.	a (for Batch lines)	b	a (Expected) (for continuous flow lines)
60–62.5	7.494	0.091	1.761
62.5–67.5	4.103	0.037	5.370
67.5–72.5	14.68	0.194	15.942
72.5 and above	3.014	0.033	4.281

These equations can be used to extend the teaching of the figures beyond their depicted scope.

The liquid whole egg product is preferably heated by contacting the product to a heated surface. The heated surface is comprised of a corrosion-resistant, nontoxic and nonabsorbent material such as stainless steel. Standards for evaluating the acceptability of such product contact surfaces (the 3-A Sanitary Standards) are known and established. See, e.g. *Egg Pasteurization Manual, supra*, at 27.

To obtain a product with reduced amounts of spoilage microorganisms, the pasteurizing apparatus should be sterilized before the liquid whole egg product is passed therethrough. Sterilizing is preferably accomplished by passing hot water under pressure through the pasteurizing apparatus, as is known in the art, so that, among other things, hot water is contacted to the heating surface at a temperature and pressure and for a time sufficient to sterilize the heating surface.

In addition, the product, after ultrapasteurization, should be aseptically packaged Aseptically packaged means packaged to the exclusion of microorganisms other than those carried by the liquid whole egg prod-

uct. Equipment suitable for aseptically packaging liquid whole egg products is commercially available.

FIG. 4 illustrates the refrigerated shelf life of liquid whole egg after it is ultrapasteurized and aseptically packaged, as explained above The term "refrigerated," as used herein, means stored at a temperature of 4° C. Time and temperatures for points on each line represent equivalent times and temperatures, as also explained above. A liquid whole egg product having a preselected shelf life of from about 4–36 weeks is made by selecting a point on a line or in a region which will provide the desired shelf life, determining the equivalent time and equivalent temperature which correspond to the point selected, and—preferably through the use of the equivalent point method—establishing the operating conditions on the particular pasteurizing apparatus being used that will provide the selected thermal treatment. Products having shelf lives not depicted in FIG. 4 are made by extrapolating the teachings of the figure, in light of the teachings above. Preferably, this process is carried out in pasteurizing apparatus which has been sterilized before the liquid whole egg product is passed therethrough, as explained above, to produce products having shelf lives of about eight weeks or more. In addition, it will be appreciated that longer shelf lives are generally obtained at the expense of greater levels of soluble protein loss. Thus, if product distribution systems do not require otherwise, products with shelf lives of up to about 32 weeks are preferred, and products with shelf lives up to about 24 weeks are more preferred.

FIG. 5 combines portions of FIGS. 3 and 4. It shows how the thermal treatments selected to provide a desired shelf life can at the same time be selected to provide products with good functional properties. More particularly, thermal treatments can be selected which produce liquid whole egg products having the desired shelf life and a soluble protein loss not greater than 5%.

The foregoing graphs have been presented to aid the understanding of the present invention. Some variation about the plotted lines is to be expected when the present invention is practiced on different equipment, or with different products. These graphs are accordingly not to be taken as limiting the present invention, as departures could be made therefrom while still capturing and benefitting from the teachings of the invention.

To obtain a superior ultrapasteurized liquid whole egg product, the contact time of the liquid product to heated surfaces during pasteurization should be reduced. More particularly, every particle of liquid whole egg product should be in contact with the heated surface or surfaces of the unit in which the product is heated for a total time less than the residence time of the particle in the heating unit. (The term "particle" as used herein has its standard meaning in the egg pasteurization field. See, e.g., 7 C.F.R. § 59.570(b) (1985)). This is accomplished by mixing the product at least periodically while it is being heated. In a continuous flow pasteurizing apparatus, such mixing is accomplished by introducing turbulence into the stream of the product at least periodically while it is being heated, as discussed below Other steps which are preferably employed to reduce fluid element contact time to heated surfaces include providing portions of the thermal treatment in which fluid elements are not in contact with heated surfaces, such as by providing a portion of the thermal treatment in a holding section, and by providing heated contact surface area to product volume ratios of less than 18 cm²/cm³ (Thus the surface area to volume ratio

is preferaby less than about 10, and is more preferably in the area of about 2).

It is also desirable to induce physical forces to make the product more homogeneous prior to thermal treatment, such as by inducing shear forces capable of reducing protein and fat unit size. This is preferably accomplished by dispersing the product prior to heating. Dispersing may be carried out with a dispersing valve or with a timing pump, as is known in the art. Such treatment advantageously reduces fouling, and serves to reduce any tendency of the product to coagulate. Such a dispersing step may be carried out by conducting a more rigorous homogenization step, but it is recommended that such more expensive homogenizing equipment be used as described below.

It is preferable that a homogenization step after heating be included. The term "homogenized," as used herein, means to subject the product to physical forces to reduce particle size. Such procedures are known in the art, and may be carried out on different types of equipment. It is preferable to carry out this homogenizing step with homogenizing equipment at total pressures of about 1,000 p.s.i. or more. Pressures of about 1,500 p.s.i. or more are more preferred, and pressures of 2,000 p.s.i. or more still more preferred.

Of these steps, it is particularly desirable to mix the liquid whole egg product at least periodically while it is heated. As noted above, in continuous flow equipment mixing is carried out by at least periodically subjecting the stream of liquid whole egg product to turbulence while it is heated. Turbulence, which is the mixing of particles over the cross-section of the product stream, is discussed in the *Egg Pasteurization Manual* at pages 6–8. Such turbulence is characterized by a Reynolds number greater than about 2,300, and preferably greater than about 4,600. Commercial high temperature, short time pasteurizing units are available which at least periodically impart turbulence to the stream of product being pasteurized while the product is being heated. For the purposes of the present invention, greater levels of turbulence are preferred. Thus the liquid whole egg product is preferably subjected to turbulence for a major portion of the time it is heated. Plate heat exchangers, trombone heat exchangers, spiral heat exchangers, and scrape surface heat exchangers are illustrative of the types of known heat exchangers which can be used to subject liquid whole egg products to turbulence while they are heated The physical forces induced in scrape surface heat exchangers are generally thought of as "mixing," but these exchangers induce turbulence at least in regions of the product stream, and are therefore considered to induce turbulence for purposes of the present invention.

Examples of whole egg products which can be pasteurized in liquid form by the method of the present invention include whole egg, fortified whole egg (whole egg with added yolk), salt whole egg (e.g., salt 10%), sugar whole egg (e.g., sugar 10%), blends of whole egg with syrup solids, syrups, dextrose and dextrins and/or gums and thickening agents, blends of whole eggs with less than 1% sugar and/or salt, scrambled egg mixes (for example, a mix of about 51% egg solids, 30% skim milk solids, 15% vegetable oil and 1.5% salt), reduced cholesterol egg products and blends thereof, custard blends, and the like. Products which are extremely sensitive to thermal processing and which are particularly suitable for ultrapasteurization by the present invention include, for example, liquid whole

egg and blends thereof (less than 2% added nonegg ingredients), fortified whole egg and blends thereof (24–38% egg solids, 2–12% added nonegg ingredients), liquid salt whole egg, liquid sugar whole egg, and other liquid whole egg blends which are 24–38% egg solids and 12% or less of added nonegg ingredients. Terms used herein have their standard meaning in accordance with industry and regulatory usage. See, e.g., 7 C.F.R. § 59.570(b) (1985).

The invention having been explained in general terms above, the following examples are provided to further illustrate the invention.

EXAMPLES 1–10

Raw Egg Product. Raw liquid whole egg was obtained from a local breaking plant (Gold Kist, Durham, N.C.). The egg was taken from their raw holding tank which was agitated to thoroughly blend approximately 30,000 pounds of egg. The egg was manually filled into 13.6 kg (30 lb) metal cans and were kept refrigerated before being transported 13.2 km (20 mi) to our laboratory in an insulated truck. The egg was held overnight at 4° C. (40° F.) or allowed to stand at room temperature for up to 12 hours to achieve higher bacterial numbers.

Thermal Processes. The time-temperature processes used in this study were designed to be equal to or more severe than minimum conditions defined by the 9D line for the destruction of Salmonella in whole egg (USDA, 1969) and within predetermined limits of denaturation of egg protein defined as percent soluble protein loss (%SPL) by Hamid-Samimi et al., *J. Food Sci.* 49:132 (1984). The objectives of this design were to provide Salmonella negative whole egg with a low number of surviving spoilage organisms while retaining adequate functional properties.

The thermal processing system used is outlined in FIG. 1. It consisted of a plate-type heat exchanger for preheat, various modifications of the No-Bac Unitherm model XLV (Cherry Burrell Corporation, Cedar Rapids, Iowa) to achieve different holding times, an aseptic homogenizer operated at 10.34 mPa (1,500 p.s.i.), and an aseptic packaging system (Model AB-3-250, Tetra Pak Inc., Dallas, Tex.). The flow rate was 2.89×10^{-4} m³/sec (275 GPH) with heating, holding, and cooling pipe diameters of 12.45 mm ID (5/8" nominal) stainless steel.

Before each process the entire system was sterilized at 121° C. for 30 minutes using hot water in the product section and steam in the heating media section and then cooled. The product and heating media temperatures were recorded for evaluation of the thermal effect of the heating section and to determine the total thermal effects. (Swartzel, *J. Agri. Food Chem.* 34:396 (1986). The temperatures were measured using Type T thermocouples with an electronic data logger (Model 9302, Monitor Labs., Inc., San Diego, Calif.). Each thermocouple probe was scanned every 30 seconds (one minute for process #1) and the readout sent to a computer for analyses The specific locations of the thermocouples in the system were as described by Swartzel and Jones. Paper No. 84-6006 of the American Society of Agricultural Engineers (1984).

Approximately one hour prior to initiation of each process, 408.2 kg (900 lb) of raw egg were transferred from the metal cans to a 568 1 (150 gal) vessel (Creamery Package Mfg. Co., Chicago, Ill.) and then mixed at room temperature with the stirring propeller at ca. 30

r.p.m. This volume of egg required approximately 20 minutes to process, therefore the last liter of egg was processed not later than 80 minutes after being removed from the cooler. Nine processes designated 1, 2, 3, 4, 5, 6, 7, 8, and 9 were run. Process 6 was repeated and designated 6.1. They were conducted two days apart on egg picked up on the same day. Egg for processes 6.1 to 9 were held at room temperature for not more than 12 hours to achieve a higher initial microbial load. All egg incubated at room temperature was chilled to 4° C. (40° F.) prior to processing.

After holding the egg at the scheduled process time and temperature and prior to packaging, the temperature was reduced to less than 10° C. (50° F.) in less than 26 seconds. Occasionally, due to technical difficulties it was not possible to cool the processed egg to below 10° C. In those instances the processed egg was moved into a freezer at −20° C. for 20 minutes after packaging. The packaging material was a low oxygen permeable laminate of polyethylene, paper, and aluminum foil formed into 250 ml containers (Tetra Pak aseptic filler model AB-3). Each package was dated and coded so that egg processed in the first seven minutes, the second seven minutes, and the remaining time were numbered 1, 2, and 3, respectively. The processed and packaged egg was held overnight at 4° C. (40° F.) prior to obtaining samples and being distributed for four and 10° C. storage.

Sampling Samples of raw egg for physical, chemical, and functional testing were aseptically removed from the mixing vat approximately 30 minutes prior to processing. The samples were then held overnight at 4° C. for evaluation with the pasteurized egg. Pasteurized samples were obtained on the day after processing or at selected times during storage at four and 10° C. Analyses were made on the combined contents of three or four individual packages representing the first, second, and third portions of each process run. When four packages were required, two packages from the middle portion of each process were used. Any sediment on the bottom of the cartons was scraped out and mixed into the egg by magnetic stirring.

Chemical Assays. The pH of the product was determined with a Fisher Accumet pH meter, model 600, equipped with a calomel reference and glass indicating electrodes. Solids were determined in triplicate by weighing two ml samples into disposable aluminum pans and drying in a forced draft oven for 24 hours. The AOAC (1985) microKjeldahl procedure was used to determine protein content of the samples. The extent of denaturation was estimated by determining the loss of soluble protein as described by Hamid-Samimi et al., supra, and the alpha-amylase activity of the egg was determined as described by Shrimpton and Monsey, *J. Hyg.* 60:153 (1962).

Sponge Cakes. True sponge cakes were made by using half of the amounts of ingredients listed following the procedures given by Gorman and Ball (1986) (Chapter 15 in *Egg Science and Technology,* 3rd Ed., W. J. Stadelman and O. J. Cotterill, Eds., AVI Publishing Co., Inc. Westport, Conn.) with the omission of vanilla. Two separate batches of batter were mixed for each treatment and 340 g of batter was weighed into rectangular pans (21.5×11.5×6.5 cm, id.). Cakes were baked at 191° C. for 25 minutes, inverted on a wire rack and allowed to stand at room temperature overnight. Heights were determined from the mean of four measurements along the center line of the long axis of the

cake. Cakes were then kept in plastic bags for further rheological evaluations.

Textural properties of the cakes were evaluated using an Instron Universal Testing Machine (Model 1122, Instron Engineering Corporation, Canton, Mass.). A plate was connected to a 2000-g load cell and positioned at the surface of the 5-cm cube of cake. The cross head and chart speeds were 200 mm/min and 100 mm/min, respectively. Three samples from each cake were subjected to deformation-relaxation cycles. The cubed cake samples were kept in a plastic bag before and after each test. The water activity of the cake samples were determined by placing three Durotherm (Lufft, West Germany) water activity meters in the plastic bag. Each meter was calibrated daily with a solution of barium chloride (aW 0.90 at 20° C.).

Custards. Duplicate custards of the flan type were made. Ingredients were 190-ml evaporated milk, 196-g sweetened condensed milk, 125-g whole egg, 50-g water, and one teaspoon vanilla. All ingredients were blended in a Waring blender at low speed for one minute and 360-g were weighed into a rectangular pan (14.3×8.0×5.6 cm, id.) which had been sprayed with "PAM" (Boyle-Midway, Inc., New York, N.Y.). Pans were placed in a tray containing 2.5-cm water and baked at 191° C. for 40 minutes. After overnight storage at 10° C., height of the custard in the pan was determined from the mean of three measurements made and with calipers along the center line of the long axis of the custard. Custards were removed from the pan after the sides were loosened with a spatula and allowed to stand at room temperature for 45 minutes. Height was again determined and percent sag was calculated according to Gardner et al. *Poultry Sci.* 61:75 (1982). Custards were stored in plastic bags at 10° C. for rheological evaluation.

The flat plate described above for evaluation of cake texture was replaced with a 10.5 mm diameter rod with a semispherical tip and force-deformation curves to failure were obtained for each custard. Cross head speed was 100 mm/min and all other parameters were the same as used in evaluations of the cakes Five values were averaged to obtain the penetration force (FI) for each custard.

Organoleptic Evaluation. Flavor of processed and stored egg was evaluated by one judge using the USDA palatability score (Laboratory Methods for Egg Products, USDA, Agricultural Marketing Service Poultry Division, Grading Branch, Washington, D.C. 20250 (1984)).

Thermal Process. The process times and temperatures used in this study are presented in Table 2.

TABLE 2

Actual, Equivalent Times and Temperatures, Calculated Heating Value of Treatments and Predicted % SPL Based on Heating Value[a]					
	Actual		Equivalent		Heating	Theoreti-
Proc. No.	Time (Sec.)	Temp. (°C.)	Time (Sec.)	Temp. (°C.)	Value[b] (G × 10[42])	cal % SPL[c]
1	26.2	63.7	30.4	63.1	6.1	0.52
2	92.0	63.8	97.5	63.3	20.8	1.74
3	192.2	65.3	192.4	65.1	72.8	5.97
4	9.2	67.8	15.7	66.5	8.4	0.71
5	56.9	68.2	63.0	67.5	44.6	3.70
6	123.0	68.3	125.5	67.9	99.4	8.10
6.1	123.0	68.9	129.0	68.4	117.6	9.50
7	2.7	71.5	9.5	68.5	8.9	0.75
8	30.1	72.2	36.5	71.5	78.9	6.46

TABLE 2-continued

Actual, Equivalent Times and Temperatures, Calculated Heating Value of Treatments and Predicted % SPL Based on Heating Value[a]					
	Actual		Equivalent		Heating	Theoreti-
Proc. No.	Time (Sec.)	Temp. (°C.)	Time (Sec.)	Temp. (°C.)	Value[b] (G × 10[42])	cal % SPL[c]
9	56.7	72.0	62.5	71.8	146.8	11.70

[a]See Swartzel, J. Food Sci. 47:1886 (1982), and Hamid-Samimi et al., supra (1984) for descriptions of heating value and % SPL.
[b]G values are determined based on activation energy for SPL.
[c]Based on laboratory batch data.

The 10 processes, numbers 1–9, were performed in the same chronological order as they are numbered. After gaining process experience and as the result of evaluations during the study, it was determined that longer holding times and temperatures than expected could be used. The actual temperatures reported in Table 3 are the averages of temperature readings, every 30 seconds, of the temperature probes at the beginning and end of the holding tube.

Equivalent times and temperatures as well as holding times and temperatures are set forth in Table 2. It can be seen that equivalent times are generally longer than the corresponding holding times, and equivalent temperatures are generally lower than the corresponding holding temperatures. At longer times, the differences between corresponding holding temperatures and equivalent temperatures are smaller.

The calculated heating value, G, shown in Table 2, gives a means for making a comparison of the relatively severity of the different processes. Processes 9, 6.1, 6 and 8 had the highest G values, respectively. The percent SPL based on the heating value (G) are also shown in Table 2.

Chemical Properties of Processed Egg. The results of alpha-amylase activity assays (Table 3) confirms that the enzyme is inactivated by mild heat processes. Table 3 shows that the thermal processes used did not affect protein content or the soluble protein content.

TABLE 3

Thermal Effects on Alpha-Amylase Activity, Protein Content and % Soluble Protein							
Process No.	Alpha-Amylase[a]			MicroKjeldahl[b]			% Soluble Protein[c] (From Absorbance)
	Raw	UHT	Plant	Raw	UHT	Plant	
1	0.045	0.048	0.099	13.10	11.60	13.1	86.2
2	0.033	0.588	—	12.59	11.96	—	102.3
3	0.055	1.050	—	11.67	11.32	—	101.3
4	0.029	0.031	0.137	11.83	11.79	11.51	101.1
5	0.046	1.000	—	10.19	10.13	—	100.3
6	0.053	1.120	—	12.27	12.34	—	100.9
6.1	0.040	1.130	—	12.70	12.54	—	103.3
7	0.052	0.764	—	12.37	12.53	—	104.5
8	0.063	1.000	—	11.19	11.42	—	100.4
9	0.060	1.170	—	11.74	11.77	—	100.7

[a]Alpha-Amylase data is reported as the absorbance at 585 nm. Activity is inversely related to absorbance.
[b]MicroKjeldahl data is reported as percent protein.
[c]Absorbance at 280 nm of heated egg/control (raw) egg in solution as described by Hamid-Samimi et al., supra (1984).

The chemical data indicate that the processes did not result in extensive damage to the egg proteins. The predicted percent soluble protein losses (Table 3) were based on studies conducted with small amounts of egg (1 ml) being heated in the cup of a brookfield viscometer (Hamid-Samimi et al., supra, 1984). The egg was heated while various shear rates were applied to simu-

late egg under dynamic conditions that exist in conventional heat exchangers. Thus, this work revealed that the model system resulted in prediction equations that underestimated the thermal treatments that liquid whole egg products could tolerate while still obtaining products with good functional properties. Analysis of the causes of these unexpectedly good results led to the guidelines discussed above which should be followed to obtain functionally superior ultrapasteurized products.

Function of Processed Eggs. The functional properties of the processed eggs agreed with the physical and chemical results. Based on the data presented in Tables 4 and 5 for nonstored egg, there appeared to be very little heat effect on the performance of the ultrapasteurized egg relative to raw or commercially pasteurized egg. Cake height as an indication of the leavening ability and force to deform, springiness, and relaxation parameter (Peleg and Normand, *Rheologica Acta* 22:108 (1983)) as indicators of textural properties were very similar for all egg examined.

TABLE 4

Functional Properties of Cakes for Control (Raw),
Ultrapasteurized (UP) at Zero Day Storage, and
Commercially Pasteurized Eggs (Plant)

Variable	Treat-ment	Mean	Minimum	Maximum	n	C.V.
Maximum	Raw	10.02	7.79	13.70	10	17.3
Force[a]	UP	10.49	9.18	12.91	10	10.5
(N)	Plant	9.73	9.56	9.91	2	2.5
Relaxa-	Raw	0.394	0.379	0.417	10	3.24
tion[b]	UP	0.410	0.395	0.442	10	3.34
Para-	Plant	0.402	0.402	0.403	2	0.17
meter						
Spring-	Raw	0.83	0.81	0.86	10	1.94
iness[c]	UP	0.83	0.81	0.87	10	2.47
	Plant	0.82	0.81	0.82	2	1.32
Cake	Raw	65.1	63.3	66.7	10	1.66
Height	UP	61.7	55.1	65.5	10	5.26
(mm)	Plant	64.8	64.7	64.8	2	0.11
Water	Raw	0.873	0.832	0.891	10	2.53
Activity	UP	0.875	0.835	0.892	10	2.37
	Plant	0.892	0.892	0.892	1	—

[a]Force required to deform the sample of cake by 26 mm.
[b]Asymptotic relaxation value as defined by Peleg and Normand, supra (1983).
[c]Ratio of the second peak force to the first peak force in the force deformation cycle.

TABLE 5

Functional Properties of Custards for Controls.
(Raw), Zero Day Storage Ultrapasteurized (UP)
and Commercially Pasteurized Eggs (Plant)

Variable	Treat-ment	Mean	Minimum	Maximum	n	C.V.
Penetra-	Raw	0.82	0.76	0.96	10	8.20
tion	UP	0.70	0.59	0.80	10	8.56
Force	Plant	0.79	0.77	0.81	2	3.69
(N)						
Custard	Raw	35.7	35.1	36.7	10	1.66
Height	UP	35.6	35.1	36.3	10	5.26
(mm)	Plant	34.6	34.0	35.3	2	0.11
% Sag	Raw	7.2	5.65	9.54	10	16
	UP	7.1	5.41	8.56	10	13
	Plant	4.6	2.66	6.51	2	59

The water activity of the cakes were similar indicating that the experimental handling procedures for the cakes were uniform and should not have affected the instrumental evaluation of textural properties. The custard data indicated that all egg sources evaluated had good ability to form gels. The gels had excellent integrity as indicated by the relatively low percent sag, yet the custards were relatively tender as indicated by the penetration forces. Although weep was not measured, very little syneresis was noted even after holding the custards

overnight for textural evaluations. The limited organoleptic evaluation of the processed eggs indicated that the thermal processes did not affect flavor or aroma in scrambled eggs relative to scrambled egg made from a fresh shell egg. The USDA palatability scores were seven to eight (eight being the highest score).

Refrigerated Storage Effect. As long as the processed egg was not obviously spoiled, as indicated by organoleptic evaluations, storage at 4° C. maintained the chemical, functional, and organoleptic properties of the processed egg up to 24 weeks for some of the samples. The data presented in Tables 6, 7, and 8 were taken from stored egg that was judged organoleptically sound. The criteria for that judgment were: (1) that the color was normal, i.e., within the expected range of color observed for eggs immediately post-processing, and (2) that there were no objectional aromas or flavors. In this study, because of the sampling procedure where most of the samples were checked at four-week intervals, there were no borderline decisions, a sample was obviously acceptable or unacceptable. Bright yellow colors, off-aromas, and pH values below seven were typical of samples judged to be spoiled.

TABLE 6

Means for Proteins, Solids and pH for Controls
(Raw), Commercially Pasteurized (Plant) and
Ultrapasteurized (UP) Egg

Variable	Treat-ment[a]	Mean	Minimum	Maximum	n	C.V.
%	Raw	11.92	10.19	13.10	10	6.8
Protein	Plant	12.30	11.51	13.10	2	9.1
	UP 0	11.74	10.13	12.54	10	6.0
%	Raw	24.6	23.9	25.2	10	1.6
Solids	Plant	24.8	24.4	25.2	2	2.5
	0	24.5	24.0	25.0	10	1.3
	4	24.4	24.0	24.9	10	1.3
	UP 8	24.4	24.0	24.7	9	0.9
	12	24.3	23.8	24.7	7	1.3
	18	24.9	24.4	25.5	2	3.1
	24	24.8	24.7	24.9	2	0.3
pH	Raw	7.5	7.2	7.6	10	1.7
	Plant	7.1	7.1	7.2	2	0.5
	0	7.5	7.3	7.6	10	1.4
	4	7.4	7.2	7.6	10	1.4
	UP 8	7.4	7.3	7.5	9	1.2
	12	7.3	7.2	7.4	7	1.2
	18	7.4	7.4	7.4	2	0
	24	7.4	7.4	7.4	2	0

[a]Numbers indicate storage at 4° C. in weeks for processed eggs.

TABLE 7

Functional Properties of Cakes Made from Eggs
Stored at 4° C.

Variable	Storage (Weeks)	Mean	Minimum	Maxi-mum	n	C.V.
Maximum	4	9.78	7.90	14.95	10	21.3
Force[a]	8	10.37	7.82	14.53	9	20.5
(N)	12	11.29	8.84	14.28	7	18.2
	18	11.42	10.32	12.53	2	13.6
	24	10.53	9.57	11.49	2	12.9
Relaxa-	4	.3937	0.3759	0.4167	10	3.7
tion	8	.3876	0.3636	0.4132	9	3.9
Para-	12	.3846	0.3717	0.4032	7	3.0
meter[b]	18	.3788	0.3788	0.3788	2	3.1
	24	.3745	0.3704	0.3788	2	1.5
Spring-		0.829	0.799	0.853	10	1.7
iness[c]	8	0.834	0.811	0.872	9	2.0
	12	0.834	0.820	0.843	7	0.9
	18	0.831	0.829	0.832	2	0.3
	24	0.815	0.787	0.843	2	4.9
Height	4	61	54	65	10	6.02
(mm)	8	64	63	67	9	2.06
	12	64	60	65	7	2.7

TABLE 7-continued

Functional Properties of Cakes Made from Eggs Stored at 4° C.

Variable	Storage (Weeks)	Mean	Minimum	Maximum	n	C.V.
	18	63	62	65	2	3.0
	24	65	65	65	2	0.22
Water	4	0.860	0.796	0.888	10	4.2
Activity	8	0.884	0.868	0.900	9	1.1
	12	0.879	0.844	0.896	7	2.0
	18	0.872	0.872	0.872	1	—
	24	0.879	0.876	0.882	2	0.4

*See Table 4 for definition of terms.

TABLE 8

Functional Properties of Custards Made from Eggs Stored at 4° C.

Variable	Storage (Weeks)	Mean	Minimum	Maximum	n	C.V.
Pene-	4	0.68	0.47	0.77	10	12.7
tration	8	0.70	0.64	0.76	9	9.1
Force	12	0.75	0.57	0.83	7	20.3
(N)	18	0.94	0.85	1.02	2	12.6
	24	0.82	0.76	0.88	2	10.5
Custard	4	35	34	36	10	2.4
Height	8	35	34	36	9	1.6
(mm)	12	35	35	36	7	1.2
	18	36	36	36	2	0.4
	24	35	35	35	2	1.0
% Sag	4	7.1	3.0	11.6	10	38.1
	8	5.9	3.5	7.5	9	20.5
	12	6.5	4.6	8.0	7	19.5
	18	7.2	6.4	8.1	2	15.9
	24	6.6	4.9	8.2	2	36.0

Visual observations of the interiors of opened packages revealed very little sedimentation during storage. A very thin layer of a fine, light yellow, granular-like material was observed on the bottom of cartons after four weeks of refrigerated storage.

Shelf Life. The times of spoilage of egg from each trial are presented in Table 9.

TABLE 9

Shelf Life for Liquid Whole Egg Stored at 4° C.

Process	Shelf Life (Weeks)
1	4–8
2	8–12
3	>12
4	8–12
5	>18
6	18–24
6.1	>24
7	12–18
8	20–24
9	18–20

These data were used to generate the time and temperature guidelines set forth in FIG. 5.

The invention has been discussed with a degree of specificity above. This discussion has been provided for illustrative purposes only, with the scope of the invention being defined by the following claims.

That what which is claimed is:

1. A method of ultrapasteurizing a liquid whole egg product, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is

(a) heated to a predetermined holding temperature by contacting said liquid whole egg product to a heated surface, then

(b) maintained at said predetermined holding temperature for a predetermined holding time, and then

(c) cooled, wherein the total thermal treatment received by the liquid whole egg product is defined by an equivalent temperature and an equivalent time defining a point above the 5% SPL (BATCH) line of FIG. 3, but insufficient to cause coagulation of the liquid whole egg product, and then

(d) aseptically packaged to provide a packaged liquid whole egg product characterized by a refrigerated shelf life of about four weeks to about 36 weeks.

2. A method according to claim 1, wherein said pasteurizing apparatus is sterilized before said liquid whole egg product is passed therethrough, and wherein said packaged liquid whole egg product is characterized by a preselected shelf life of about eight weeks to about 36 weeks.

3. A method according to claim 1, wherein said liquid whole egg product is subjected to turbulence for a major portion of the time said liquid whole egg product is heated.

4. A method of ultrapasteurizing a liquid whole egg product, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is heated to a predetermined real temperature by contacting said liquid whole egg product to a heated surface while at least periodically subjecting said continuous stream of liquid whole egg product to turbulence, wherein the total thermal treatment received by the liquid whole egg product is described by an equivalent time and an equivalent temperature defining a point above the 5% SPL (BATCH) line of FIG. 3, but insufficient to cause said liquid whole egg product to coagulate, followed by aseptically packaging the liquid whole egg product to provide a package liquid whole egg product characterized by a refrigerated shelf life of about four weeks to about 36 weeks.

5. A method according to claim 4, wherein said liquid whole egg product is subjected to turbulence for a major portion of the time said liquid whole egg product is heated.

6. A method according to claim 4, wherein said liquid whole egg product is dispersed before said liquid whole egg product is heated.

7. The method according to claim 4, wherein said pasteurizing apparatus is sterilized before said liquid whole egg product is passed therethrough, and wherein said packaged liquid whole egg product is characterized by a preselected shelf life of about eight weeks to about 36 weeks.

8. A method of ultrapasteurizing a liquid whole egg product, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is

(a) heated to a predetermined holding temperature by contracting said liquid whole egg product to a heated surface while at least periodically subjecting said continuous stream of liquid whole egg product to turbulence, then

(b) maintained at said predetermined holding temperature for a predetermined holding time, and then

(c) cooled, wherein the total thermal treatment received by the liquid whole egg product is defined by an equivalent time and an equivalent temperature above the 5% SPL (batch) line of FIG. 3, but insufficient to cause said liquid whole egg product to coagulate, and then (d) aseptically packaged to

provide a packaged liquid whole egg product characterized by a refrigerated shelf life of about four weeks to about 36 weeks.

9. A method according to claim 8, wherein said liquid whole egg product is subjected to turbulence for a major portion of the time said liquid whole egg product is heated.

10. A method according to claim 8, wherein said liquid whole egg product is dispersed before said liquid whole egg product is heated.

11. A method according to claim 8, wherein said pasteurizing apparatus is sterilized before said liquid whole egg product is passed therethrough, and wherein said packaged liquid whole egg product is characterized by a preselected shelf life of about eight weeks to about 36 weeks.

12. A method of making a packaged liquid whole egg product characterized by a preselected refrigerated shelf life of about four weeks to about 36 weeks, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is heated by contacting said liquid whole egg product to a heated surface for a predetermined time and to a predetermined temperature while at least periodically subjecting said continuous stream of liquid whole egg product to turbulence, wherein the liquid whole egg product is heated for a predetermined time and to a predetermined temperature selected so that the total thermal treatment received by the liquid whole egg product is defined by an equivalent time and an equivalent temperature not greater than the expected 5% SPL (continuous processing) line of FIG. 3, and wherein said predetermined temperature and said predetermined time are chosen to impart said preselected shelf life to said liquid whole egg product, followed by aseptically packaging the liquid whole egg product.

13. A method according to claim 12 wherein said pasteurizing apparatus is sterilized before said liquid whole egg product is passed therethrough, and wherein said packaged liquid whole egg product is characterized by a preselected shelf life of about eight weeks to about 36 weeks.

14. A method according to claim 12 wherein said liquid whole egg product is subjected to turbulence for

major portion of the time said liquid whole egg product is heated.

15. A method of making a packaged liquid whole egg product characterized by a preselected refrigerated shelf life of about four weeks to about 36 weeks, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is

(a) heated by contacting said liquid whole egg product to a heated surface for a time sufficient to raise said liquid whole egg product to a predetermined holding temperature while at least periodically subjecting said continuous stream of liquid whole egg product to turbulence, then

(b) maintained at said predetermined hold temperature for a predetermined hold time, wherein said holding temperature and holding time are selected so that the total thermal treatment received by the liquid whole egg product is defined by an equivalent time and an equivalent temperature not greater than the expected 5% SPL (continuous processing) line of FIG. 3, and wherein said holding temperature and holding time are selected to impart said preselected shelf life to said liquid whole egg product, and then

(c) cooled, followed by

(d) aseptically packaging the liquid whole egg product.

16. A method according to claim 15, wherein said pasteurizing apparatus is sterilized before said liquid whole egg product is passed therethrough, and wherein said packaged liquid whole egg product is characterized by preselected shelf life of about eight weeks to about 36 weeks.

17. A method according to claim 16 wherein said liquid whole egg product is subjected to turbulence for a major portion of the time said liquid whole egg product is heated.

18. A method according to claim 1, 4, 8, 12, 16, wherein said liquid whole egg product is liquid whole egg.

19. A method according to claim 1, 4, 8, 12, 16, wherein said liquid whole egg product is a liquid whole egg blend which is about 24–38% egg solids and about 12% or less of added nonegg ingredients.

* * * * *

REEXAMINATION CERTIFICATE (4000th)

United States Patent [19]

Swartzel et al.

[11] B1 4,957,759

[45] Certificate Issued Feb. 29, 2000

[54] **METHOD FOR THE ULTRAPASTEURIZATION OF LIQUID WHOLE EGG PRODUCTS**

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Reexamination Requests:
   No. 90/003.630, Nov. 10, 1994
   No. 90/004.272, Jun. 11, 1996
   No. 90/004.274, Jun. 13, 1996

Reexamination Certificate for:
   Patent No.: 4,957,759
   Issued: Sep. 18, 1990
   Appl. No.: 07/311,594
   Filed: Feb. 16, 1989

[*] Notice: This patent is subject to a terminal disclaimer.

Certificate of Correction issued Jan. 7, 1992.

Related U.S. Application Data

[63] Continuation of application No. 06/904,744, Sep. 8, 1986, Pat. No. 4,808,425.

[51] Int. Cl.[7] A23L 3/00
[52] U.S. Cl. 426/399; 426/521; 426/614
[58] Field of Search 426/399, 521, 426/614

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Primary Examiner—Anthony Weier

[57]   ABSTRACT

Methods of ultrapasteurizing liquid whole egg products in continuous flow, high temperature, short time pasteurization equipment are provided. The equivalent point method is preferably used to evaluate the total thermal treatment received by the product in this equipment. Also disclosed is a method of making liquid whole egg products having preselected, extended, refrigerated shelf lives.

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REEXAMINATION CERTIFICATE
ISSUED UNDER 35 U.S.C. 307

THE PATENT IS HEREBY AMENDED AS INDICATED BELOW.

Matter enclosed in heavy brackets [ ] appeared in the patent, but has been deleted and is no longer a part of the patent; matter printed in italics indicates additions made to the patent.

AS A RESULT OF REEXAMINATION. IT HAS BEEN DETERMINED THAT:

Claims 1 and 4 are determined to be patentable as amended.

Claims 2, 3, 5 and 6, dependent on an amended claim, are determined to be patentable.

1. A method of making a packaged liquid whole egg product characterized by a preselected refrigerated shelf life of about four weeks to about 36 weeks, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is heated by contacting said liquid whole egg product to a heated surface for a predetermined time and to a predetermined temperature while at least periodically subjecting said continuous stream of liquid whole egg product to turbulence, wherein the liquid [while] *whole* egg product is heated for a predetermined time and to a predetermined temperature insufficient to cause more than a 5% soluble protein loss from said product, wherein the total thermal treatment received by the liquid whole egg product

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is described by an equivalent temperature and an equivalent time defining a point above the 5% SPL (BATCH) line of FIG. 3, and wherein said predetermined temperature and said predetermined time are chosen to impart said preselected shelf life to said liquid whole egg product, followed by aseptically packaging the liquid whole egg product.

4. A method of making a packaged liquid whole egg product characterized by a preselected refrigerated shelf life of about four weeks to about 36 weeks, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is

    (a) heated by contacting said liquid whole egg product to a heated surface for a time sufficient to raise said liquid whole egg product to a predetermined holding temperature while at least periodically subjecting said continuous stream of liquid whole egg product to turbulence, then

    (b) maintained at said [preselected] *predetermined* holding temperature for a predetermined holding time, wherein said holding temperature and holding time are selected to cause a soluble protein loss of not more than 5% from said product, and wherein said holding temperature and holding time are selected to impart said preselected shelf life to said liquid whole egg product, and then

    (c) cooled wherein the total thermal treatment received by the liquid whole egg product is described by an equivalent temperature and an equivalent time defining a point above the 5% SPL (BATCH) line of FIG. 3, followed by

    (d) aseptically packaging the liquid whole egg product.

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REEXAMINATION CERTIFICATE (4021st)

United States Patent [19]

Swartzel et al.

[11] B1 4,994,291

[45] Certificate Issued   *Mar. 21, 2000

[54] METHOD FOR THE ULTRAPASTEURIZATION OF LIQUID WHOLE EGG

[75] Inventors: Kenneth R. Swartzel; Hershell R. Ball, Jr.; Mohammad-Hossein Hamid-Samimi, all of Raleigh, N.C.

[73] Assignee: North Carolina State University, Raleigh, N.C.

Reexamination Requests:
   No. 90/003,631, Nov. 10, 1994
   No. 90/004,546, Feb. 11, 1997

Reexamination Certificate for:
   Patent No.:   4,994,291
   Issued: Feb. 19, 1991
   Appl. No.:   07/535,718
   Filed: Jun. 11, 1990

[*] Notice: This patent is subject to a terminal disclaimer.

Certificate of Correction issued Jul. 28, 1992.

Related U.S. Application Data

[63] Continuation of application No. 07/311,594, Feb. 16, 1989, Pat. No. 4,957,759, which is a continuation of application No. 06/904,744, Sep. 8, 1986, Pat. No. 4,808,425.

[51] Int. Cl.[7] A23L 3/00
[52] U.S. Cl. 426/399; 426/521; 426/614
[58] Field of Search 426/399, 525, 426/614, 106, 520

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(List continued on next page.)

Primary Examiner—Anthony J. Weier

[57]   ABSTRACT

Methods of ultrapasteurizing liquid whole egg products in continuous flow, high temperature, short time pasteurization equipment are provided. The equivalent point method is preferably used to evaluate the total thermal treatment received by the product in this equipment. Also disclosed is a method of making liquid whole egg products having preselected, extended, refrigerated shelf lives.

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(d) aseptically packaging the non-sterile pasteurized liquid whole egg.

16. A method of making packaged liquid whole egg characterized by a preselected refrigerated shelf life of about four weeks to about 36 weeks, comprising passing the liquid whole egg as a continuous stream through a pasteurizing apparatus to produce non-sterile pasteurized liquid whole egg, during which the liquid whole egg is heated by contacting said liquid whole egg to a heated surface for a predetermined time and to a predetermined temperature while at least periodically subjecting said continuous stream of liquid whole egg to turbulence, wherein the liquid whole egg is heated for a predetermined time and to a predeter-

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mined temperature insufficient to cause more than a 5% soluble protein loss therefrom, wherein the total thermal treatment received by the liquid whole egg [product] is described by an equivalent temperature and an equivalent time defining a point above the 5% [(]SPL[)] (BATCH) line of FIG. 3, and wherein said predetermined temperature and said predetermined time are chosen to impart said preselected shelf life to said liquid whole egg, followed by aseptically packaging the non-sterile pasteurized liquid whole egg.

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REEXAMINATION CERTIFICATE
ISSUED UNDER 35 U.S.C. 307

THE PATENT IS HEREBY AMENDED AS
INDICATED BELOW.

Matter enclosed in heavy brackets [ ] appeared in the patent, but has been deleted and is no longer a part of the patent; matter printed in italics indicates additions made to the patent.

AS A RESULT OF REEXAMINATION, IT HAS BEEN DETERMINED THAT:

The patentability of claims 19–21 is confirmed.

Claim 3 is cancelled.

Claims 1, 4, 5, 9, 10, 13 and 16 are determined to be patentable as amended.

Claims 2, 6–8, 11, 12, 14, 15, 17 and 18, dependent on an amended claim, are determined to be patentable.

1. A method of ultrapasteurizing liquid whole egg, comprising passing the liquid whole egg as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg is heated to a predetermined real temperature, by contacting said liquid whole egg to a heated surface wherein the total thermal treatment received by the liquid whole egg is described by an equivalent temperature and an equivalent time defining a point above the 5% SPL (BATCH) line of FIG. 3, but insufficient to cause coagulation of the liquid whole egg *followed by the step of aseptically packaging the liquid whole egg to provide a packaged liquid whole egg having an extended refrigerated shelf life.*

4. A method of ultrapasteurizing liquid whole egg, comprising passing the liquid whole egg as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg is

   (a) heated to a predetermined holding temperature by contacting said liquid whole egg to a heated surface, then

   (b) maintained at said predetermined holding temperature for a predetermined holding time, and then

   (c) cooled, wherein the total thermal treatment received by the liquid whole egg is defined by an equivalent temperature and an equivalent time defining a point above the 5% SPL (BATCH) line of FIG. 3, but insufficient to cause coagulation of the liquid whole egg[.]; *and*

   (d) *aseptically packaging the liquid whole egg to provide a packaged liquid whole egg having an extended refrigerated shelf life.*

5. A method of ultrapasteurizing liquid whole egg, comprising passing the liquid whole egg as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg is heated to a predetermined real temperature by contacting said liquid whole egg to a heated surface while at least periodically subjecting said continuous stream of liquid whole egg to turbulence, wherein the total thermal treatment received by the liquid whole egg is described by an equivalent time and an equivalent temperature defining a point above the 5% SPL (BATCH) line of FIG. 3, but insufficient to cause said liquid whole egg to coagulate, *followed by the*

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step of aseptically packaging the liquid whole egg to provide a packaged liquid whole egg having an extended refrigerated shelf life.

9. A method of ultrapasteurizing liquid whole egg, comprising passing the liquid whole egg as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg is

   (a) heated to a predetermined holding temperature by contacting said liquid whole egg to a heated surface while at least periodically subjecting said continuous stream of liquid whole egg to turbulence, then

   (b) maintained at said predetermined holding temperature for a predetermined holding time, and then

   (c) cooled, wherein the total thermal treatment received by the liquid whole egg is defined by an equivalent time and an equivalent temperature *defining a point* above the 5% SPL (BATCH) line of FIG. 3, but insufficient to cause said liquid whole egg to coagulate[.]; *and*

   (d) *aseptically packaging the liquid whole egg to provide a packaged liquid whole egg having an extended refrigerated shelf life.*

10. A method of making packaged liquid whole egg characterized by a preselected refrigerated shelf life of about four weeks to about 36 weeks, comprising passing the liquid whole egg as a continuous stream through a pasteurizing apparatus to produce non-sterile pasteurized liquid whole egg, during which the liquid whole egg is heated by contacting said liquid whole egg to a heated surface for a predetermined time and to a predetermined temperature while at least periodically subjecting said continuous stream of liquid whole egg [product] to turbulence, wherein the liquid whole egg is heated for a predetermined time and to a predetermined temperature insufficient to cause more than a 5% soluble protein loss therefrom, *wherein the total thermal treatment received by the liquid whole egg is described by an equivalent temperature and an equivalent time defining a point above the 5% SPL (BATCH) line of FIG. 3 and wherein said predetermined temperature and said predetermined time are chosen to impart said preselected shelf life to said liquid whole egg, followed by aseptically packaging the non-sterile pasteurized liquid whole egg.*

13. A method of making packaged liquid whole egg characterized by a preselected refrigerated shelf life of about four weeks to about 36 weeks, comprising passing the liquid whole egg as a continuous stream through a pasteurizing apparatus to produce non-sterile pasteurized liquid whole egg, during which the liquid whole egg is

   (a) heated by contacting said liquid whole egg to a heated surface for a time sufficient to raise said liquid whole egg to a predetermined holding temperature while at least periodically subjecting said continuous stream of liquid whole egg to turbulence, then

   (b) maintained at said predetermined holding temperature for a predetermined holding time, wherein said holding temperature and holding time are selected to cause a soluble protein loss of not more than 5% therefrom, *wherein the total thermal treatment received by the liquid whole egg is described by an equivalent temperature and an equivalent time defining a point above the 5% SPL (BATCH) line of FIG. 3 and wherein said holding temperature and holding time are selected to impart said preselected shelf life to said liquid whole egg,* and then

   (c) cooled, *followed by*

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(d) aseptically packaging the non-sterile pasteurized liquid whole egg.

16. A method of making packaged liquid whole egg characterized by a preselected refrigerated shelf life of about four weeks to about 36 weeks, comprising passing the liquid whole egg as a continuous stream through a pasteurizing apparatus to produce non-sterile pasteurized liquid whole egg, during which the liquid whole egg is heated by contacting said liquid whole egg to a heated surface for a predetermined time and to a predetermined temperature while at least periodically subjecting said continuous stream of liquid whole egg to turbulence, wherein the liquid whole egg is heated for a predetermined time and to a predeter-

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mined temperature insufficient to cause more than a 5% soluble protein loss therefrom, wherein the total thermal treatment received by the liquid whole egg [product] is described by an equivalent temperature and an equivalent time defining a point above the 5% [(]SPL[)] (BATCH) line of FIG. 3, and wherein said predetermined temperature and said predetermined time are chosen to impart said preselected shelf life to said liquid whole egg, followed by aseptically packaging the non-sterile pasteurized liquid whole egg.

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US004808425B1

REEXAMINATION CERTIFICATE (4093rd)

United States Patent [19]

[11] B1 4,808,425

Swartzel et al.

[45] Certificate Issued May 30, 2000

[54] **METHOD FOR THE ULTRAPASTEURIZATION OF LIQUID WHOLE EGG PRODUCTS**

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Reexamination Requests:
 No. 90/003,629, Nov. 10, 1994
 No. 90/003,755, Jan. 25, 1995

Reexamination Certificate for:
 Patent No.: 4,808,425
 Issued: Feb. 28, 1989
 Appl. No.: 06/904,744
 Filed: Sep. 8, 1986

Certificate of Correction issued Nov. 7, 1989.

[51] Int. Cl.[7] A23B 5/005; A23L 1/32; A23L 3/16

[52] U.S. Cl. 426/399; 426/521; 426/614

[58] Field of Search 426/399, 521, 426/520, 614, 106

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Primary Examiner—Anthony Weier

[57] **ABSTRACT**

Methods of ultrapasteurizing liquid whole egg products in continuous flow, high temperature, short time pasteurization equipment are provided. The equivalent point method is preferably used to evaluate the total thermal treatment received by the product in this equipment. Also disclosed is a method of making liquid whole egg products having preselected, extended, refrigerated shelf lives.

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REEXAMINATION CERTIFICATE ISSUED UNDER 35 U.S.C. 307

THE PATENT IS HEREBY AMENDED AS INDICATED BELOW.

Matter enclosed in heavy brackets [ ] appeared in the patent, but has been deleted and is no longer a part of the patent; matter printed in italics indicates additions made to the patent.

AS A RESULT OF REEXAMINATION, IT HAS BEEN DETERMINED THAT:

Claim 3 is cancelled.

Claims 1, 4, 5, 9, 10, 15, 18 and 24–26 are determined to be patentable as amended.

Claims 2, 6–8, 11–14, 16, 17 and 19–23, dependent on an amended claim, are determined to be patentable.

1. A method of ultrapasteurizing a liquid whole egg product, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is heated to a predetermined real temperature, by contacting said liquid whole egg product to a heated surface wherein the total thermal treatment received by the liquid whole egg product is described by an equivalent temperature and an equivalent time defining a point above the 5% SPL (BATCH) line of FIG. 3, but insufficient to cause coagulation of the liquid whole egg product followed by the step of aseptically packaging the liquid whole egg product to a packaged liquid whole egg product having an extended refrigerated shelf life.

4. A method of ultrapasteurizing a liquid whole egg product, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is

  (a) heating to a predetermined holding temperature by contacting said liquid whole egg product to a heated surface, then

  (b) maintained at said predetermined holding temperature for a predetermined holding time, and then

  (c) cooled, wherein the total thermal treatment received by the liquid whole egg product is defined by an equivalent temperature and an equivalent time defining a point above the 5% SPL (BATCH) line of FIG. 3, but insufficient to cause coagulation of the liquid whole egg product; and

  (d) aseptically packaging the liquid whole egg product to provide a packaged liquid whole egg product having an extended refrigerated shelf life.

5. A method of ultrapasteurizing a liquid whole egg product, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is heated to a predetermined real temperature of at least 63.7° C. by contacting said liquid whole egg product to a heated surface while at least periodically subjecting said continuous stream of liquid whole egg product to turbulence, wherein the total thermal treatment received by the liquid whole egg product is described by an equivalent time and an equivalent temperature defining a point above the 5% SPL (BATCH) line of FIG. 3, but insufficient to cause said liquid whole egg product to coagulate followed by the step of aseptically

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packaging the liquid whole egg product to provide a packaged liquid whole egg product having an extended refrigerated shelf life.

9. A method of ultrapasteurizing a liquid whole egg product, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is

  (a) heated to a predetermined holding temperature by contacting said liquid whole egg product to a heated surface while at least periodically subjecting said continuous stream of liquid whole egg product to turbulence, then

  (b) maintained at said predetermined holding temperature for a predetermined holding time, and then

  (c) cooled, wherein the total thermal treatment received by the liquid whole egg product is defined by an equivalent time and an equivalent temperature above the 5% SPL (BATCH) line of FIG. 3, but insufficient to cause said liquid whole egg product to coagulate; and

  (d) aseptically packaging the liquid whole egg product to provide a packaged liquid whole egg product having an extended refrigerated shelf life.

10. A method of ultrapasteurizing a liquid whole egg product, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is

  (a) heated to a predetermined holding temperature, then

  (b) maintained at said predetermined holding temperature for a predetermined holding time, then

  (c) homogenized at said predetermined holding temperature, and then

  (d) cooled, wherein the total thermal treatment received by the liquid whole egg product is defined by an equivalent temperature and an equivalent time defining a point above the (9D) Samonella line of FIG. 3, but insufficient to cause coagulation of the liquid whole egg product, and where the liquid whole egg product which is homogenized consists essentially of the liquid whole egg product which is heated.

15. A method of making a packaged liquid whole egg product characterized by a preselected refrigerated shelf life of about four weeks to about 36 weeks, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is heated by contacting said liquid whole egg product to a heated surface for a predetermined time and to a predetermined temperature of at least 63.7° C. while at least periodically subjecting said continuous stream of liquid whole egg product to turbulence, wherein the liquid whole egg product is heated for a predetermined time and to a predetermined temperature insufficient to cause more than a 5% soluble protein loss from said product, wherein the total thermal treatment received by the liquid whole egg product is described by an equivalent temperature and an equivalent time defining a point above the 5% SPL (BATCH) line of FIG. 3 and wherein said predetermined temperature and said predetermined time are chosen to impart said preselected shelf life to said liquid whole egg product, followed by aseptically packaging the liquid whole egg product.

18. A method of making a packaged liquid whole egg product characterized by a preselected refrigerated shelf life of about four weeks to about 36 weeks, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is

  (a) heated by contacting said liquid whole egg product to a heated surface for a time sufficient to raise said liquid

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whole egg product to a predetermined holding temperature of at least 63.7° C. while at least periodically subjecting said continuous stream of liquid whole egg product to turbulence, then

(b) maintained at said predetermined holding temperature for a predetermined holding time, wherein said holding temperature and holding time are selected to cause a soluble protein loss of not more than 5% from said product, wherein the total thermal treatment received by the liquid whole egg product is described by an equivalent temperature and an equivalent time defining a point above the 5% SPL (BATCH) line of FIG. 3 and wherein said holding temperature and holding time are selected to impart said preselected shelf life to said liquid whole egg product, and then

(c) cooled, followed by

(d) aseptically packaging the liquid whole egg product.

24. A method of ultrapasteurizing a liquid whole egg product, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is

(a) heated to a predetermined holding temperature, then

(b) maintained at said predetermined holding temperature for a predetermined holding time, and then

(c) cooled, wherein the total thermal treatment received by the liquid whole egg product is defined by an equivalent temperature and an equivalent time defining a point above the 15% SPL (BATCH) line of FIG. 3, but insufficient to cause coagulation of the liquid whole egg product; and

(d) aseptically packaging the liquid whole egg product to provide a packaged liquid whole egg product having an extended refrigerated shelf life.

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25. A method of ultrapasteurizing a liquid whole egg product, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is heated to a predetermined real temperature by contacting said liquid whole egg product to a heated surface, wherein the total thermal treatment received by the liquid whole egg product is described by an equivalent temperature and an equivalent time defining a point above the 5% SPL (BATCH) line of FIG. 3, but insufficient to cause coagulation of the liquid whole egg product, and wherein the total thermal treatment received by the product is insufficient to cause more than a 5% soluble protein loss from the product followed by the step of aseptically packaging the liquid whole egg product to provide a packaged liquid whole egg product having an extended refrigerated shelf life.

26. A method of ultrapasteurizing a liquid whole egg product, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is heated to a predetermined real temperature, wherein the total thermal treatment received by the liquid whole egg product is described by an equivalent temperature and an equivalent time defining a point above the 15% SPL (BATCH) line of FIG. 3, but insufficient to cause coagulation of the liquid whole egg product, and wherein the total thermal treatment received by the product is insufficient to cause more than a 5% soluble protein loss from the product followed by the step of aseptically packaging the liquid whole egg product to provide a packaged liquid whole egg product having an extended refrigerated shelf life.

*   *   *   *   *

(19) **United States**

(12) **Reissued Patent**
Swartzel et al.

(10) Patent Number: **US RE37,225 E**
(45) Date of Reissued Patent: **Jun. 12, 2001**

(54) **METHOD FOR THE ULTRAPASTEURIZATION OF LIQUID WHOLE EGG PRODUCTS**

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(21) Appl. No.: **08/061,985**

(22) Filed: **May 14, 1993**

Related U.S. Patent Documents

Reissue of:
(64) Patent No.: **5,019,408**
    Issued: **May 28, 1991**
    Appl. No.: **07/628,716**
    Filed: **Dec. 17, 1990**

U.S. Applications:
(

(63) Continuation of application No. 07/880,899, filed on May 8, 1992, now abandoned, which is a continuation of application No. 07/535,718, filed on Jun. 11, 1990, now Pat. No. 4,994,291, which is a continuation of application No. 07/311,594, filed on Feb. 16, 1989, now Pat. No. 4,957,759, which is a continuation of application No. 06/904,744, filed on Sep. 8, 1986, now Pat. No. 4,808,425.

(51) Int. Cl.[7] A23L 1/32; A23L 3/16; A23B 5/005

(52) U.S. Cl. 426/399; 426/521; 426/614

(58) Field of Search 426/399, 521, 426/520, 614, 106

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Primary Examiner—Anthony J. Weier

(74) *Attorney, Agent, or Firm*—Myers Bigel Sibley & Sajovec, P.A.

(57) **ABSTRACT**

Methods of ultrapasteurizing liquid whole egg products in continuous flow, high temperature, short time pasteurization equipment are provided. The equivalent point method is preferably used to evaluate the total thermal treatment received by the product in this equipment. Also disclosed is a method of making liquid whole egg products having preselected, extended, refrigerated shelf lives.

The questions raised in reexamination request No. 90/003,682, filed Jan. 5, 1995, have been considered and the results thereof are reflected in this reissue patent which constitutes the reexamination certificate required by 35 U.S.C. 307 as provided in 37 CFR 1.570(e).

26 Claims, 4 Drawing Sheets
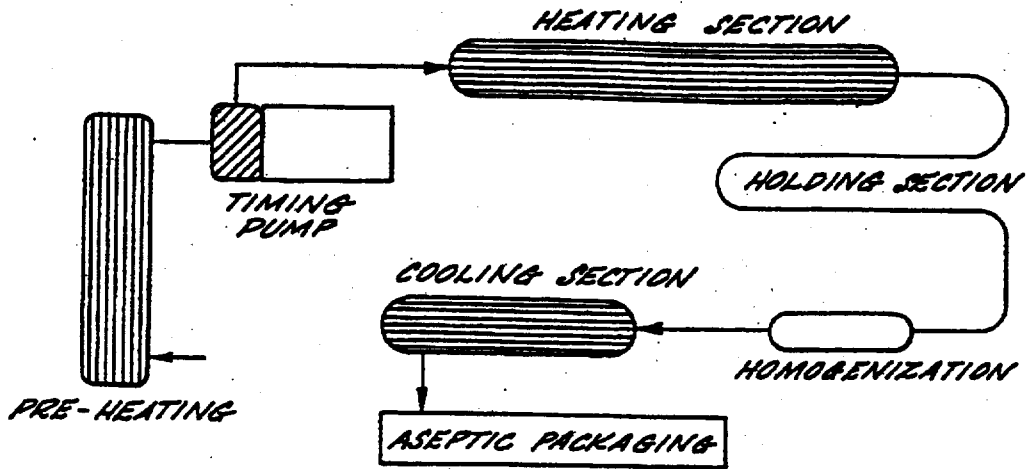
HEATING SECTION

HOLDING SECTION

TIMING PUMP

COOLING SECTION

HOMOGENIZATION

PRE-HEATING

ASEPTIC PACKAGING

$$\text{fig. 1.}$$

CONTINUOUS FLOW PASTEURIZING APPARATUS

LWE IN

HEATER   HOLDING   COOLER

SECTION

LWE OUT

t_H

HEATING STAGE   HOLDING STAGE   COOLING STAGE
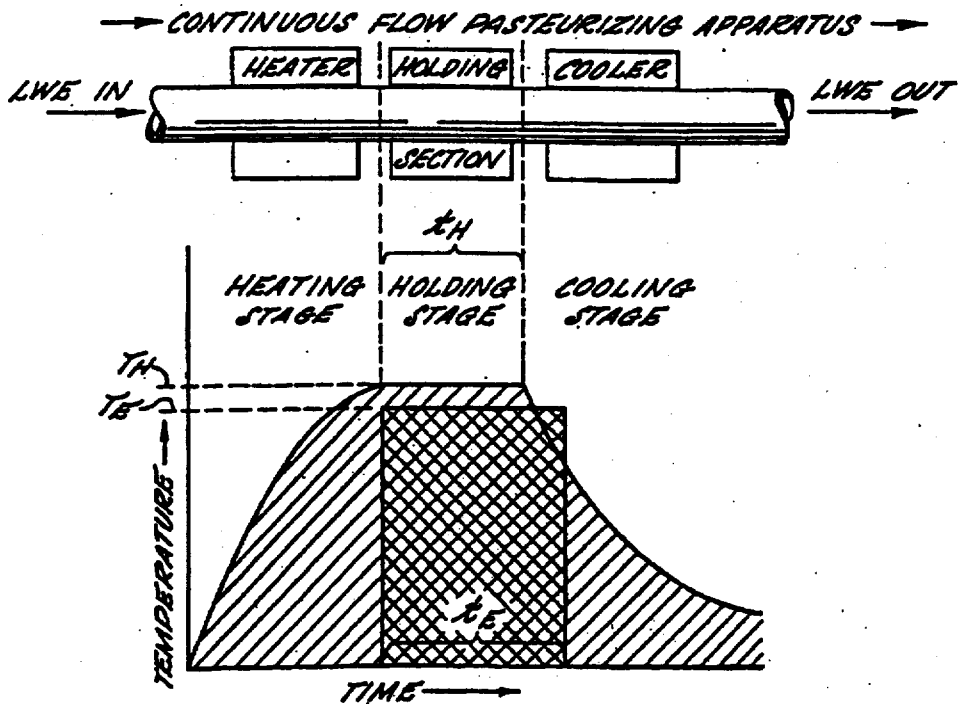
T_H
T_E

t_E

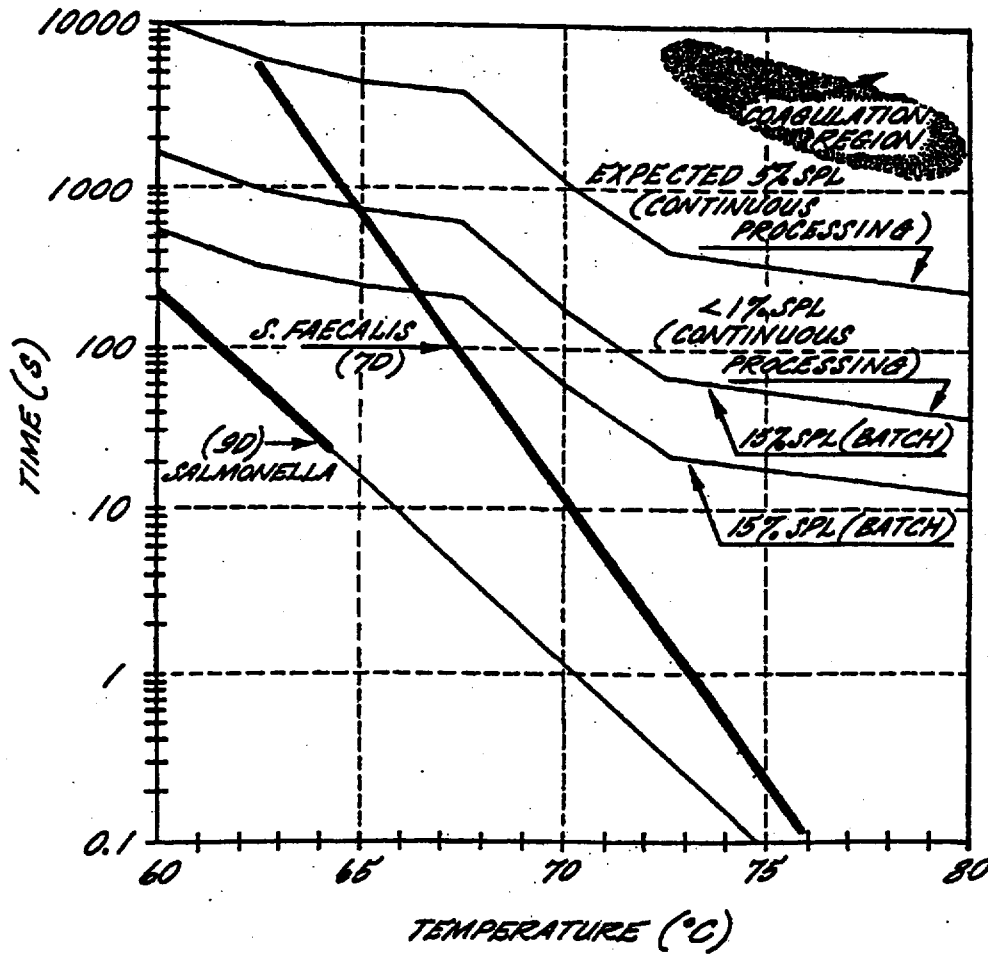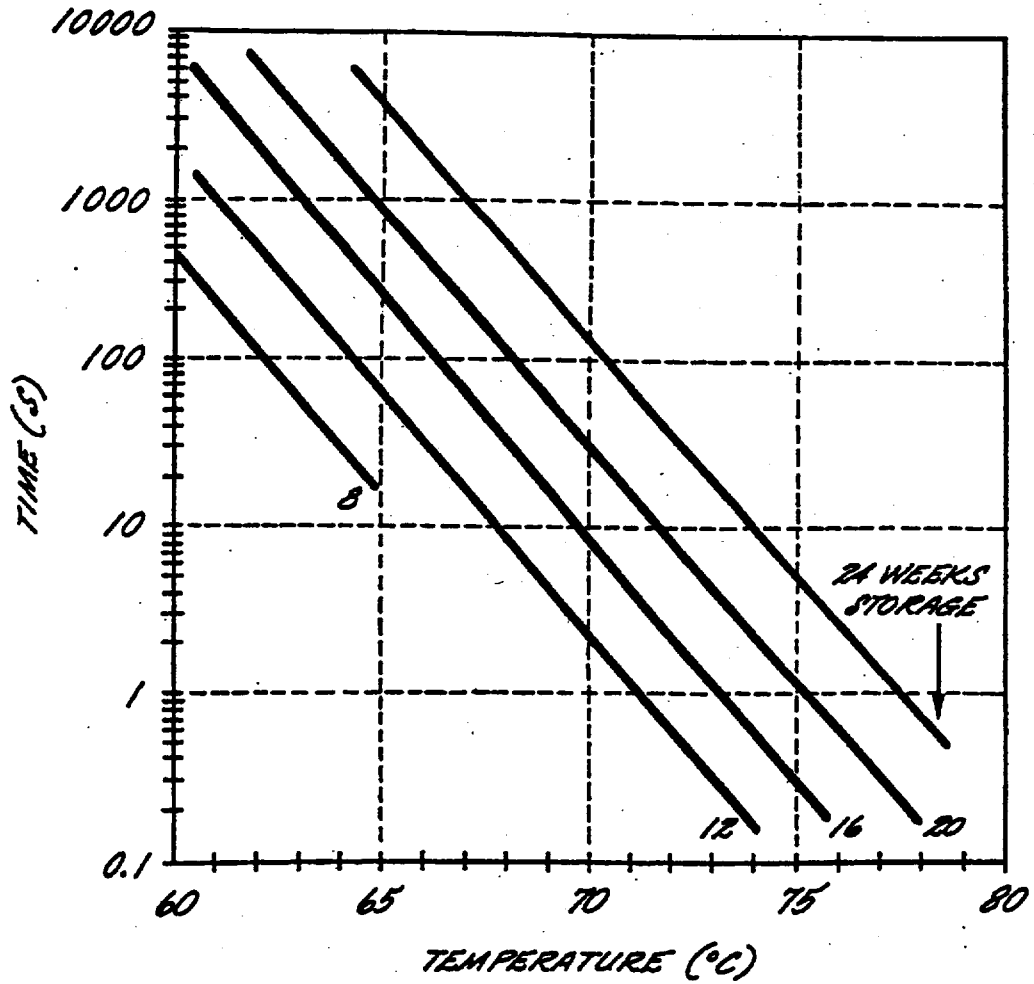TEMPERATURE

TIME

$$\text{fig. 2.}$$
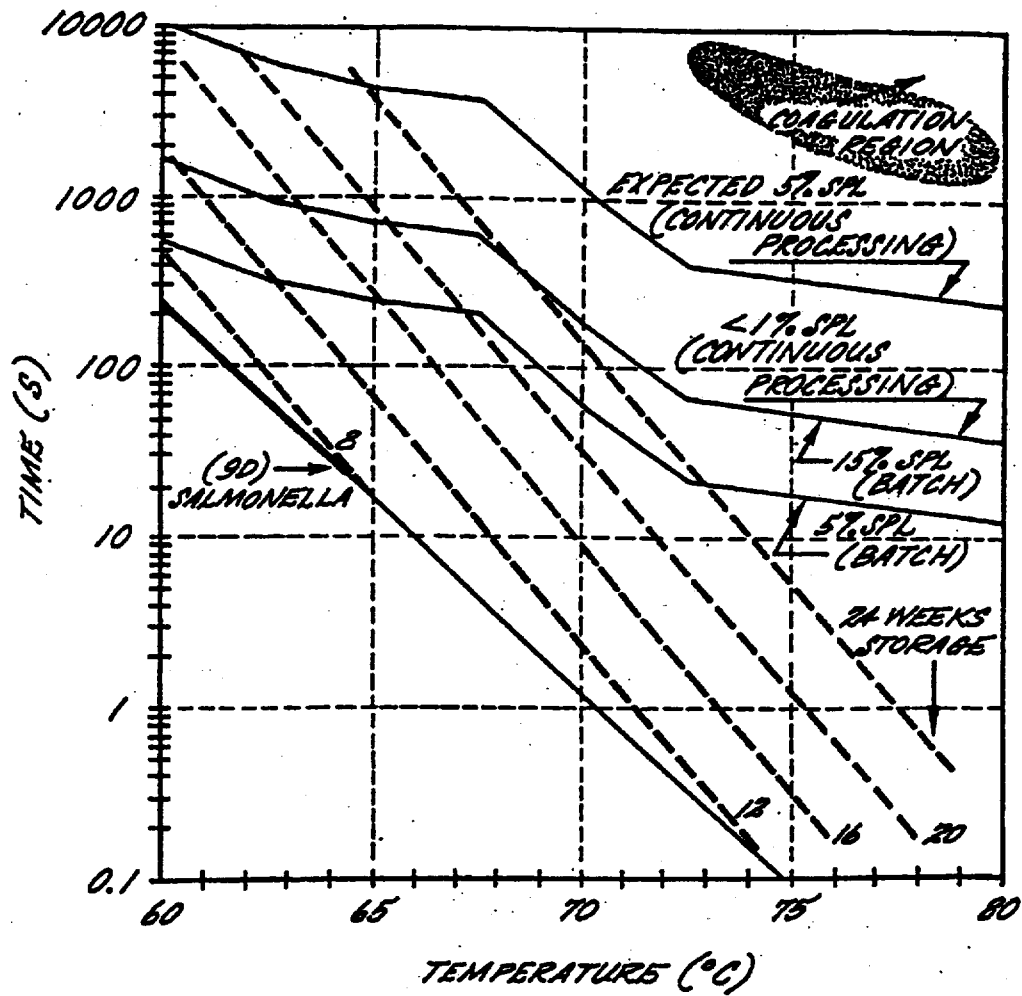
Fig. 3.

Fig. 4.

Fig.5.

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METHOD FOR THE ULTRAPASTEURIZATION OF LIQUID WHOLE EGG PRODUCTS

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

This application is a continuation of prior reissue application Ser. No. 07/880,899, filed May 8, 1992, now abandoned the disclosure of which is incorporated by reference herein in its entirety. [This] application *Ser. No. 07/880,899 is a reissue application of U.S. application Ser. No. 07/628,716 filed Dec. 17, 1990 and now U.S. Pat. No. 5,019,408 which* is a continuation of pending prior U.S. application Ser. No. 07/535,718, filed Jun. 11, 1990 now U.S. Pat. No. 4,994,291, which is a continuation of prior U.S. application Ser. No. 07/311,594, filed Feb. 16, 1989, now U.S. Pat. No. 4,957,759, which is a continuation of prior U.S. application Ser. No. 06/904,744, filed Sept. 8, 1986, now U.S. Pat. No. 4,808,425, issued Feb. 28, 1989.

DESCRIPTION OF THE INVENTION

The present invention relates to the pasteurization of liquid whole egg products generally, and particularly relates to ultrapasteurization methods which can be used to produce liquid whole egg products which have good functional properties and which have extended refrigerated shelf lives.

BACKGROUND OF THE INVENTION

The U.S. egg industry produced more than 300 million pounds of frozen pasteurized egg products in 1985. The relatively mild pasteurization processes used are designed to eliminate Salmonella from eggs for all practical purposes, but do not destroy organisms capable of spoiling egg products held under refrigerated temperatures above freezing. The survival of spoilage organisms in pasteurized egg, coupled with conventional packaging technology, results in products with limited shelf life (7–14 days at 40° F.) that require freezing and frozen distribution systems for preservation. Freezing is cost intensive, lowers the functional quality (flavor, performance, etc.) of the egg product, and results in an inconvenient product that requires thawing prior to use.

Standard pasteurization practices for liquid whole egg products are generally discussed in the Egg Pasteurization Manual (USDA Agricultural Research Service 1969). See also U.S. Pat. No. 3,949,099 to Kaufman, at column 1, lines 46–58 (summarizing pasteurization processes). The Egg Pasteurization Manual notes that experiments conducted in England to establish treatment conditions used there, which were carried out in a high temperature, short time pasteurization unit, included trials with holding times of two and one-half minutes and temperatures up to 151 degrees Fahrenheit (66.1 degrees Centigrade). The functional quality of these eggs is not discussed; however, it is noted that England adopted a lower temperature of 148 degrees Fahrenheit as a treatment condition. The Manual observes that such "severe" treatments help increase the stability of egg products in liquid form, but does not teach how this can be accomplished without sacrificing desirable functional properties of the products. For other types of egg products which are more heat stable, pasteurization temperatures as high as 152 degrees Fahrenheit (66.67 degrees Centigrade) have been reported. Again, little is known about how to ultrapasteurize (decrease the number of spoilage microorganisms to

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levels lower than obtained with a pasteurization procedure) these products by heating without sacrificing functional performance.

Higher temperatures than those investigated in England have been explored. See e.g., Essary, E. O., Rony, P. R., and Collins, W. F., New uses of heated aseptically packaged fluid egg products. Report to the American Egg Board (1983). This work suggested that merging techniques of ultrapasteurization with aseptic packaging can be accomplished to yield safe, stable, and functional liquid whole egg. This research suggested and used a heat exchanger operated in laminar flow to process whole egg at elevated temperatures, and used an ethylene oxide-flushed glove box to aseptically package the product (neither device approved for the commercial production of a salable product). Holding temperatures of up to 154 degrees Fahrenheit (67.8 degrees Centigrade) were reported. The results of this pioneering work demonstrated the possibility of extending the refrigerated shelf life of liquid whole egg products, but did not enable the commercial production of a refrigerated product which could be sold to consumers.

To carry out ultrapasteurization of liquid whole egg products on commercial equipment, the time and temperature parameters of the thermal treatment must be selected with care. Arbitrary increases in thermal treatment will likely produce a functionally unacceptable product, or—even worse—coagulation of the product and blockage of the pasteurizing equipment. Because such pasteurizing equipment operates at high pressures (e.g., 1,500 p.s.i. and more) the consequences of blockage are serious. For these reasons, it is essential to know how liquid whole egg products respond to various thermal treatments before experimenting with the production of these products on commercial equipment.

Because this essential information was not available, Hamid-Samimi investigated the time and temperature parameters which should be used in commercial equipment to obtain a functionally acceptable, ultrapasteurized, liquid whole egg product M. H. Hamid-Samimi, Criteria Development for Extended Shelf-Life Pasteurized Liquid Whole Egg. Ph.D. Thesis, North Carolina State University (1984). This research was carried out at the laboratory bench, with a Brookfield viscometer, which processed the product in small batches rather than continuously. Processing times and temperatures defining thermal treatments producing a soluble protein loss (SPL) of up to 5% from the product, as an upper limit, were suggested as producing a functionally acceptable product. The suggested 5% SPL limit was defined by a graph line in the thesis: this line is reproduced herein in FIG. 3 as the 5% SPL (Batch) line. Time and temperature values tested by other investigators which were believed to be the limits of pasteurization are summarized in M. H. Hamid-Samimi and K. R. Swartzel, J. Food Processing and Preservation 8: 219, 221 FIG. 1 (1984). All are below the 5% SPL (Batch) line.

The present inventors sought to test the predictions of Hamid-Samimi by ultrapasteurizing liquid whole egg on continuous flow, high temperature, short time pasteurization equipment. It was unexpectedly found that functionally acceptable liquid whole egg can be produced at times and temperatures greater than previously believed. These findings, which will be explained in detail below, enable the commercial production of functionally acceptable products with longer refrigerated shelf lives than heretofore available. As will also be explained below, discovery of these unexpected results has led to the identification of several steps which should be taken to produce ultrapasteurized liquid whole egg products that have superior functional properties.

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The object of the present invention, in short, is to provide liquid whole egg products for refrigerated distribution which have greatly reduced levels of spoilage microorganisms, while still having good functional properties.

SUMMARY OF THE INVENTION

This object is achieved by a method of ultrapasteurizing liquid whole egg products. The method comprises passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is heated to a predetermined real temperature. The method is practiced so that the total thermal treatment received by the liquid whole egg product is described by an equivalent temperature and an equivalent time (these terms are explained in detail below) defining a point above the 5% SPL (Batch) line of FIG. 3, but insufficient to cause coagulation of the product.

Also disclosed herein is a method of making a package liquid whole egg product characterized by a preselected refrigerated shelf life of from about four weeks to about 36 weeks. This method comprises passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is heated for a predetermined time and to a predetermined temperature. The predetermined time and the predetermined temperature are chosen to impart the preselected shelf life to the liquid whole egg product. After it is heated, the liquid whole egg product is aseptically packaged.

Preferably, the continuous stream of liquid whole egg product referred to in each of the methods above is at least periodically subjected to turbulence while it is heated. The liquid whole egg products are also, preferably, homogenized after they have been heated. In addition, the methods described above are more narrowly described as methods in which the liquid whole egg product is heated to a predetermined holding temperature, then maintained at said predetermined holding temperature for a predetermined holding time, and then cooled.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of a continuous flow pasteurizing apparatus suitable for carrying out the present invention.

FIG. 2 is a diagram illustrating the differences and relations between real holding times and holding temperatures, and equivalent times and equivalent temperatures for describing total thermal treatments, in continuous flow pasteurizing equipment.

FIG. 3 is a graph showing time and temperature regions for the ultrapasteurization of liquid whole egg products.

FIG. 4 is a graph showing equivalent times and equivalent temperatures that give particular refrigerated shelf lives for liquid whole egg.

FIG. 5 is a combination graph in which FIGS. 3 and 4 are superimposed, with the S. faecalis line removed

DETAILED DESCRIPTION OF THE INVENTION

Thermal treatments simultaneously produce beneficial and undesirable changes in food products. Knowledge of kinetic methods, and how they can be applied to the mechanics of designing a thermal process, aids in attaining food quality retention and process efficiency. Determining the time and temperature requirement for a thermal process depends upon destruction of spoilage and disease causing

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microbial spores while minimizing undesirable physical, chemical and biological transformations that occur within the product.

As schematically shown in FIG. 1, with arrowheads indicating direction of flow, continuous flow thermal processing equipment comprises heating, holding, and cooling sections. The thermal treatment received by the product in the heating and cooling stage, (illustrated in FIG. 2), is oftentimes not considered instead, only the holding time (t_H) and holding temperature (T_H) are considered. However, when products are pasteurized in such equipment at higher temperatures and shorter times, as is taught herein, the contribution of the heating stage, and perhaps the cooling stage, to the total thermal treatment of the product becomes significant, and must be accounted for if a product with good functional qualities is to be obtained and coagulation during pasteurization is to be avoided. It is accordingly recommended that the equivalent point method for evaluating thermal treatments be applied in practicing the present invention. As explained in detail below, this method describes the total thermal treatment received by a product in continuous flow equipment with one equivalent time (t_E) and one equivalent temperature (T_E) (see FIG. 2).

Procedures for use of the equivalent point method for analyzing the thermal effects on products during continuous flow heating have been previously outlined (Swartzel, 1982, J. Food Sci. 47:1886 and Swartzel, 1986, J. Agric. Food Chem 34:397) and are known to those skilled in the art This method differs substantially from previous methods in that all other methods define the thermal treatment based upon a single factor such as enzyme inactivation, microbial destruction, protein denaturation, nutrient loss, etc. The problem with these other methods in that a physical and/or chemical effect (flavor, color, product separation and gelation during storage if thermally related) may actually be the shelf life limiting factor.

The unique feature of the equivalent point method lies in the fact that, they for any thermal curve, one equivalent time and equivalent temperature combination exists (see FIG. 2). This equivalent time and temperature combination will yield the exact thermal effect on all constituents within the product as would the original thermal curve. This unique time and temperature combination is not dependent on individual constituent kinetics, as are all previous thermal evaluation procedures (it is independent of constituent activation energy).

To determine the equivalent point of a thermal system, a complete thermal history of the treatment must be available. This is obtained by measuring mixed mean product temperatures at various locations (entrance to the heat exchanger, exit of the heat exchanger and at least two locations inside the heat exchanger). Time is calculated by correlating means residence time with location of the temperature probe. With heat exchangers into which it is difficult or impractical to insert thermal probes, time-temperature curves are calculated based on knowledge of the product's physical characteristics and on the geometry of the processing equipment.

With available time-temperature curves and a basic knowledge of kinetic relationships, equivalent points can routinely be calculated. The log of a product constituent concentration ratio (initial concentration divided by concentration after treatment) is set equivalent to the integration of that constituent's Arrhenius equation (or any other appropriate function describing the temperature dependency of the rate of the reaction associated with the constituent change)

for the particular time-temperature interval (thermal history previously defined) For a given activation energy each section of a thermal treatment (heating, holding, and cooling) will produce a unique thermal constituent concentration ratio For the difference sections the effect may be summed For the original activation energy selected, a linear infinite log (time)-temperature relationship exists. Any and all of these infinite time and temperature combinations would produce the same thermal effect on a constituent (with the same activation energy) as during the original thermal treatment. By reexamining the original thermal curves with different activation energies a series of infinite linear log (time)-temperature relationships are developed (one line in a log (time)-temperature plot per activation energy). Uniquely all lines intersect at one point. This unique time-temperature is the equivalent point for the original thermal curve. It accounts for all thermal treatment and is used to accurately predict constituent change, or product characteristic.

FIG. 3 sets forth thermal treatments which should be used to ultrapasteurize liquid whole egg products. Thermal treatments defined by points above the 5% SPL (Batch) line have not heretofore been suggested. For practicing the present invention in continuous flow processing equipment, the thermal treatment is described by a point on FIG. 3 defining an equivalent time and an equivalent temperature, as explained above. The thermal treatment should be more than sufficient to pasteurize the liquid whole egg product "Pasteurize" means to cause a nine log cycle (9D) or 99.9999999% reduction in Salmonella in the product being treated. The thermal treatment should be insufficient to cause the liquid whole egg product to coagulate. The thermal treatment should more particularly cause not more than a 15% soluble protein loss (SPL) in the liquid whole egg product being treated, and will preferably cause not more than 5% soluble protein loss in the product being treated. The expected 5% SPL (continuous processing) line on FIG. 3 indicated approximately the upper limit on thermal treatments which can be tolerated without sustaining more than a 5% soluble protein loss (the exact location of this line for any one process will depend on the physical factors discussed below). More preferably, the thermal treatment will be designed to produce not more than about a 1% soluble protein loss from the product. As shown in FIG. 3, equivalent times and equivalent temperatures defining points along the line previously believed to represent the line at which a 15% soluble protein loss would be obtained (the 15% SPL (Batch) line), are now known to represent thermal treatments which produce ultrapasteurized products having less than a 1% soluble protein loss under continuous flow.

The line defining thermal treatments causing a seven log cycle reduction in the spoilage bacteria Streptococcus faecalis is labeled in FIG. 3 as the S. faecalis (7D) line. The S. faecalis line has a steeper slope than the several SPL lines. This illustrates that thermal treatments employing higher temperatures and shorter times are preferred for practicing the present invention. Thus, holding soluble protein loss constant (so that treatment time must be decreased as treatment temperature is increased), thermal treatments in which the product is subjected to treatment temperatures of about 67.0 degrees Centigrade or more are preferred to thermal treatments in which the product is subjected to treatment temperatures of 65° C.; treatment temperatures of about 69.0° C. or more are preferred to treatment temperatures of 67° C.; treatment temperatures of about 71.0° C. or more are preferred to treatment temperatures of 69° C.; treatment temperatures of about 73.0° C. or more are pre-

ferred to 71° C.; and so on. The foregoing statement is true whether the real temperatures (or holding temperatures) of the processes are being compared, or equivalent temperatures are being compared (thus the term "treatment temperature" is used to encompass both).

Treatment temperatures are primarily limited by the ability to accurately time the duration of the thermal treatment: as temperature is increased the treatment time must be decreased, and shorter treatment times are more difficult to administer with precision. Generally, equivalent temperatures not more than about 90° C. are preferred, and equivalent temperatures not more than about 80° C. are more preferred.

Desirable thermal treatments for practicing the present invention can also be described with reference to the S. faecalis lines. Preferably, the thermal treatment will define a point above the S. faecalis (7D) line, and more preferably the thermal treatment will define a point above the S. faecalis (9D) line. While this latter line is not plotted in FIG. 3, it can be plotted in accordance with the equations given below.

Equations for lines in the figures are as follows, where t=time in seconds, T=temperature in degrees Centigrade, and n=number of decimal reductions. Salmonella line: log (t)=15.96−0.227(T). S. faecalis lines: log(t)=24.62+log(n)−0.346(T). % SPL lines: log(t)=10 g(% SPL)=9−b, where a and b are given in Table 1 below:

TABLE 1

T range ° C.	a (for Batch lines)	b	a (Expected) (for continuous flow lines)
60–62.5	7.494	0.091	8.761
62.5–67.5	4.103	0.037	5.370
67.5–72.5	14.68	0.194	15.942
72.5 and above	3.014	0.033	4.281

These equations can be used to extend the teaching of the figures beyond their depicted scope.

The liquid whole egg product is preferably heated by contacting the product to a heated surface. The heated surface is comprised of a corrosion-resistant, nontoxic and nonabsorbent material such as stainless steel. Standards for evaluating the acceptability of such product contact surfaces (the 3-A Sanitary Standards) are known and established. See, e.g. Egg Pasteurization Manual, supra, at 27.

To obtain a product with reduced amounts of spoilage microorganisms, the pasteurizing apparatus should be sterilized before the liquid whole egg product is passed therethrough. Sterilizing is preferably accomplished by passing hot water under pressure through the pasteurizing apparatus, as is known in the art, so that, among other things, hot water is contacted to the heating surface at a temperature and pressure and for a time sufficient to sterilize the heating surface.

In addition, the product, after ultrapasteurization, should be aseptically packaged. Aseptically packaged means packaged to the exclusion of microorganisms other than those carried by the liquid whole egg product. Equipment suitable for aseptically packaging liquid whole egg products is commercially available.

FIG. 4 illustrates the refrigerated shelf life of liquid whole egg after it is ultrapasteurized and aseptically packaged, as explained above. The term "refrigerated," as used herein, means stored at a temperature of 4° C. Time and temperatures for points on each line represent equivalent times and temperatures, as also explained above. A liquid whole egg

product having a preselected shelf life of from about 4–36 weeks is made by selecting a point on a line or in a region which will provide the desired shelf life, determining the equivalent time and equivalent temperature which correspond to the point selected, and—preferably through the use of the equivalent point method—establishing the operating conditions on the particular pasteurizing apparatus being used that will provide the selected thermal treatment. Products having shelf lives not depicted in FIG. 4 are made by extrapolating the teachings of the figure, in light of the teachings above. Preferably, this process is carried out in pasteurizing apparatus which has been sterilized before the liquid whole egg product is passed therethrough, as explained above, to produce products having shelf lives of about eight weeks or more. In addition, it will be appreciated that longer shelf lives are generally obtained at the expense of greater levels of soluble protein loss. Thus, if product distribution systems do not require otherwise, products with self lives of up to about 32 weeks are preferred, and products with shelf lives up to about 24 weeks are more preferred.

FIG. 5 combines portions of FIGS. 3 and 4. It shows how the thermal treatments selected to provide a desired shelf life can at the same time be selected to provide products with good functional properties. More particularly, thermal treatments can be selected which produce liquid whole egg products having the desired shelf life and a soluble protein loss not greater than 5%.

The foregoing graphs have been presented to aid the understanding of the present invention. Some variation about the plotted lines is to be expected when the present invention is practiced on different equipment, or with different products. These graphs are accordingly not to be taken as limiting the present invention, as departures could be made therefrom while still capturing and benefitting from the teachings of the invention.

To obtain a superior ultrapasteurized liquid whole egg product, the contact time of the liquid product to heated surfaces during pasteurization should be reduced. More particularly, every particle of liquid whole egg product should be in contact with the heated surface or surfaces of the unit in which the product is heated for a total time less than the residence time of the particle in the heating unit. (The term "particle" as used herein has its standard meaning in the egg pasteurization field. See, e.g., 7 C.F.R. § 59.570(b) (1985)). This is accomplished by mixing the product at least periodically while it is being heated. In a continuous flow pasteurizing apparatus, such mixing is accomplished by introducing turbulence into the stream of the product at least periodically while it is being heated, as discussed below Other steps which are preferably employed to reduce fluid element contact time to heated surfaces include providing portions of the thermal treatment in which fluid elements are not in contact with heated surfaces, such as by providing a portion of the thermal treatment in a holding section, and by providing heated contact surface area to product volume ratios of less than 18 cm²/cm³ (Thus the surface area to volume ratio is preferably less than about 10, and is more preferably in the area of about 2).

It is also desirable to induce physical forces to make the product more homogeneous prior to thermal treatment, such as by inducing shear forces capable of reducing protein and fat unit size. This is preferably accomplished by dispersing the product prior to heating. Dispersing may be carried out with a dispersing valve or with a timing pump, as is known in the art. Such treatment advantageously reduces fouling, and serves to reduce any tendency of the product to coagulate. Such a dispersing step may be carried out by conduct-

ing a more rigorous homogenization step, but it is recommended that such more expensive homogenizing equipment be used as described below.

It is preferable that a homogenization step after heating be included. The term "homogenized," as used herein, means to subject the product to physical forces to reduce particle size. Such procedures are known in the art, and may be carried out on different types of equipment. It is preferable to carry out this homogenizing step with homogenizing equipment as total pressures of about 1,000 p.s.i. or more. Pressures of about 1,500 p.s.i. or more are more preferred, and pressures of 2,000 p.s.i. or more still more preferred.

Of these steps, it is particularly desirable to mix the liquid whole egg product at least periodically while it is heated. As noted above, in continuous flow equipment mixing is carried out by at least periodically subjecting the stream of liquid whole egg product to turbulence while it is heated. Turbulence, which is the mixing of particles over the cross-section of the product stream, is discussed in the Egg Pasteurization Manual at pages 6–8. Such turbulence is characterized by a Reynolds number greater than about 2,300, and preferably greater than about 4,600. Commercial high temperature, short time pasteurizing units are available which at least periodically impart turbulence to the stream of product being pasteurized while the product is being heated. For the purposes of the present invention, greater levels of turbulence are preferred. Thus the liquid whole egg product is preferably subjected to turbulence for a major portion of the time it is heated. Plate heat exchangers, trombone heat exchangers, spiral heat exchangers, and scrape surface heat exchangers are illustrative of the types of known heat exchangers which can be used to subject liquid whole egg products to turbulence while they are heated. The physical forces induced in scrape surface heat exchangers are generally thought of as "mixing," but these exchangers induce turbulence at least in regions of the product stream, and are therefore considered to induce turbulence for purposes of the present invention.

Examples of whole egg products which can be pasteurized in liquid form by the method of the present invention include whole egg, fortified whole egg (whole egg with added yolk), salt whole egg (e.g., salt 10%), sugar whole egg (e.g., sugar 10%), blends of whole egg with syrup solids, syrups, dextrose and dextrins and/or gums and thickening agents, blends of whole eggs with less than 1% sugar and/or salt, scrambled egg mixes (for example, a mix of about 51% egg solids, 30% skim milk solids, 15% vegetable oil and 1.5% salt), reduced cholesterol egg products and blends thereof, custard blends, and the like. Products which are extremely sensitive to thermal processing and which are particularly suitable for ultrapasteurization by the present invention include, for example, liquid whole egg and blends thereof (less than 2% added nonegg ingredients), fortified whole egg and blends thereof (24–38% egg solids, 2–12% added nonegg ingredients), liquid salt whole egg, liquid sugar whole egg, and other liquid whole egg blends which are 24–38% egg solids and 12% or less of added nonegg ingredients. Terms used herein have their standard meaning in accordance with industry and regulatory usage. See, e.g., 7 C.F.R. § 59.570(b) (1985).

The invention having been explained in general terms above, the following examples are provided to further illustrate the invention.

EXAMPLES 1–10

Raw Egg Product. Raw liquid whole egg was obtained from a local breaking plant (Gold Kist, Durham, N.C.). The

egg was taken from their raw holding tank which was agitated to thoroughly blend approximately 30,000 pounds of egg. The egg was manually filled into 13.6 kg (30 lb) metal cans and were kept refrigerated before being transported 13.2 km (20 mi) to our laboratory in an insulated truck. The egg was held overnight at 4° C. (40° F.) or allowed to stand at room temperature for up to 12 hours to achieve higher bacterial numbers.

Thermal Processes. The time-temperature processes used in this study were designed to be equal to or more severe than minimum conditions defined by the 9D line for the destruction of Salmonella in whole egg (USDA, 1969) and within predetermined limits of denaturation of egg protein defined as percent soluble protein loss (%SPL) by Hamid-Samimi et al., J. Food Sci. 49:132 (1984). The objectives of this design were to provide Salmonella negative whole egg with a low number of surviving spoilage organisms while retaining adequate functional properties.

The thermal processing system used is outlined in FIG. 1. It consisted of a plate-type heat exchanger for preheat, various modifications of the No-Bac Unitherm model XLV (Cherry Burrell Corporation, Cedar Rapids, Iowa) to achieve different holding times, an aseptic homogenizer operated at 10.34 mPa (1,500 p.s.i.), and an aseptic package system (Model AB-3-250, Tetra Pak Inc., Dallas, Tex.). The flow rate was $2.89 \times 10^{-4} \text{m}^3/\text{sec}$ (275 GPH) with heating, holding, and cooling pipe diameters of 12.45 mm ID (5/8" nominal) stainless steel.

Before each process the entire system was sterilized at 121° C. for 30 minutes using hot water in the product section and steam in the heating media section and then cooled. The product and heating media temperatures were recorded for evaluation of the thermal effect of the heating section and to determine the total thermal effects. (Swartzel, J. Agri. Food Chem. 34:396 (1986). The temperatures were measured using Type T thermocouples with an electronic data logger (Model 9302, Monitor Labs., Inc., San Diego, Calif.). Each thermocouple probe was scanned every 30 seconds (one minute for process #1) and the readout sent to a computer for analyses The specific locations of the thermocouples in the system were as described by Swartzel and Jones. Paper No. 84-6006 of the American Society of Agricultural Engineers (1984).

Approximately one hour prior to initiation of each process, 408.2 kg (900 lb) of raw egg were transferred from the metal cans to a 568 l (150 gal) vessel (Creamery Package Mfg. Co., Chicago, Ill.) and then mixed at room temperature with the stirring propeller at ca. 30 r.p.m. This volume of egg required approximately 20 minutes to process, therefore the last liter of egg was processed not later than 80 minutes after being removed from the cooler. Nine processes designated 1, 2, 3, 4, 5, 6, 7, 8, and 9 were run. Process 6 was repeated and designated 6.1. They were conducted two days apart on egg picked up on the same day. Egg for processes 6.1 to 9 were held at room temperature for not more than 12 hours to achieve a higher initial microbial load. All egg incubated at room temperature was chilled to 4° C. (40° F.) prior to processing.

After holding the egg at the scheduled process time and temperature and prior to packaging, the temperature was reduced to less than 1020 C. (50° F.) in less than 26 seconds. Occasionally, due to technical difficulties it was not possible to cool the processed egg to below 10° C. In those instances the processed egg was moved into a freezer at −20° C. for 20 minutes after packaging. The packaging material was a low oxygen permeable laminate of polyethylene, paper, and

aluminum foil formed into 250 ml containers. (Tetra Pak aseptic filler model AB-3). Each package was dated and coded so that egg processed in the first seven minutes, the second seven minutes, and the remaining time were numbered 1, 2, and 3, respectively. The processed and packaged egg was held overnight at 4° C. (40° F.) prior to obtaining samples and being distributed for four and 10° C. storage.

Sampling Samples of raw egg for physical, chemical, and functional testing was aseptically removed from the mixing vat approximately 30 minutes prior to processing. The samples were then held overnight at 4° C. for evaluation with the pasteurized egg. Pasteurized samples were obtained on the day after processing or at selected times during storage at four and 10° C. Analyses were made on the combined contents of three or four individual packages representing the first, second, and third portions of each process run. When four packages were required, two packages from the middle portion of each process were used. Any sediment on the bottom of the cartons was scraped out and mixed into the egg by magnetic stirring.

Chemical Assays. The pH of the product was determined with a Fisher Accumet pH meter, model 600, equipped with a calomel reference and glass indicating electrodes. Solids were determined in triplicate by weighing two ml samples into disposable aluminum pans and drying in a forced draft oven for 24 hours. The AOAC (1985) microKjeldahl procedure was used to determine protein content of the samples. The extent of denaturation was estimated by determining the loss of soluble protein as described by Hammid-Samimi et al., supra, and the alpha-amylase activity of the egg was determined as described by Shrimpton and Monsey, J. Hyg. 60:153 (1962).

Sponge Cakes. True sponge cakes were made by using half of the amounts of ingredients listed following the procedures given by Gorman and Ball (1986) (Chapter 15 in Egg Science and Technology, 3rd Ed., W. J. Stadelman and O. J. Cotterill, Eds., AVI Publishing Co., Inc. Westport, Conn.) with the omission of vanilla. Two separate batches of batter were mixed for each treatment and 340 g of batter was weighed into rectangular pans (21.5×11.5×6.5 cm, id.). Cakes were baked at 191° C. for 25 minutes, inverted on a wire rack and allowed to stand at room temperature overnight. Heights were determined from the mean of four measurements along the center line of the long axis of the cake. Cakes were then kept in plastic bags for further rheological evaluations.

Textural properties of the cakes were evaluated using an Instron Universal Testing Machine (Model 1122, Instron Engineering Corporation, Canton, Mass.) A plate was connected to a 2000-g load cell and positioned at the surface of the 5-cm cube of cake. The cross head and chart speeds were 200 mm/min and 100 mm/min, respectively. Three samples from each cake were subjected to deformation-relaxation cycles. The cubed cake samples were kept in a plastic bag before and after each test. The water activity of the cake samples were determined by placing three Durotherm (Lufft, West Germany) water activity meters in the plastic bag. Each meter was calibrated daily with a solution of barium chloride (aW 0.90 at 20° C.).

Custards. Duplicate custards of the flan type were made. Ingredients were 190-ml evaporated milk, 196-g sweetened condensed milk, 125-g whole egg, 50-g water, and one teaspoon vanilla. All ingredients were blended in a Waring blender at low speed for one minute and 360-g were weighed into a rectangular pan (14.3×8.0×5.6 cm, id.) which had been sprayed with "PAM" (Boyle-Midway, Inc., New York,

N.Y.). Pans were placed in a tray containing 2.5-cm water and baked at 191° C. for 40 minutes. After overnight storage at 10° C., height of the custard in the pan was determined from the mean of three measurements made and with calipers along the center line of the long axis of the custard. Custards were removed from the pan after the sides were loosened with a spatula and allowed to stand at room temperature for 45 minutes. Height was again determined and percent sag was calculated according to Gardner et al. Poultry Sci. 61:75 (1982). Custards were stored in plastic bags at 10° C. for rheological evaluation.

The flat plate described above for evaluation of cake texture was replaced with a 10.5 mm diameter rod with a semispherical tip and force-deformation curves to failure were obtained for each custard. Cross head speed was 100 mm/min and all other parameters were the same as used in evaluation of the cakes. Five values were averaged to obtain the penetration force (F1) for each custard.

Organoleptic Evaluation. Flavor of processed and stored egg was evaluated by one judge using the USDA palatability score (Laboratory Methods for Egg Products, USDA, Agricultural Marketing Service Poultry Division, Grading Branch, Washington, D.C. 20250 (1984)).

Thermal Process. The process times and temperatures used in this study are presented in Table 2.

TABLE 2

Actual, Equivalent Times and Temperatures, Calculated Heating Value of Treatments and Predicted % SPL Based on Heating Value[a]

| Proc. No. | Actual | | Equivalent | | Heating | |
	Time (Sec.)	Temp. (° C.)	Time (Sec.)	Temp. (° C.)	Value[b] (G × 10^{42})	Theoretical % SPL[c]
1	26.2	63.7	30.4	63.1	6.1	0.52
2	92.0	63.8	97.5	63.3	20.8	1.74
3	192.2	65.3	192.4	65.1	72.8	5.97
4	9.2	67.8	15.7	66.5	8.4	0.71
5	56.9	68.2	63.0	67.5	44.6	3.70
6	123.0	68.3	125.5	67.9	99.4	8.10
6.1	123.0	68.9	129.0	68.4	117.6	9.50
7	2.7	71.5	9.5	68.5	8.9	0.75
8	30.1	72.2	36.5	71.5	78.9	6.46
9	56.7	72.0	62.5	71.8	146.8	11.70

[a]See Swartzel, J. Food Sci. 47:1886 (1982), and Hamid-Samimi et al., supra (1984) for descriptions of heating value and % SPL.
[b]G values are determined based on activation energy for SPL.
[c]Based on laboratory batch data.

The 10 processes, numbers 1–9, were performed in the same chronological order as they are numbered. After gaining process experience and as the result of evaluations during the study, it was determined that longer holding times and temperatures than expected could be used. The actual temperatures reported in Table 3 are the averages of temperature readings, every 30 seconds, of the temperature probes at the beginning and end of the holding tube.

Equivalent times and temperatures as well as holding times and temperatures are set forth in Table 2. It can be seen that equivalent times are generally longer than the corresponding holding times, and equivalent temperatures are generally lower than the corresponding holding temperatures. At longer times, the differences between corresponding holding temperatures and equivalent temperatures are smaller.

The calculated heating value, G, shown in Table 2, gives a means for making a comparison of the relatively severity of the different processes. Processes 9, 6.1, 6 and 8 had the

highest G values, respectively. The percent SPL based on the heating value (G) are also shown in Table 2.

Chemical Properties of Processed Egg. The results of alpha-amylase activity assays (Table 3) confirms that the enzyme is inactivated by mild heat processes. Table 3 shows that the thermal processes used did not affect protein content or the soluble protein content.

TABLE 3

Thermal Effects on Alpha-Amylase Activity, Protein Content and % Soluble Protein

| Process No. | Alpha-Amylase[a] | | | MicroKjeldahl[b] | | | % Soluble Protein[c] (From Absorbance) |
	Raw	UHT	Plant	Raw	UHT	Plant	
1	0.045	0.048	0.099	13.10	11.60	13.1	86.2
2	0.033	0.588	—	12.59	11.96	—	102.3
3	0.055	1.050	—	11.67	11.32	—	101.3
4	0.029	0.031	0.137	11.83	11.79	11.51	101.1
5	0.046	1.000	—	10.19	10.13	—	100.3
6	0.053	1.120	—	12.27	12.34	—	100.9
6.1	0.040	1.130	—	12.70	12.54	—	103.3
7	0.052	0.764	—	12.37	12.53	—	104.5
8	0.063	1.000	—	11.19	11.42	—	100.4
9	0.060	1.170	—	11.74	11.77	—	100.7

[a]Alpha-Amylase data is reported as the absorbance at 585 nm. Activity is inversely related in absorbance.
[b]MicroKjeldahl data is reported as percent protein.
[c]Absorbance at 280 nm of heated egg/control (raw) egg in solution as described by Hamid-Samimi et al., supra (1984).

The chemical data indicate that the processes did not result in extensive damage to the egg proteins. The predicted percent soluble protein losses (Table 3) were based on studies conducted with small amounts of egg (1 ml) being heated in the cup of a brookfield viscometer (Hamid-Samimi et al., supra, 1984). The egg was heated while various shear rates were applied to simulate egg under dynamic conditions that exist in conventional heat exchangers. Thus, this work revealed that the model system resulted in prediction equations that underestimated the thermal treatments that liquid whole egg products could tolerate while still obtaining products with good functional properties. Analysis of the causes of these unexpectedly good results led to the guidelines discussed above which should be followed to obtain functionally superior ultrapasteurized products.

Function of Processed Eggs. The functional properties of the processed eggs agreed with the physical and chemical results. Based on the data presented in Tables 4 and 5 for nonstored egg, there appeared to be very little heat effect on the performance of the ultrapasteurized egg relative to raw or commercially pasteurized egg. Cake height as an indication of the leavening ability and force to deform, springiness, and relaxation parameter (Peleg and Normand, Rheologica Acta 22:108 (1983)) as indicators of textural properties were very similar for all egg examined.

TABLE 4

Functional Properties of Cakes for Control (Raw), Ultrapasteurized (UP) at Zero Day Storage, and Commercially Pasteurized Eggs (Plant)

Variable	Treatment	Mean	Minimum	Maximum	n	C.V.
Maximum Force[a] (N)	Raw	10.02	7.79	13.70	10	17.3
	UP	10.49	9.18	12.91	10	10.5
	Plant	9.73	9.56	9.91	2	2.5

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TABLE 4-continued

Functional Properties of Cakes for Control (Raw),
Ultrapasteurized (UP) at Zero Day Storage, and
Commercially Pasteurized Eggs (Plant)

Variable	Treat-ment	Mean	Minimum	Maximum	n	C.V.
Relaxa-tion[b]	Raw	0.394	0.379	0.417	10	3.24
	UP	0.410	0.395	0.442	10	3.34
Para-meter	Plant	0.402	0.402	0.403	2	0.17
Spring-iness[c]	Raw	0.83	0.81	0.86	10	1.94
	UP	0.83	0.81	0.87	10	2.47
	Plant	0.82	0.81	0.82	2	1.32
Cake	Raw	65.1	63.3	66.7	10	1.66
Height	UP	61.7	55.1	65.5	10	5.26
(mm)	Plant	64.8	64.7	64.8	2	0.11
Water	Raw	0.873	0.832	0.891	10	2.53
Activity	UP	0.875	0.835	0.892	10	2.37
	Plant	0.892	0.892	0.892	1	—

[a]Force required to deform the sample of cake by 26 mm.
[b]Asymptotic relaxation value as defined by Peleg and Normand, supra (1983).
[c]Ratio of the second peak force to the first peak force in the force defor-mation cycle.

TABLE 5

Functional Properties of Custards for Controls
(Raw), Zero Day Storage Ultrapasteurized (UP)
and Commercially Pasteurized Eggs (Plant)

Variable	Treat-ment	Mean	Minimum	Maximum	n	C.V.
Penetra-tion	Raw	0.82	0.76	0.96	10	8.20
	UP	0.70	0.59	0.80	10	8.56
Force (N)	Plant	0.79	0.77	0.81	2	3.69
Custard	Raw	35.7	35.1	36.7	10	1.66
Height	UP	35.6	35.1	36.3	10	5.26
(mm)	Plant	34.6	34.0	35.3	2	0.11
% Sag	Raw	7.2	5.65	9.54	10	16
	UP	7.1	5.41	8.56	10	13
	Plant	4.6	2.66	6.51	2	59

The water activity of the cakes were similar indicating that the experimental handling procedures for the cakes were uniform and should not have affected the instrumental evaluation of textural properties. The custard data indicated that all egg sources evaluated had good ability to form gels. The gels had excellent integrity as indicated by the relatively low percent sag, yet the custards were relatively tender as indicated by the penetration forces. Although weep was not measured, very little syneresis was noted even after holding the custards overnight for textural evaluation. The limited organoleptic evaluation of the processed eggs indicated that the thermal processes did not affect flavor or aroma in scrambled eggs relative to scrambled egg made from a fresh shell egg. The USDA palatability scores were seven to eight (eight being the highest score).

Refrigerated Storage Effect. As long as the processed egg was not obviously spoiled, as indicated by organoleptic evaluations, storage 4° C. maintained the chemical, functional, and organoleptic properties of the processed egg up to 24 weeks for some of the samples. The data presented in Tables 6, 7, and 8 were taken from stored egg that was judged organoleptically sound. The criteria for that judg-ment were: (1) that the color was normal, i.e., within the expected range of color observed for eggs immediately post-processing, and (2) that there were no objectional aromas or flavors. In this study, because of the sampling

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procedure where most of the samples were checked at four-week intervals, there were no borderline decisions, a sample was obviously acceptable or unacceptable. Bright yellow colors, off-aromas, and pH values below seven were typical of samples judged to be spoiled.

TABLE 6

Means for Proteins, Solids and pH for Controls
(Raw), Commercially Pasteurized (Plant) and
Ultrapasteurized (UP) Egg

Variable	Treat-ment	Mean	Minimum	Maximum	n	C.V.
% Protein	Raw	11.92	10.19	13.10	10	6.8
	Plant	12.30	11.51	13.10	2	9.1
	UP 0	11.74	10.13	12.54	10	6.0
% Solids	Raw	24.6	23.9	25.2	10	1.6
	Plant	24.8	24.4	25.2	2	2.5
	0	24.5	24.0	25.0	10	1.3
	4	24.4	24.0	24.9	10	1.3
	UP 8	24.4	24.0	24.7	9	0.9
	12	24.3	23.8	24.7	7	1.3
	18	24.9	24.4	25.5	2	3.1
	24	24.8	24.7	24.9	2	0.3
pH	Raw	7.5	7.2	7.6	10	1.7
	Plant	7.1	7.1	7.2	2	0.5
	0	7.5	7.3	7.6	10	1.4
	4	7.4	7.2	7.6	10	1.4
	UP 8	7.4	7.3	7.5	9	1.2
	12	7.3	7.2	7.4	7	1.2
	18	7.4	7.4	7.4	2	0
	24	7.4	7.4	7.4	2	0

[a]Numbers indicate storage at 4° C. in weeks for processed eggs.

TABLE 7

Functional Properties of Cakes Made from Eggs
Stored at 4° C.

Variable	Storage (Weeks)	Mean	Minimum	Maximum	n	C.V.
Maximum	4	9.78	7.90	14.95	10	21.3
Force[a]	8	10.37	7.82	14.53	9	20.5
(N)	12	11.39	8.84	14.28	7	18.2
	18	11.42	10.32	12.53	2	13.6
	24	10.53	9.57	11.49	2	12.9
Relaxa-tion	4	.3937	0.3759	0.4167	10	3.7
	8	.3876	0.3636	0.4132	9	3.9
Para-meter[b]	12	.3846	0.3717	0.4032	7	3.0
	18	.3788	0.3788	0.3788	2	3.1
	24	.3745	0.3704	0.3788	2	1.5
Spring-iness[c]		0.829	0.799	0.853	10	1.7
	8	0.834	0.811	0.872	9	2.0
	12	0.834	0.820	0.843	7	0.9
	18	0.831	0.829	0.832	2	0.3
	24	0.815	0.787	0.843	2	4.9
Height	4	61	54	65	10	6.02
(mm)	8	64	63	67	9	2.06
	12	64	60	65	7	2.7
	18	63	62	65	2	3.0
	24	65	65	65	2	0.22
Water	4	0.860	0.796	0.888	10	4.2
Activity	8	0.884	0.868	0.900	9	1.1
	12	0.879	0.844	0.896	7	2.0
	18	0.872	0.872	0.872	1	—
	24	0.879	0.876	0.882	2	0.4

[a,b,c]See Table 4 for definition of terms.

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TABLE 8

Functional Properties of Custards Made from
Eggs Stored at 4° C.

Variable	Storage (Weeks)	Mean	Minimum	Maximum	n	C.V.
Pene-	4	0.68	0.47	0.77	10	12.7
tration	8	0.70	0.64	0.76	9	9.1
Force	12	0.75	0.57	0.83	7	20.3
(N)	18	0.94	0.85	1.02	2	12.6
	24	0.82	0.76	0.88	2	10.5
Custard	4	35	34	36	10	2.4
Height	8	35	34	36	9	1.6
(mm)	12	35	35	36	7	1.2
	18	36	36	36	2	0.4
	24	35	35	35	2	1.0
% Sag	4	7.1	3.0	11.6	10	38.1
	8	5.9	3.5	7.5	9	20.5
	12	6.5	4.6	8.0	7	19.5
	18	7.2	6.4	8.1	2	15.9
	24	6.6	4.9	8.2	2	36.0

Visual observations of the interiors of opened packages revealed very little sedimentation during storage. A very thin layer of a fine, light yellow, granular-like material was observed on the bottom of cartons after four weeks of refrigerated storage.

Shelf Life. The times of spoilage of egg from each trial are presented in Table 9.

TABLE 9

Shelf Life for Liquid Whole Egg Stored at 4° C.

Process	Shelf Life (Weeks)
1	4–8
2	8–12
3	>12
4	8–12
5	>18
6	18–24
6.1	>24
7	12–18
8	20–24
9	18–20

These data were used to generate the time and temperature guidelines set forth in FIG. 5.

The invention has been discussed with a degree of specificity above. This discussion has been provided for illustrative purposes only, with the scope of the invention being defined by the following claims.

That what which is claimed is:

1. A method of ultrapasteurizing a liquid whole egg product, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is

(a) heated to a predetermined holding temperature by contacting said liquid whole egg product to a heated surface, then

(b) maintained at said predetermined holding temperature for a predetermined holding time, and then

(c) cooled, wherein the total thermal treatment received by the liquid whole egg product is defined by an equivalent temperature and an equivalent time defining a point above the 5% SPL (Batch) line of FIG. 3, but insufficient to cause coagulation of the liquid whole egg product, and then

(d) aseptically packaged to provide a packaged liquid whole egg product characterized by a refrigerated shelf life of about four weeks to about 36 weeks.

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2. A method according to claim 1, wherein said pasteurizing apparatus is sterilized before said liquid whole egg product is passed therethrough, and wherein said packaged liquid whole egg product is characterized by a preselected shelf life of about eight weeks to about 36 weeks.

3. A method according to claim 1, wherein said liquid whole egg product is subjected to turbulence for a major portion of the time said liquid whole egg product is heated.

4. A method of ultrapasteurizing a liquid whole egg product, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is heated to a predetermined real temperature by contacting said liquid whole egg product to a heated surface while at least periodically subjecting said continuous stream of liquid whole egg product to turbulence, wherein the total thermal treatment received by the liquid whole egg product is described by an equivalent time and an equivalent temperature defining a point above the 5% SPL (Batch) line of FIG. 3, but insufficient to cause said liquid whole egg product to coagulate, followed by aseptically packaging the liquid whole egg product to provide a [package] *packaged* liquid whole egg product characterized by a refrigerated shelf life of about four weeks to about 36 weeks.

5. A method according to claim 4, wherein said liquid whole egg product is subjected to turbulence for a major portion of the time said liquid whole egg product is heated.

6. A method according to claim 4, wherein said liquid whole egg product is dispersed before said liquid whole egg product is heated.

7. The method according to claim 4, wherein said pasteurizing apparatus is sterilized before said liquid whole egg product is passed therethrough, and wherein said packaged liquid whole egg product is characterized by a preselected shelf life of about eight weeks to about 36 weeks.

8. A method of ultrapasteurizing a liquid whole egg product, comprising passing the liquid whole egg product as a continuous stream through a pasteurizing apparatus, during which the liquid whole egg product is

(a) heated to a predetermined holding temperature by [contracting] *contacting* said liquid whole egg product to a heated surface while at least periodically subjecting said continuous stream of liquid whole egg product to turbulence, then

(b) maintained at said predetermined holding temperature for a predetermined holding time, and then

(c) cooled, wherein the total thermal treatment received by the liquid whole egg product is defined by an equivalent time and an equivalent temperature above the 5% SPL (batch) line of FIG. 3, but insufficient to cause said liquid whole egg product to coagulate, and then (d) aseptically packaged to provide a packaged liquid whole egg product characterized by a refrigerated shelf life of about four weeks to about 36 weeks.

9. A method according to claim 8, wherein said liquid whole egg product is subjected to turbulence for a major portion of the time said liquid whole egg product is heated.

10. A method according to claim 8, wherein said liquid whole egg product is dispersed before said liquid whole egg product is heated.

11. A method according to claim 8, wherein said pasteurizing apparatus is sterilized before said liquid whole egg product is passed therethrough, and wherein said packaged liquid whole egg product is characterized by a preselected shelf life of about eight weeks to about 36 weeks.

12. A method of making a packaged liquid whole egg product characterized by a preselected refrigerated shelf life