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Maintenance of Quality in Shell Eggs By Thermostabilization

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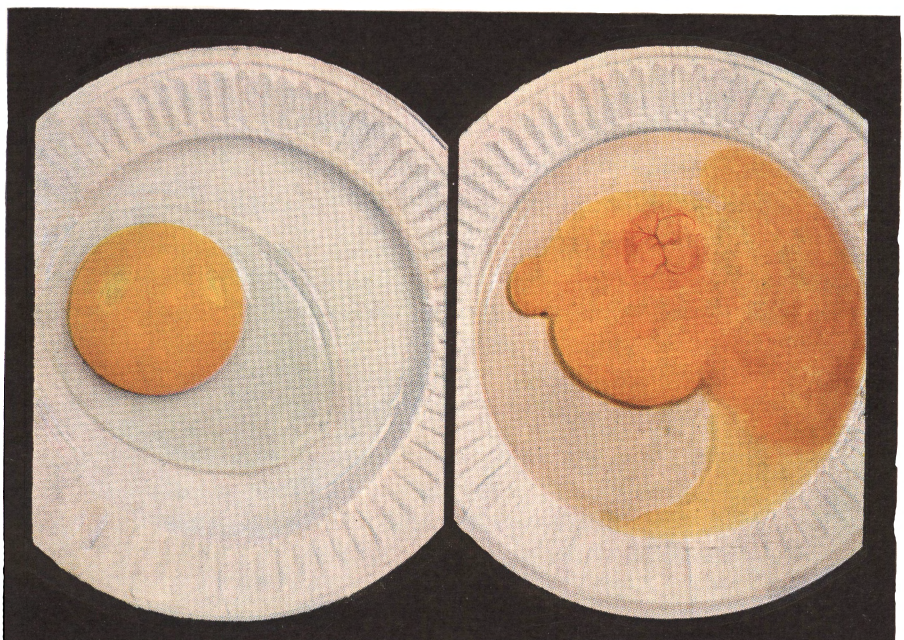

Thermostabilized **Natural**

Both were fertile eggs held three days at 100°F. The one on the left was thermostabilized and the one on the right was an untreated control.

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QUALITY FOR THE CONSUMER

One of the major problems confronting the poultry industry is that of supplying consumers with eggs of high quality. Any process that will help maintain the fresh-laid quality of eggs until they reach the ultimate consumer should prove valuable to the industry.

The problem of maintaining quality in shell eggs has been of importance since man began to use the eggs of birds for human food. His recorded efforts in preserving eggs were relatively crude as judged by present-day methods. But present-day methods when judged in the future will likely be considered equally deficient because the problem of maintaining egg quality has not yet been solved.

Minor Objectives

The major objective of all egg-processing has been to maintain egg quality. Several minor objectives leading to the major objective may be listed.

1. **To Reduce Evaporation.**—Many of the processes used for maintaining egg quality are beneficial because they reduce evaporation and thus minimize enlargement of the air cell. The commercial grade is thereby maintained.

2. **To Retain Carbon Dioxide Within the Egg.**—Processes which retard evaporation also tend to reduce the loss of carbon dioxide from the egg and thus maintain a more favorable condition for the retention of thick white. The vacuum oil process was designed specifically for introducing CO_2 into the shell egg and thereby increasing its CO_2 content.

3. **To Prevent Microbial Contamination of the Contents of the Shell Egg.**—Within recent years efforts have been made to treat shell eggs so as to increase their resistance to the invasion of micro-organisms and also to pasteurize shell eggs.

4. **To Devitalize Fertile Eggs.**—Some investigators have developed processes for destroying the early embryos present in fresh-laid eggs and thereby preventing any subsequent loss of egg quality in such eggs because of embryonic development.

Acknowledgments:—The author wishes to recognize the cooperation and assistance of Harold Biellier, James Forward and Mrs. Martha Lorah in making these investigations and also to thank Professor H. L. Kempster for his advice and suggestions. The author wishes also to express his appreciation to Drs. Raymond J. Penn and Marvin A. Schaars of the Department of Agricultural Economics, and Prof. J. G. Halpin and Dr. W. W. Cravens of the Department of Poultry Husbandry of the University of Wisconsin for their advice and suggestions in the preparation of this publication.

Note.—This report is a part of the material submitted by the author to the Graduate School of the University of Wisconsin to complete the requirements for the degree of Doctor of Philosophy, December, 1950.

5. **To Stabilize the Thick Albumen.**—It has been found that the thick albumen may be stabilized somewhat against liquefaction by retarding the loss of CO_2 or by the use of heat.

Attempts to preserve eggs or maintain their quality may be grouped into (1) those where environment is modified or controlled and (2) those where the eggs are treated or processed. The latter processes will be reviewed here.

REVIEW OF LITERATURE

A. Partially Sealing or Coating the Shell with Oil.—Oils of various kinds have been used since at least 1807 for preserving eggs. Spamer (1931) reported that as early as 1807 the Dutch preserved eggs by placing them in linseed oil for a half day and then drying on racks. Such eggs were kept for 4 or 5 months. This process continued to be used until about 1914 when it was replaced by other processes, one of which was pickling in lime water, a process first used in Holland about 1875.

The literature reveals that a vast amount of time and effort has been expended by investigators in trying to develop not only commercial methods but methods suitable for home use in preserving eggs. The activity in testing processes for home use was especially pronounced from 1890 to 1910. Egg production was then highly seasonal; very few eggs being produced in late fall and winter. More recent research has been concerned with processes which supplement and accompany refrigeration.

In 1911, Ellef Petersen and Victor Clairemont patented (U. S. Patent 999,589) an oil process for preserving shell eggs which they described as follows:

"The juice of cactus is mixed with the oil of cotton seed in the proportions of one-third part of the former to two-thirds part of the latter and the mixture heated to the boiling point and then allowed to cool to 100° F. The eggs to be preserved are then submerged in the solution and allowed to remain therein for a period of twenty-four consecutive hours, at the end of which time they are taken out and allowed to drain until such time as they have become thoroughly dry. The eggs are then packed in crates or otherwise stored after the usual manner.

"As a substitute for the oil of cotton seed, it has been found that olive oil, and also milk, may be used with equally as good results. When used with milk, the proportions are one-third cactus juice and two-thirds milk. It is possible also to use as the oil element of the solution, cotton-seed oil, olive oil and milk combined."

In 1914, Victor Clairemont patented (U. S. Patent 1,092,897) a process for preserving eggs by first heating them in a solution for a short time at about 100° F. to temper the shell and then immersing the eggs in a solution heated to 250° F. long enough to coagulate the albumen next to the shell and then applying a sealing coating to the outer side of the shell.

In 1916, Arthur N. Bennett obtained a patent (U. S. Patent 1,197,707) for a process for preserving eggs which consisted of first heating the eggs for 4 to 30 seconds in hot air at 200° F. to 600° F. to coagulate the albumen next to the shell and then oil processing in petrolatum.

In 1921, Victor Clairemont and C. T. Lehman patented (U. S. Patent 1,388,024) another process for preserving shell eggs for which their patent claims were: "A composition for treating eggs which comprises a light mineral oil of the Russian variety, paraffin which has been dissolved in oil and rosin, in the proportions such that the oil acts as a medium for introducing paraffin and rosin into the pores of the shells of eggs, the rosin aids the paraffin in hardening and remaining solid as a thin hard coating without embodying a rosin taste to the eggs, the rosin also acts as a germicide and paraffin reduces the glazelike appearance of the rosin."

In 1922, I. M. Kasser patented (U. S. Patent 1,424,484) a process for preserving shell eggs by sealing them with vegetable oils (cottonseed, linseed, etc.) by passing the eggs while submerged through hot and cold zones so as to both heat and cool them in oil.

Almy et al (1922) reported experiments in which they found that cottonseed oil and heavy mineral oil were most effective. They measured results by evaporation (loss in weight). They reported the following results:

Treatment	Loss in weight (%) after 12 days at 40° C.
Mineral oil A, specific gravity .869, Viscosity at 100° F. of 134 Saybolt units	0.6
Mineral oil D, specific gravity .851, Viscosity at 100° F. of 44 Saybolt units	3.6
Untreated eggs	8.1

Swenson and James (1931) reported results obtained with vacuum oil dipped eggs stored from January to December. This method of sealing eggs consists of evacuating the chamber while the eggs are under oil and then raising the eggs above the oil and releasing the vacuum with CO_2. The value of this process as indicated in the following table, was determined by the change in candling grades.

	Per cent of eggs in each grade			
	Specials	Extras	Standards	Trades
January—unoiled	62.5	37.5		
January—oil dipped	58.1	39.8	2.2	
January—Vacuum oil dipped	47.3	41.9	10.8	
June—unoiled	.0	37.5	54.2	
June—oil dipped	26.8	49.5	17.2	
June—vacuum oil dipped	24.7	50.5	17.2	
September—unoiled	0	0	95.8	4.2
September—oil dipped	7.3	67.8	16.7	4.2
September—vacuum oil dipped	15.6	58.3	15.5	2.2
December—unoiled	0	0	45.8	54.1
December—oil dipped	1.0	29.1	57.2	7.3
December—vacuum oil dipped	3.0	43.7	46.5	2.2

Swenson et al (1933) reported a study of flavor in oil processed eggs from which they concluded that oil processing did not adversely affect egg flavor during storage.

Swenson, Slocum and James (1936) reported satisfactory results from oil processing shell eggs with oil held at 60° F. and 80° F.; in fact, better results were obtained with oil held at 60° F. The oil used had a viscosity of 30/60 Saybolt seconds at 100° F. and a pour point of 40° F.

McIntosh et al (1942) reported comparative studies of the culinary quality and physical properties of eggs to determine the best time of processing after gathering. Eggs were poached and boiled. They were scored for flavor, texture, color and appearance. Physical measurements were made including appearance when broken on a flat surface, clinging quality of the shell after boiling, volume and stability of the beaten albumen and the pH of the yolk and albumen.

Eggs processed the day after gathering were superior to those processed immediately after laying, noon or evening of the day laid, or the third day after gathering. Eggs processed on the day laid gave a 300 per cent increase of volume on whipping as compared to 500 per cent when oil processed the day following laying and 550 per cent for fresh egg controls. The drip volume (cc.) after 5 minutes was 4.30 cc. for eggs processed the day laid as compared to 0.72 cc. for eggs processed the day following laying and 0.45 cc. for fresh eggs.

Evans (1942) reported results of experiments in which a paraffin base oil with a Saybolt viscosity of 75-81 at 100° F., a pour point of about 38° F. and a specific gravity of 0.846 was diluted with solvents derived from the distillation of petroleum. Results were measured by changes in the albumen index and the diameter of the air cell of eggs, from the same pullets, held for two weeks at 60-80° F. He concluded that an oil diluted with up to 50 per cent of a solvent was as effective as an undiluted oil in maintaining egg quality. However, he concluded that the danger of the inflammable fumes from the solvent more than offset the advantages of using it.

H. A. Mulvaney in 1940 was granted U. S. Patent 2,221,343 for a method of processing and precooling eggs in oil.

Reedman and Hopkins (1942) reported tests made of oil processing in combination with egg case liner bags using eggs from three commercial sources. They held the eggs for 35 days at 70° F. and 90% R.H. and then determined loss and condition. They reported that under the conditions of the experiment oil treatment followed by packaging in sealed egg case liner bags retarded greatly the development of internal defects (molds and rots) and severe external mold. Oil treatment alone was beneficial but the use of egg case liner bags on untreated eggs was detrimental. Evidently unoiled eggs when bagged gave off enough moisture to create favorable conditions for mold development. These investigators reported that eggs oiled and bagged shipped to England did not arrive in good condition.

Gibbons, Fulton and Hopkins (1942) also reported results of storing oiled and bagged eggs under constant and fluctuating temperatures and humidities. Though the development of external mold and internal defects was high in all lots, the oiled and bagged eggs kept better than the controls.

Mallman and Davidson (1944) reported the results of experiments in which moldicides were added to oil to prevent the development of mold on shell eggs. Eggs were processed in oil of 50 to 60 Saybolt viscosity to which had been added Dowicide 7 (penta chloro phenol) and Dowicide 1 (ortho phenyl phenol). The eggs were held at 68° F. and 100% R.H. to develop mold. Under these conditions 0.1 per cent of these substances were not effective in preventing mold on the surface of the shell but 0.25%, 0.50%, 1.0% and 2.0% Dowicide 7 did prevent mold on eggs held as described above.

Funk (1945), reporting on the effect of oil processing shell eggs which were held in cold storage, presented the following data:

Treatment	No. Eggs	Percentage of each grade 1st	2nd	3rd	Ined.	Albumen Score
Oil processed	5950	83.5	13.1	1.6	1.6	3.0
Controls	5950	70.7	26.0	1.2	2.1	3.2
Difference in favor of oil processing		+12.8	—12.9	+.4	—.5	—.2

Thayer and Thompson (1945) reported a formula for an egg sealer which they recommended for use on the farm. The formula for the paste was:

	Paraffin wax	40 grams
	Aerosol	4 grams
	Diglycol Laurate S	100 c.c.
or	Diglycol Stearate S	20 grams
	Water	200 c.c.
	Dowicide A (10%)	40 c.c.

A solution for dipping the eggs was made by mixing one pint of this paste with 7 quarts of water. They reported that the loss in weight of the sealed eggs was only one-fourth of that of untreated eggs.

Rosser (1942) reported experiments he had conducted which were designed to measure the effect of oil dipping, surface disinfection with hydrogen peroxide before oiling and handling on mold growth on the shell and internal spoilage when eggs were held under conditions conducive to mold development (lots were stored 25 to 32 days where the temperature alternated every two days between 17.6° C. and 95.7% R.H. and 23.5° C. and 69.6% R.H.; then for 10 to 17 days where the temperature and humidity were held constant at 21° C. and 90% R.H.) . Their report showed that oil dipping and ordinary handling increased mold growth on the shell. The fact that oil dipped eggs showed 70.6 per cent spoiled as compared to 52.2 per cent spoiled in the untreated lots suggests that oil processing had increased spoilage; however, statistical analysis did not establish this difference as significant.

Gibbons, Michael and Irish (1947) reported the results of experiments in which they used various oils and at oil temperatures of 76°, 100° and 130° F. Results were measured by determining weight loss, yolk index, height of thick white and pH of lots of eggs held for 4 and 12 weeks at 70° F. and for other lots held for 8, 24, and 40 weeks at 30° F. From their results they concluded that: "Viscosity of the oil seemed more important than pour point, although at 30° F. there was some indication that a high pour point was advantageous. Oiled eggs maintained their grades two to three times longer than unoiled eggs and lost from 1/10 to 1/4 as much weight. Heavy oil diluted with mineral spirits did not give as good results as lighter oils of comparable viscosity. The addition of vaseline and magnesium stearate improved the action of the light oils. There was little difference in the quality of eggs dipped into oils maintained at 76°, 100°, and 130° F."

Romanoff and Yushok (1948) reported experiments in which they added acids to mineral oil and measured the results by the evaporation and the pH of the egg. They improved the protective qualities of mineral oil by adding lactic acid and stearic acid, stearic acid, and acetic acid.

B. Sealing with Plastics

Within recent years, since the plastics have been developed, the question of more complete sealing of shell eggs by using plastics has arisen.

Rosser et al (1942) reported the use of polyvinyl alcohol (one of the plastics) as a sealing agent for shell eggs. From their tests they concluded that when used alone it enhanced the growth of surface mold. However, when they added 2.8% dimethylol urea to the 7% dimethylol alcohol mold growth was inhibited.

Yushok and Romanoff (1942) reported the results of their experiments in reducing evaporation and minimizing pH changes in eggs by the use of plastics. The plastics used and some of the results obtained are presented in the following table:

Effect of Synthetic Resin Films on Loss in Weight of Eggs and on Alkalinity of Albumen[1]

Synthetic Resin			Solvent	Relative loss in weight of eggs[2]	Alkalinity of Albumen[3]
Type	Description	Concentration by weight			
		Pct.		Pct.	pH
Polyvinyl alcohol	Medium viscosity	4.0	Water	67	9.2
Polyvinyl acetate	Softening point, 66° C.	10.0	Ethyl alcohol, 95 pct.	36	8.6
Polyvinyl acetate	Softening point, 77° C.	10.0	Ethyl alcohol, 95 pct.	32	8.5
Polyvinyl acetate	Softening point, 86.5° C.	10.0	Ethyl alcohol, 95 pct.	29	8.0
Polystyrene	Loabond emulsion, 40 pct. solids	—	Water	38	9.1
Polystyrene	Molecular weight, 30,000	10.0	Ethyl acetate	26	8.9
Polystyrene	Molecular weight, 102,000	5.0	Ethyl acetate	22	8.9
Chlorinated rubber	Viscosity, 125 centipoises	10.0	Carbon tetrachloride	21	8.7
Chlorinated rubber	Viscosity, 125 centipoises	10.0	Ethyl acetate	17	8.3
Mineral-oil-dipped eggs				12	7.8
Untreated eggs				100	9.4

[1]Eggs held for a 10-day period at 37.5° C. (99.5° F.) and about 35 per cent relative humidity. [2]The percentage loss in weight of each set of treated eggs was divided by the percentage loss in weight of untreated eggs, then multiplied by 100 to give this index. [3]The pH of albumen from strictly fresh eggs was about 7.7.

From their experiments these workers concluded that, "Newly laid eggs coated with films of chlorinated rubber, polystyrene, or polyvinyl acetate lose substantially less carbon dioxide and water during storage than untreated eggs. Ability of chlorinated rubber and polystyrene to preserve fresh eggs is improved by inclusion of either dibutyl phthalate or n-butyl stearate in the plastic solutions. The preservative value of these plasticized resins is somewhat increased by small amounts of petrolatum and microcrystalline wax. Inclusion of cetyl pryridinium chloride, an effective inhibitor of mold growth, does not decrease the sealing ability of plastic coatings.

Cracked eggs are as effectively sealed by plastic films as eggs with sound shells. Dipping cracked eggs in mineral oil does not decrease their perishability.

The change in appearance of the yolk and albumen in eggs coated when less than eight hours old is closely related to the loss of carbon dioxide and water. For best preservation the plastic coating of eggs should be carried out at the place of production, preferably the same day the eggs are laid. Plastic films, which are non-toxic, tasteless, and odorless, can be formed on eggs by a simple dipping and spraying method, without the use of elaborate equipment. Cost of the plastic materials and modifiers is not prohibitive for practical use.

These workers also stated that, "An approximate index of the preservative value of a coating method is provided by comparing the percentage loss in weight from an egg, sealed when fresh, with that from an untreated egg held in the same environment. Under our high temperature test conditions, a plastic-coated fresh egg which loses one-tenth as much weight as an untreated egg can be expected to maintain its original quality about 10 times as long as an untreated egg."

This statement assumes that all quality changes parallel loss in weight and pH changes and that similar changes occur at cold storage temperatures as at the high temperatures used in these experiments. Such assumptions cannot be made as anyone who has worked with cold storage egg experiments knows very well. Only in a very general way can one interpolate from high temperature to low temperature conditions for shell eggs.

C. Sealing with Other Substances

The sealing or coating of shell eggs with various greases, and other substances is no doubt as old as that reported by Spamer (1807) for linseed oil as used in Holland. The earliest record the writer has found was U. S. Patent 65,988 issued June 25, 1867 to Ben D. Atwell and Miss G. H. Crawford of Portage City, Wisconsin, for an Improved Mode of Keeping Eggs. Their patent stated: "The nature of our invention consists in the following proportions: To make a gallon of the preserving-fluid, take two ounces of white glue, one ounce isinglass, soaked over night in one (1) quart of cold water; then simmer over a slow fire until dissolved. In three (3) quarts of water dissolve one (1) ounce unslaked lime, and add two (2) table-spoonfuls of cornstarch. Now boil the whole together, and, while boiling, dip the eggs in and hold them there from five to ten seconds. Then lay them out and let them dry. A wire dipper should be used. The eggs should be kept separate until dry, or they will stick together. After drying they are all right, and can be kept in any convenient thing or place."

It is of interest to note the patents granted for preserving eggs by coating the shell. Some of these patents examined by the writer or found referred to in the literature are listed on the next page.

Patentee and Date	Country, Patent No.		Substance
Atwell and Crawford (1867)	U. S.	65,988	White glue and isinglass
Good (1880)	U. S.	225,518	Borax, sugar, and lime
Stead (1882)	British	4,910	Sodium silicate in Vacuum
Gray (1887)	U. S.	358,565	Boiling tallow and soda
Jessen (1890)	British	15,580	Rubber coated paper
Mills (1891)	British	17,717	Gelatin
Markham (1895)	British	3,513	Boric acid
Reinhardt (1898)	British	18,130	Sulphuric acid
Reinhardt (1899)	German	112,892	Sulphuric acid
Lorne (1901)	British	18,439	Oil, wax or varnish with or without disinfectants
Barlow (1902)	British	11,054	Oil plus an antiseptic and also varnish
Stukes (1902)	U.S.	649,899	Oil plus an antiseptic
Schultz (1902)	British	1,328	Gelatinous starch solution
Fryklind (1907)	British	9,898	Linseed oil
Garrigon (1907)	French	394,455	Alum-treated plaster solution
Cihlar (1910)	German	245,785	Immersion 6 hours in strong alcohol
Jacobsen (1910)	Danish	14,902	Alum
Jacoby (1910)	German	251,281	Paraffin and formaldehyde
Duboux and Rapin (1911)	German & U. S.	262,064 1,019,614	Rubbing with vaseline to which have been added: talcum, 10%; aluminum tannate, 1%; pulverized tragecanth 40%
Jerne (1911)	British	2,145	Nitrocellulose and camphor
Jerne (1913)	U. S.	1,043,600	Coating with gelatin and a celluloid-like compound
Clairemont (1914)	U. S.	1,092,897	Cactus juice
Coleman (1914)	U. S.	1,120,029	Cottonseed oil and gutta-percha
Davis and Metz (1916)	British	105,840	Tung oil
Christensen (1916)	U. S.	1,184,621	Magnesium chloride
Subirana (1917)	Swiss	74,124	Cottonseed oil
de la Mota (1918	U. S.	1,229,592	Coating with a fatty substance and then with colloidal
Aston and Stevens (1924)	British	242,780	Paraffin, beeswax and boric acid
Forler and Edser (1926)	British	274,200	Lanolin
Willis (1927)	Australian	10,250	Agar-Agar and Irish moss
Lipcscy (1930)	British	364,128 & 364,129	Wax and shellac
Greensmith (1934)	British	409,623	Paraffin, tallow and boric acid
Rollman (1934)	German	604,386	Rubber
Doyle and Doyle	British	463,403	Celluloid

Abigail S. White in 1875 was granted a patent (U. S. Patent 172,677) for a compound for preserving eggs prepared in the following manner:

"Dissolve one pound of gum-arabic and one pound of alum in twenty-five (25) gallons of hot water; and, in carrying out the invention, use or apply it in the following manner, to wit: Put the eggs in a wire basket, and dip them into the compound while hot, about fifteen seconds, keeping it at about the same temperature while being used.

"The gum-arabic makes the shell of the egg, which is porous, air-tight, and the alum prevents the varnished appearance which the gum-arabic gives it, making it appear rough like a new-laid egg."

John F. Timmons in 1889 patented a composition for coating eggs which he described as follows: "My composition consists of the following ingredients, combined in the proportions stated, viz: pure water, one gallon; gum-shellac, two ounces; bicarbonate of soda, three ounces; white glue, one ounce; Spanish whiting, one ounce; these ingredients to be mixed as follows: heat the water to boiling point, then add the shellac and soda, stir until dissolved, and add the other ingredients.

"In using the above-named composition the eggs should be immersed in the fluid while it is hot and immediately removed. This coats the egg in such a manner that it will keep in a fresh state as long as may be desired."

In addition to the many patents issued a number of the Agricultural Experiment Stations conducted tests with various methods for preserving eggs including dry packing, immersing in liquids and the use of substances for coating the shells.

W. P. Wheeler reported in 1890 the results of his tests as follows: "Fresh eggs were wiped with a rag saturated with fat or oil in which has been mixed some antiseptic. Eggs packed in April and May in salt which were previously wiped with cottonseed oil to which had been added boracic acid were ⅓ spoiled in 4 to 5 months. Eggs wiped as above and stored in bran were all spoiled in 4 months. Eggs packed in salt during March and April after wiping with vaseline to which salicylic acid has been added kept for 4 and 5 months without loss and were much superior to ordinary limed eggs. All eggs were held in a barn cellar at 60 to 70° F."

W. R. Graham (1899) reported the results of tests in which he compared lots of eggs dipped in melted vaseline and pure water glass with other lots stored in water glass, lime water and dry packing. He reported that eggs dipped in melted vaseline and stored in egg cases were well preserved but they had the undesirable flavor of the vaseline. He also stated shell eggs dipped in pure water glass, dried and stored were fairly well preserved but lacked flavor.

A. A. Brigham (1901) reported tests in which he used vaseline. He reported that vaseline as compared to water glass was effective for only a few weeks.

Dvoracheck and Stout (1918) reported tests with eggs held 6 to 9 months in a cool dry room as follows:

Flemings Egg Preservative—Eggs bad; moldy, sour and musty.
Yankee Egg Preserver—Very bad; yolks cheesy, moldy.
E-Z Egg Preservative—Moldy on surface and in air cell.
Vaseline—Sour, musty, yolks stuck to air cell.

Jones and Dubois (1920) reported results from using soap, paraffin, water glass, vaseline and egg white for preserving shell eggs. They used gasoline solutions of aluminum soap and paraffin. The gasoline imparted a taste to the eggs which was overcome by either dipping the eggs in dilute sulphuric acid before dipping in the soap or by using instead of gasoline the pentane fraction of gasoline which is tasteless, odorless and colorless. They held the eggs for 2 weeks at 37.5° C. They reported the aluminum soap eggs in perfect condition, the water glass eggs as not good and all other lots spoiled.

Swingle and Poole (1923) reported tests in which they compared the keeping quality of eggs preserved in water glass and with various egg coatings (Fresh Egg Keep, Crisco, Snowdrift, lard, lard plus 2% thymol, and pure water glass). They found that water glass in a 1:20 solution showed antiseptic value in 5 minutes. They also used the Clairemont oil processing method. Of all the methods tested they concluded that water glass 1:25 by measure was most effective.

Hearst and Hearst (1948) were granted U. S. Patent 2,438,168 for a process they called Stabilization of Shell Eggs. Their process consists of using an oil-in-water emulsion of waxes having different melting points (beeswax, montan wax, ceresin, paraffin, petrolatum, and the like) to which is added a preservative (low molecular esters of p-hydroxy benzoic acid). This emulsion is irradiated with ultra-violet light before using. The patentees claim that irradiation of the emulsion imparts unusual preservative power to the emulsion and they cite the following results of a series of tests they made.

	Average weight fresh	Average weight after 3 months storage 75-80° F.	Loss	Whites score	Yolks score
	Grams	Grams	Per cent		
Treated (Irradiated)	56.7	55.0	3.0	3.0	2.6
Treated (Not irradiated)	57.0	53.6	6.0	4.2	4.0
Untreated	58.9	42.1	28.5	4.8	4.6

D. Using Electricity to Maintain Egg Quality

The writer has been consulted within recent years by two parties who thought they could maintain egg quality unusually well by using electrical methods. One, an X-Ray specialist from Kansas City, Missouri, who was apparently using X-Rays to arrest embryonic development, did not divulge his secret. The other stated that he was passing an electric current through the egg.

Funk (1931 unpublished) found that X-Ray dosages of 2500 r units when applied to fertile eggs before incubation completely devitalized them.

Bless and Romanoff (1943) reported that an X-Ray dosage of 250 r units stimulated embryonic growth and that 5000 r units applied to unincubated fertile eggs reduced hatchability to 0.

The development and use of electronics for heating other substances has created some interest in using this method for treating eggs. Walter

M. Urbain and Paul Schauert were issued U. S. Patent 2,473,041, June 14, 1949, entitled High-Frequency Electrostatic Field Apparatus for Egg Pasteurization. This patent was assigned to Swift & Company, Chicago. It was claimed for this process that it would stabilize the albumen, destroy the embryo and pasteurize the egg meat.

E. The Use of Heat to Improve the Keeping Quality of Shell Eggs

Various attempts to use heat to improve the keeping quality of shell eggs have been recorded.

Atwell and Crawford in 1867 recommended dipping eggs in a boiling mixture of glue, isinglass, unslaked lime and corn starch for from 5 to 10 seconds. Gray in 1887 obtained a patent for preserving shell eggs by dipping them just long enough to bring the eggs into contact with a boiling mixture of tallow 10 lbs. and soda 2 lbs.

Wm. Schoning of Christiania, Norway, in 1902 was granted a patent (U. S. Patent 709,583) for a process for preserving eggs for which he made the following claim: "I claim as my invention—

"Process for preserving eggs, which consists in first warming the fresh eggs in warm water (not boiling) for a few seconds and then immediately they are removed from the warm water, allowing them to cool in a solution of cold salt water, sal-ammoniac, and silicate of soda, in the manner and for the purpose substantially as described."

John A. Rylander of Norrkoping, Sweden, in 1902 was granted a patent (U. S. Patent 696,495) for the following process for preserving eggs: "A process for preserving eggs, which consists in first heating air saturated with salicylic acid dissolved in alcohol to 80° Centigrade, subjecting the eggs to such air, and in applying a solution of potassium silicate previously heated at or about 80° Centigrade when in a cooled state."

Carl Bach-Wiig of Bon, Norway, in 1903 was granted U. S. Patent 739,137 for the following claim: "The herein-described method of preserving eggs consisting in first heating the eggs to about 140° to 150° Fahrenheit and then coating them with waste sulfite lye freed from sulfur compounds, as set forth."

Jacobsen in 1910 in Danish patent 14,902 recommended that shell eggs be immersed for 15 minutes in water at 35° C. and in boiling water for 5 seconds, cooled in water and then dried.

Clairemont in 1914 (U. S. Patent 1,092,897) obtained a patent for which he made the following claims: "Having thus described my invention what I claim and desire to secure by Letters Patent of the United States is—

"1. A process for preserving eggs which consists in coagulating the albumen of the egg content immediately in contact with the inner side of the shell without affecting the edible portion by suddenly subjecting the eggs to a higher temperature than that of boiling water for a short period of time, and in applying a sealing coating to the outer side of the shell while in a heated condition.

"2. The process of preserving eggs, which consists in immersing the eggs in a solution adapted to form a sealing coating and heated to a temperature of approximately 250° F. for a period of time sufficient only to coagulate the albumen content in immediate contact with the inner side of the shell and render innocuous the germ spores on the exterior of the shell without affecting the edible portion of the egg.

"3. The process of preserving eggs which consists in first immersing the eggs in a solution heated to a comparatively low temperature (approximately 100° F.) for a brief period of time to temper the shell and in immediately thereafter immersing the eggs in a solution heated to 250° F. or upward for a period of time insufficient to noticeably coagulate the albumen contents save in immediate proximity to the shell, and in subsequently cooling said eggs.

"4. The process of preserving eggs which consists in first tempering the shells by subjecting the eggs to a moderate degree of heat, secondly, while still warm, immersing the eggs in a solution heated to a temperature in excess of 250° F., and in applying a sealing coating to the outer side of the shell."

Thornburg in 1915 (U. S. Patent 1,163,873) patented a process for reducing bacteria in shell eggs intended for breaking purposes by heating them for approximately one hour at 110° F. to 132° F.

Almy, Macomber and Hepburn (1922) reported heating shell eggs in hot air at 320° C. and 610° C. for 5 seconds. They measured results by loss in weight of eggs held for 35 days at room temperature. The results were as follows:

	Loss in Weight
Eggs treated for 5 seconds at 320° C.	8.4%
Eggs treated for 5 seconds at 610° C.	7.8%
Untreated eggs	8.0%

In 1916, S. F. Henderson was granted U. S. Patent 1,777,105 for a method of preserving eggs by dipping them for 5 seconds into a heated (210° to 225° F.) liquid oil (petrolatum).

Funk (1943) announced a process which he termed Thermostabilization by which the quality of shell eggs was maintained by reason of the fact that (1) the fertile eggs were devitalized so that subsequently they reacted as infertile eggs, (2) the thick albumen was stabilized so that such eggs retained their fresh appearance much longer than natural unheated eggs and (3) a pasteurizing effect was obtained. These results were secured by heating shell eggs by immersing them in water or oil long enough to heat them throughout but regulating the temperature and time to avoid any perceptible coagulation. Eggs immersed for 10 minutes in oil held at 140° F. were reported to give satisfactory results. Later the process was modified to 15 minutes in water at 130° F. and after drying oil processing.

Barott and McNally (1943) using Funk's conditions of treatment established time and temperature for obtaining different stages of opacity of the albumen.

Romanoff and Romanoff (1944) reported their results from experiments with a flash heat treatment. They immersed the eggs in boiling water for 5 seconds. They considered this process "to be an efficient method for the preservation of table eggs."

Bose and Stewart (1948) reported results from experiments in which shell eggs were heated from 20 to 90 minutes in water held at 130° F. from which they concluded that: "Experiments were conducted to determine the comparative and complementary effects of heat treatment and oiling on the keeping quality of shell eggs stored at room temperature. Eggs were treated both 5 hours after laying and 4 days after laying. The eggs were heat treated in water at 130° F.; they were oiled by dipping for one minute in a commercial egg processing oil held at room temperature.

Heat treatment produced a definite improvement in the initial albumen index of the 4-day-old eggs but not in the 5-hour-old eggs. The degree of improvement was roughly linear with time of treatment.

With 5-hour-old eggs, complementary effects of oiling and heat treatment on keeping quality were noted only during the early stages of heat treatment. No complementary effects were noted for the 4-day-old eggs.

With respect to the retention of yolk quality, complementary effects were noted with both 5-hour-old and 4-day-old eggs. Again the effects were noted only during the early stages of heating.

When eggs were heat treated for sufficient time to secure maximal stabilization, little or no complementation occurred."

Stewart and Bose (1948) reporting on "Factors influencing the efficiency of Solvent-oil Mixtures in the Preservation of Shell Eggs" summarized their findings as follows: "A study was made of certain solvent-oil mixtures on the retention of quality of shell eggs kept at room temperature and also when stored at 30° F. In addition, the effect of time after laying before oiling on keeping quality was studied.

The results indicate that pentane-mineral oil mixtures are very efficient in preventing quality losses in shell eggs. As little as 1-2% oil in pentane greatly minimized quality changes in the thick white; 10% oil in pentane gives practically the same retention of quality as did oil itself.

Eggs dipped in mixtures containing 10% or less oil were practically free of "shine" within a few hours after treatment. This is considered to be of commercial significance because of the objection to the trade to oiliness.

Other petroleum solvents were not as effective as pentane for diluting the processing oil. The relative effectiveness of these various solvents seemed to be inversely proportional to their molecular weight. Carbon tetrachloride behaved similarly to pentane; acetone behaved like the high molecular weight hydro-carbons.

The optimal retention of the thick white condition was obtained when eggs were oiled as soon as possible after laying.

However, eggs oiled very soon after laying have an undesirable amount of thin white after storage. It is recommended that for all-around keeping quality, eggs best be oiled approximately 18 hours after laying."

EXPERIMENTAL

Since it was observed that laboratory findings with high quality eggs were not always applicable to commercial conditions, the experimental results obtained under laboratory conditions will be discussed separately from the results secured under commercial conditions.

Laboratory Experiments

The process of Thermostabilization was discovered and first applied in the Department of Poultry Husbandry with eggs produced on the University of Missouri Poultry Farm. In later experiments eggs were obtained from the regular commercial channels of trade and processed at the University of Missouri. More recently eggs commercially stabilized have been used in these experiments.

The results obtained with high quality eggs produced by the University of Missouri and reported in Missouri Agricultural Experiment Station Research Bulletins 362 and 364 showed that three very beneficial effects in maintaining egg quality were obtained. They were:

1. Devitalizing fertile eggs so that no embryonic development was possible subsequent to stabilization.
2. Stabilizing the thick albumen so that it changed to thin white only very slowly.
3. Pasteurizing shell eggs against many of the organisms which cause spoilage in storage.

The results reported here were obtained subsequent to those reported in Missouri Agricultural Experiment Station Research Bulletins 362 and 364. In these experiments the temperature of the eggs before thermostabilizing was 60° F. to 70° F.

Comparison of Thermostabilization and Flash-Heat Treatment for Maintaining Shell Egg Quality.—Romanoff and Romanoff (1944) reported that shell eggs dipped in boiling water for five seconds kept unusually well and they considered flash heat treatment "to be an efficient method for the preservation of table eggs." Since these experiments suggested a much simpler method than thermostabilization for maintaining quality in shell eggs, tests were designed to compare the two methods. A comparison of the keeping quality of eggs treated in this manner with thermostabilized eggs, is shown in Tables 1, 2, and 3. It was evident from these results that flash heat treatment has little if any value in maintaining the keeping quality of shell eggs either at room temperature or in cold storage. The eggs which were thermostabilized only or thermostabilized and oil processed maintained their quality remarkably well when held at 75° F. to 85° F.

The flash heat treatment does not provide sufficient time for the heat to penetrate the egg and stabilize the albumen as does the longer heat treatment of thermostabilization.

Effect of Thermostabilization on the Whipping Properties of Egg Albumen.—The albumen of eggs treated by this process require more time for whipping and the volume of foam is less than that of unprocessed eggs. Table 4 shows the results of duplicate tests repeated in March 1945. This confirms other tests and the observations made by Funk in 1943. At that

Table 1.--Flash Heat Treatment Compared to Thermostabilization for Maintaining Egg Quality. March, 1945. 10 Egg Samples.

Treatment	Embryonic Development	Albumen Score	Albumen Height (mm.)
	Held 28 Days at 80-85°F.		
Lot A. Fresh-laid eggs held in boiling water for 5 seconds	Pronounced	4.0	2.6
Lot B. Fresh-laid eggs held in water for 15 minutes at 130°F.	None	2.9	4.6
Lot C. Fresh-laid eggs held in water for 15 minutes at 130°F. and after drying dipped in oil	None	2.4	5.2
	Held 13 Days at 80-85°F.		
A. Fresh-laid eggs held in boiling water for 5 seconds	Pronounced	3.4	3.5
B. Fresh-laid eggs held in water for 15 minutes at 130°F.	None	2.5	5.4
C. Fresh-laid eggs held in water for 15 minutes at 130°F. and after drying dipped in oil	None	2.4	5.5
D. Untreated controls	Pronounced	3.6	3.2

Table 2.--Deterioration in Thermostabilized Shell Eggs as Compared to Eggs Flash-Heat Treated. April, 1945. 10 Egg Samples

	Edible Condition of the Eggs After Holding at 75-85°F.					
	Two Weeks			Four Weeks		
	Albumen			Albumen		
Treatment	Height mm.	Score	Germ Development	Height mm.	Score	Germ Development
			FIRST TEST			
Untreated, controls	3.2	3.6	Pronounced	2.2	4.0	Pronounced
Shell eggs immersed for 5 seconds in boiling water	3.5	3.4	Pronounced	2.7	3.8	Pronounced
Shell eggs immersed in water (130°F.) for 15 minutes	5.4	2.5	None	3.9	3.0	None
Shell eggs immersed in water (130°F.) for 15 minutes and oil processed	5.5	2.4	None	5.4	2.3	None
			SECOND TEST			
Shell eggs immersed for 5 seconds in boiling water	3.6	3.2	Pronounced	2.6	4.0	Some eggs inedible
Shell eggs immersed in water (130°F.) for 15 minutes	6.2	1.9	None	4.6	2.9	None
Shell eggs immersed in water (130°F.) for 15 minutes and oil processed	6.7	1.6	None	5.2	2.4	None

Table 3.--The Effect of Thermostabilization on the Keeping Quality of Shell Eggs, Stored in a Cold Storage Warehouse From April 13 to October 29, 1945. 10 Egg Samples.

Lot	Treatment of Eggs	Albumen Score	Albumen Height (mm.)
F.	Soiled shell eggs washed in a one percent cleansing solution (15 minutes at 130°F.)	2.85	3.95
G.	Soiled shell eggs washed in a one percent cleansing solution (15 minutes at 130°F.) plus an exposure in water for 10 seconds at 160°F.	2.35	4.49
H.	Soiled shell eggs washed in a one percent cleansing solution	3.30	3.14
I.	Soiled shell eggs washed in a one percent cleansing solution plus an exposure in water 10 seconds at 160°F.	3.30	3.23

time he reported that other cooking tests (frying, poaching and boiling) showed thermostabilized eggs superior to natural eggs held under similar conditions.

Another observation is that the shell of a stabilized egg adheres to the albumen more than in a nonstabilized egg.

Effect of Thermostabilization and Oil Processing on the Keeping Quality of Fresh-Laid Eggs.—To test the effectiveness of thermostabilization in

Table 4.--Effect of Thermostabilization on the Whipping Properties of Egg Albumen. Duplicate Samples of 165 cc of Albumen Whipped With a Kitchen Aid (Electrical Beater) on Speed 8, 1946.

Lots	Whipping Time	Height (Inches) of Albumen in Bowl
March 16, 1946		
A. Fresh, untreated controls	60 sec.	2.50
	75 sec.	3.25
B. Fresh eggs stabilized for 15 minutes in water held at 130°F.	80 sec.	2.00
	135 sec.	3.00
C. Fresh eggs immersed for 90 minutes in water held at 130°F.	210 sec.	1.25
	135 sec.	1.50
March 30, 1946		
D. Fresh, untreated controls	60 sec.	3.50
	55 sec.	3.50
E. Fresh eggs stabilized for 7 minutes at 130°F. and 7 minutes at 136°F.	230 sec.	2.50
	210 sec.	2.50
F. Fresh eggs stabilized for 15 minutes in water held at 130°F.	195 sec.	2.63
	180 sec.	2.63

maintaining the quality of fresh-laid eggs, eggs produced on the University Poultry Farm were oil processed, thermostabilized, thermostabilized and oil processed the day following production and their keeping quality compared with natural eggs. The results of these tests are presented in Tables 5, 6, 7 and 8 and in Figures 1, 2 and 3.

The results (Table 6) showed that a low albumen (Cornell) score which indicates high quality was maintained by thermostabilization much better than by oil processing. There was some benefit from oil processing but much less than from thermostabilization. Albumen height measure-

Table 5.--Changes in the Albumen Score of Thermostabilized Eggs Held at Room Temperature. Experiment Started February 18, 1947. 10 Egg Samples.

Time Held (Days)	Untreated Controls	Thermostabilized	Thermostabilized Plus Oil Processed	Oil Processed
0	1.8	1.9		
7	2.3	2.1	2.1	2.3
14	2.8	2.1	2.2	2.5
21	3.0	2.1	2.2	2.7
28	2.9	2.3	2.2	2.7
35	3.4	2.3	2.4	2.6
42	3.6	2.4	2.2	2.9
49	3.5	2.5	2.2	3.2

Table 6.--Changes in the Albumen Height of Thermostabilized Eggs Held at Room Temperature. Experiment Began February 18, 1947. 10 Egg Samples.

Time Held (Days)	Untreated Controls	Thermostabilized	Thermostabilized Plus Oil Processed	Oil Processed
0	8.4	7.4		
7	5.5	6.5	6.8	6.7
14	4.4	6.7	6.8	5.7
21	4.0	6.1	6.7	5.1
28	3.8	5.2	6.7	4.6
35	3.1	5.4	5.6	4.8
42	2.7	5.4	6.0	4.2
49	2.9	5.2	5.7	3.8

ments, which are more objective measurement of albumen condition, also showed (Table 7) that oil processing was only slightly effective in retaining the thick albumen of an egg. Thermostabilization was highly effective in this respect.

Table 7.--Changes in the Yolk Index (Height ÷ Width) of Thermostabilized Eggs Held at Room Temperature. Experiment Began February 18, 1947. 10 Egg Samples.

Time Held (Days)	Untreated Controls	Thermostabilized	Thermostabilized and Oil Processed	Oil Processed
7	.36	.39	.40	.41
14	.39	.35	.40	.39
21	.33	.33	.36	.39
28	.29	.29	.31	.36
35	.25	.26	.35	.34
42	.22	.24	.33	.35
49	.23	.23	.33	.35

Table 8.--Changes in the Strength of the Yolk Membrane of Thermostabilized Eggs Held at Room Temperature. Grams Pressure per 10 Square Cm. Surface Area of Vitelline Membrane Required to Rupture Membrane. Experiment Began February 18, 1947. 10 Egg Samples.

Time Held (Days)	Untreated Controls	Thermostabilized	Thermostabilized and Oil Processed	Oil Processed
0	138	124		
7	79	109	104	87
14	97	100	106	84
21	65	80	84	87
28	68	84	79	53
35	72	64	81	62
42	69	74	65	72
49	59	62	61	57

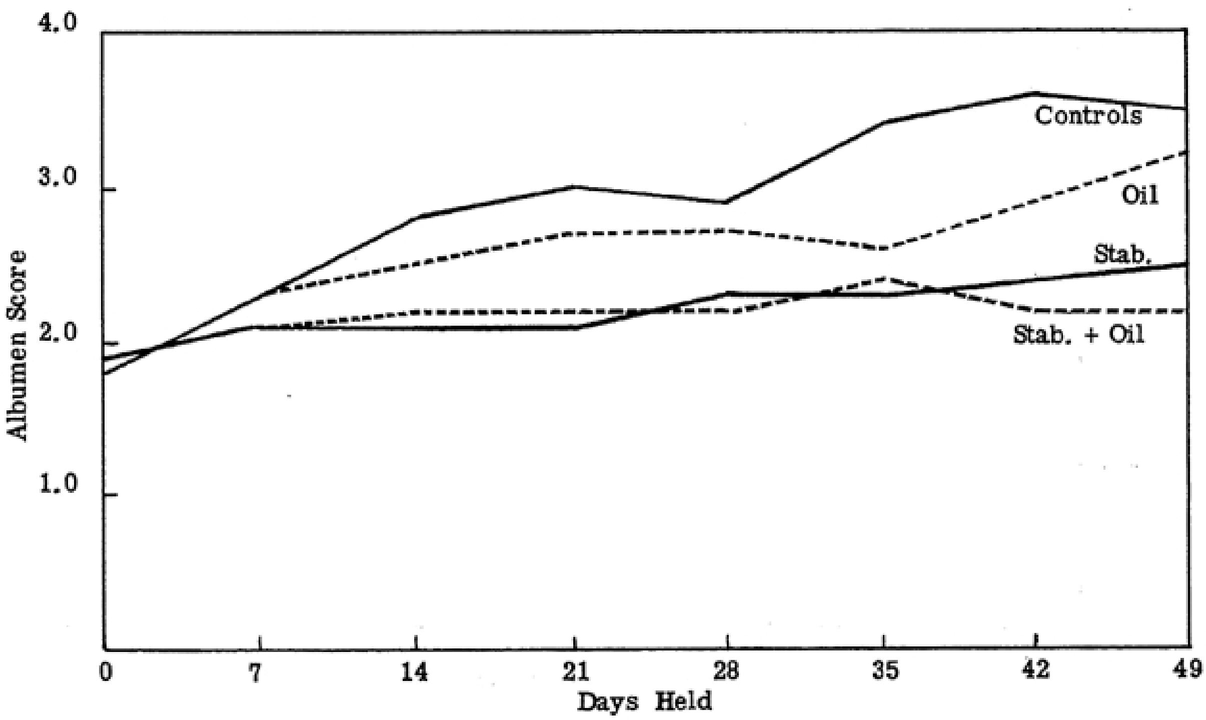

Figure 1.—The effect of thermostabilization and oil processing on the albumen score of shell eggs held at room temperature. 1947.

A high and therefore more desirable yolk index $\frac{\text{height}}{\text{(width)}}$ was retained (Table 8) by oil processing but not by thermostabilization. The strength of the yolk membrane of the different lots was measured by determining the pressure required per 10 square centimeters to rupture the vitelline membrane (Table 8). These results indicated that neither oil processing nor thermostabilization affected the strength of the vitelline membrane.

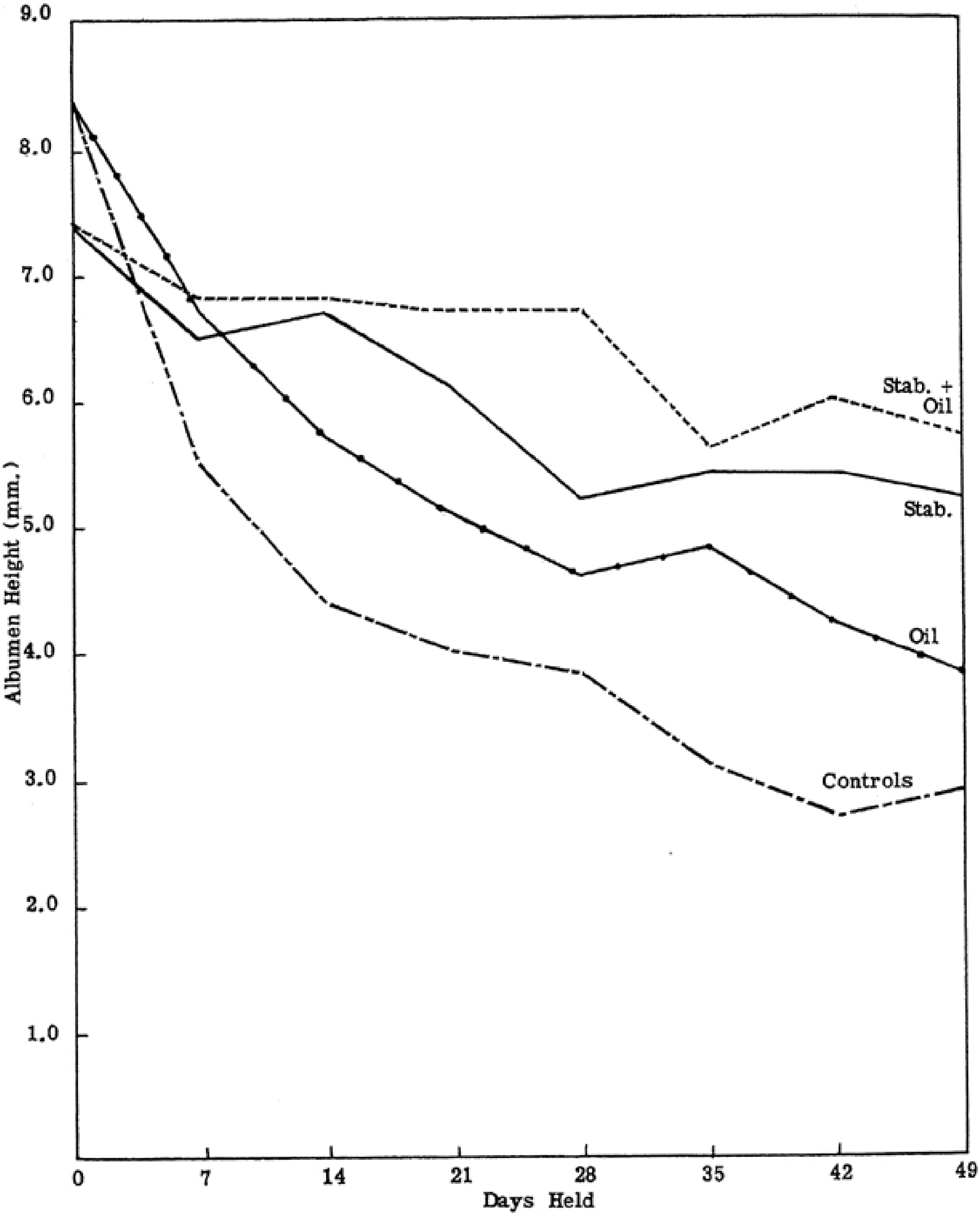

Figure 2.—The effect of thermostabilization and oil processing on the albumen height of shell eggs held at room temperature. 1947.

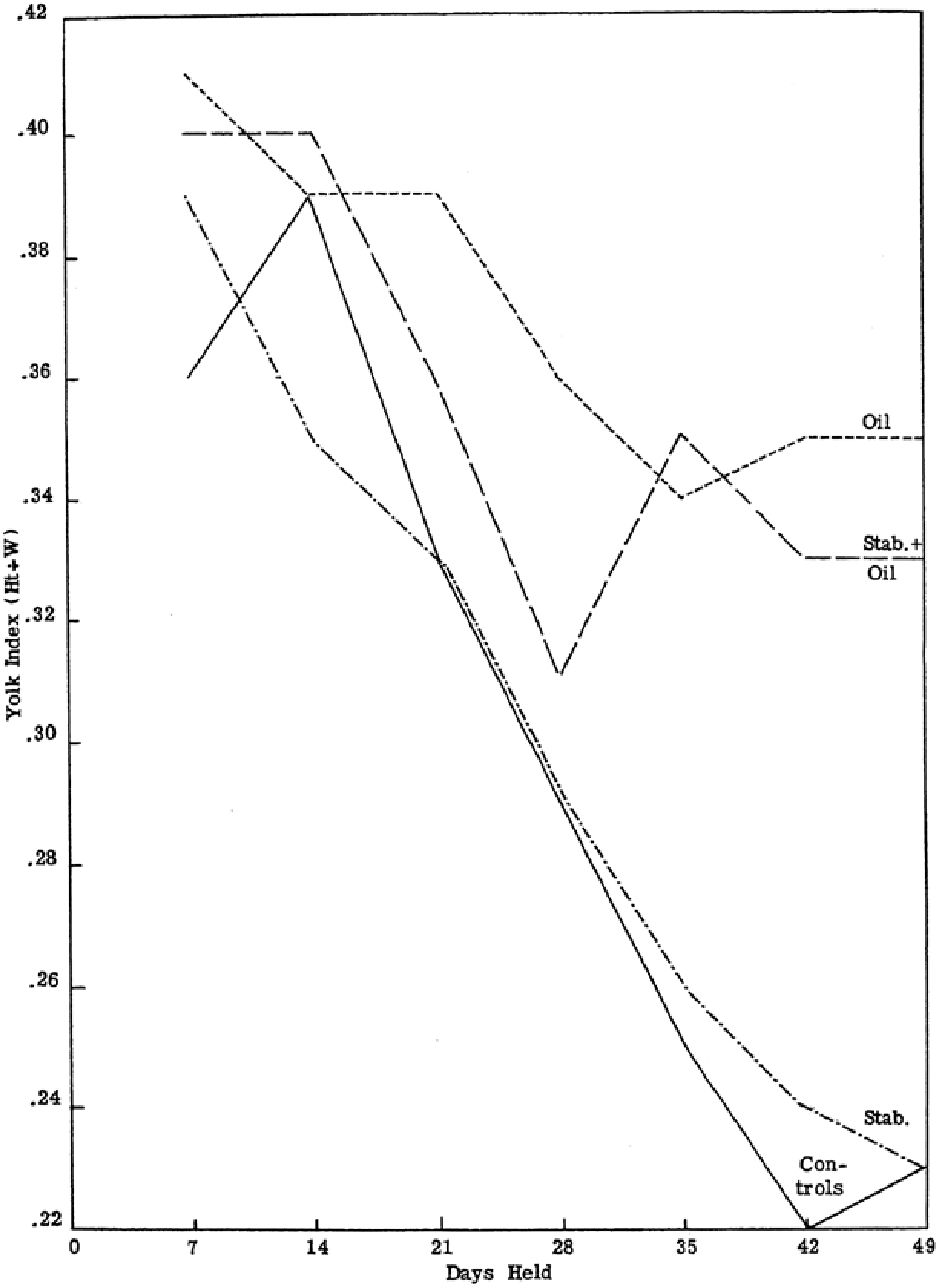

Figure 3.—The effect of thermostabilization and oil processing on the yolk index of shell eggs held at room temperature. 1947.

Some observers have thought that the yolk membrane was weakened as a result of heating but such a conclusion was not substantiated by these results.

The Effect of Thermostabilization on Maintaining the Fresh Appearance of Eggs.—The value of thermostabilization for maintaining the fresh appearance of eggs as determined by albumen condition is also shown in Figures 4, 5, 6 and 7. Eggs held in storage at 30° F. for 60 days and 6 months came out of storage with approximately the same albumen condi-

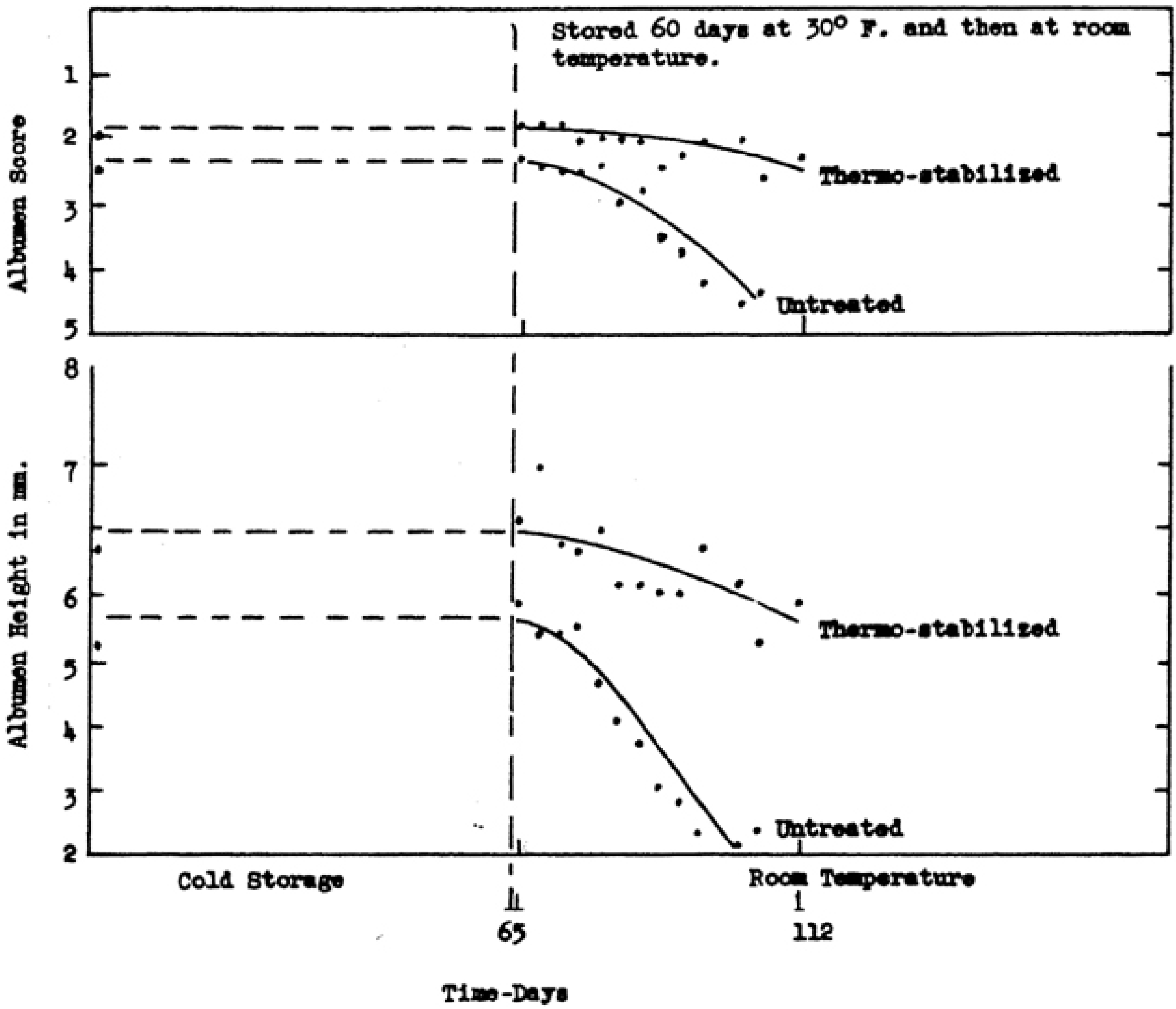

Figure 4.—Change in albumen condition of thermostabilized and untreated eggs held for 60 days at 30° F. and thereafter at room temperature.

tion as when they were stored. When subsequently held at room temperature the natural eggs declined in albumen height and albumen score quite rapidly whereas thermostabilized eggs maintained their albumen height and score remarkably well.

Eggs held at 50° F. and 70° F. showed that thermostabilization maintained quite well the fresh appearance of the albumen under these temperature conditions.

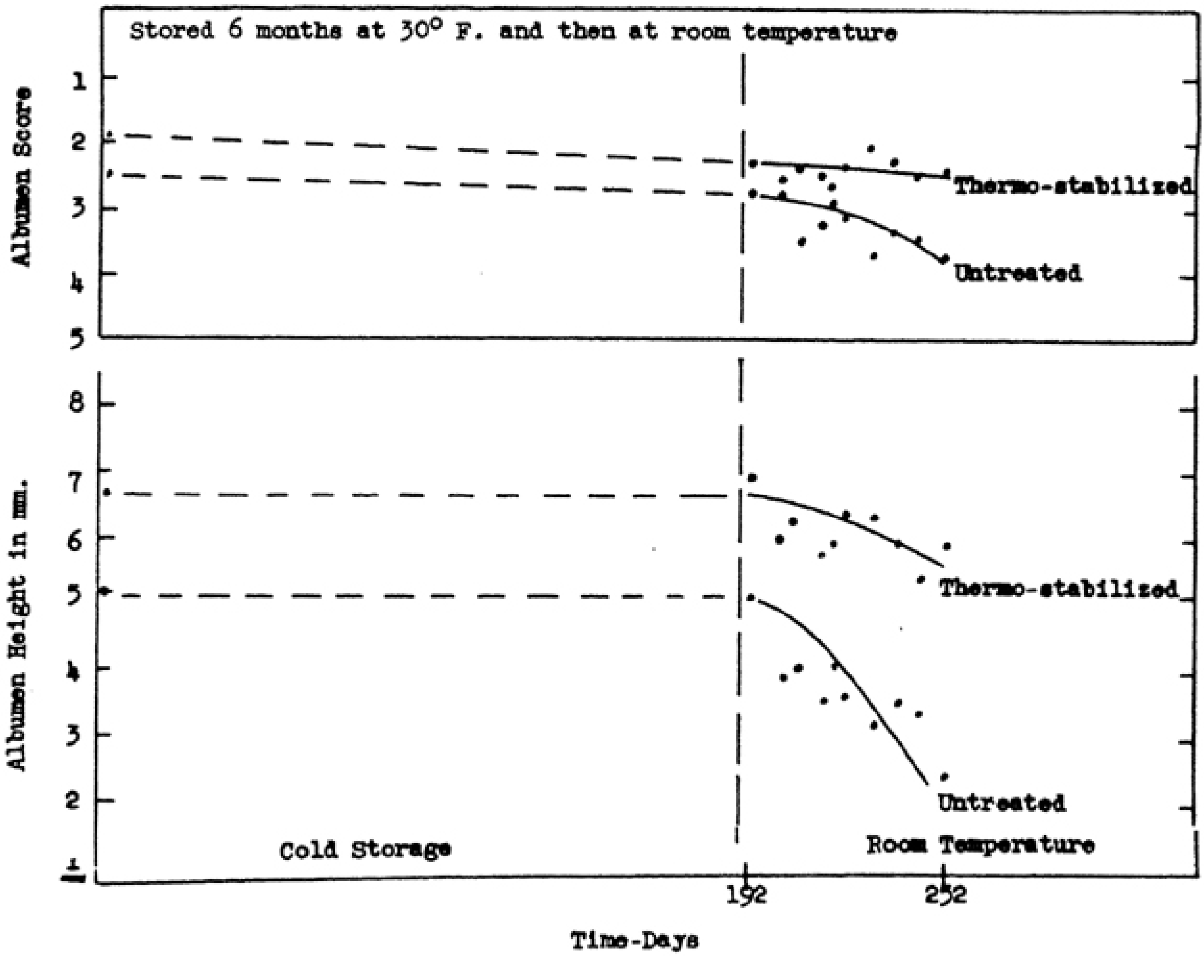

Figure 5.—Change in albumen condition of thermostabilized and untreated eggs held for 6 months at 30° F. and thereafter at room temperature.

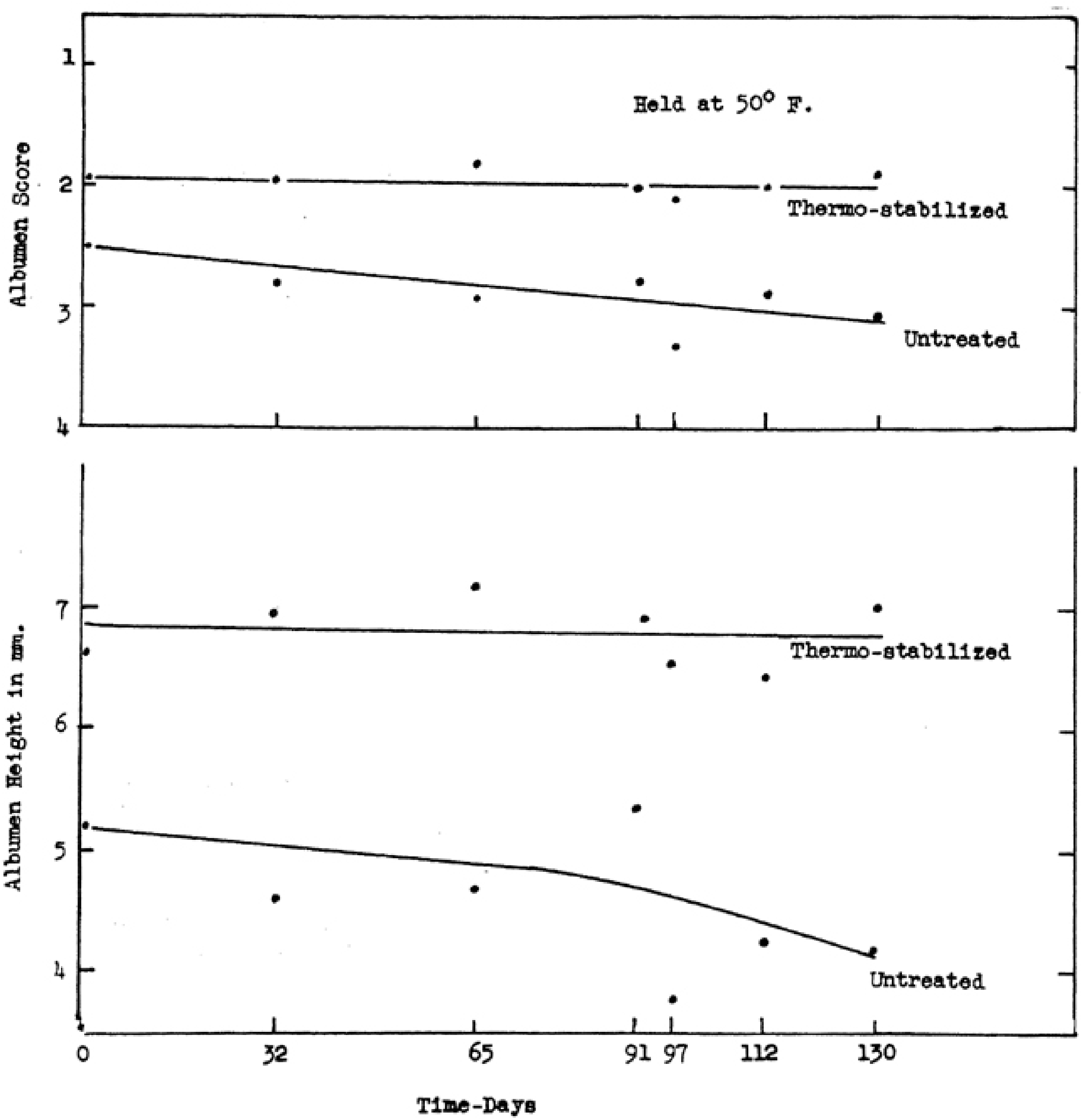

Figure 6.—Change in albumen condition of thermostabilized and untreated eggs held at 50° F.

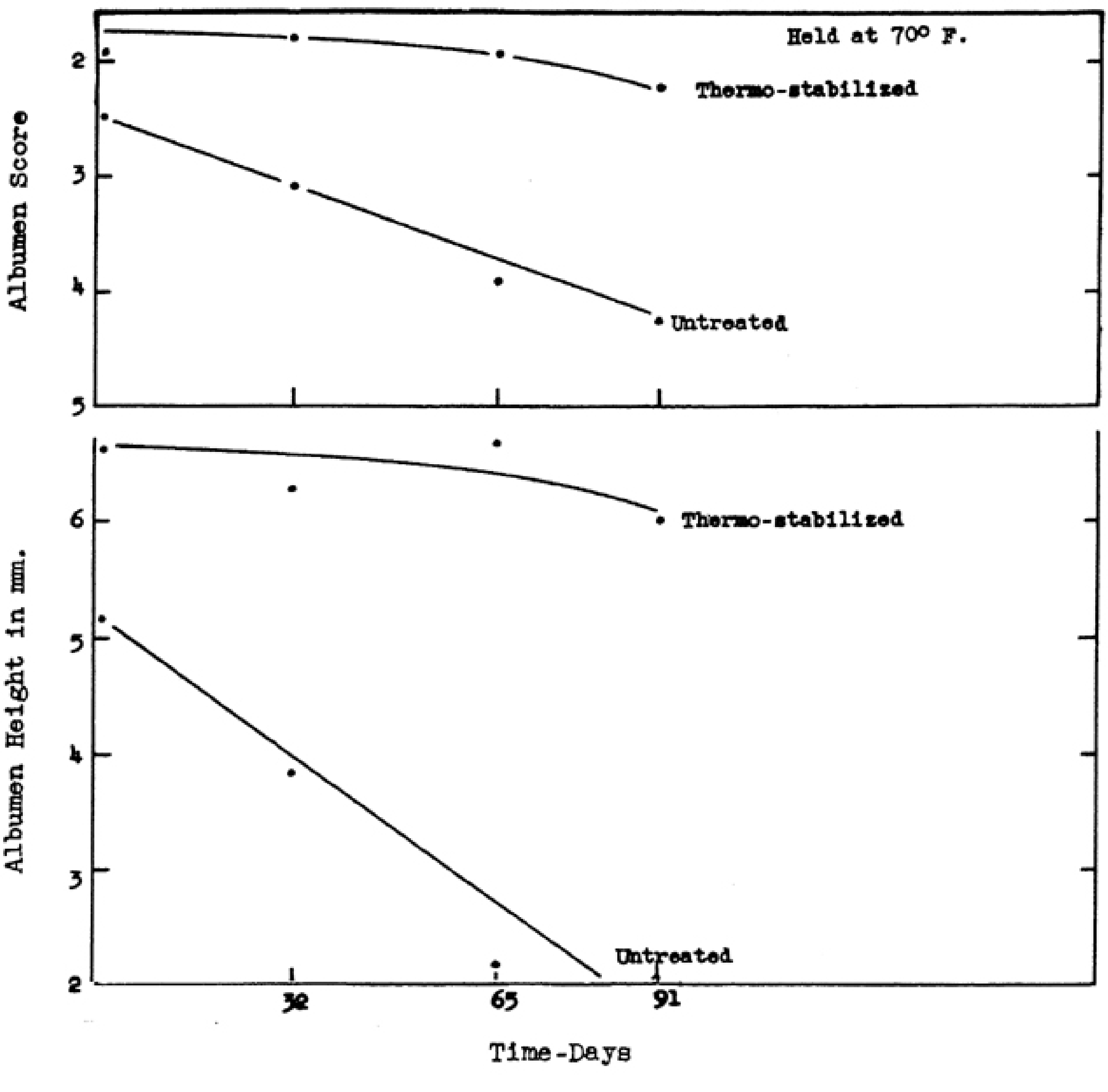

Figure 7.—Change in albumen condition of thermostabilized and untreated eggs held at 70° F.

Maintaining the Quality of Different Grade Eggs.—That thermostabilization maintained the quality of grade A eggs remarkably well was established early in our investigations. That this process also maintains the quality of grade B and grade C eggs equally as well if not better is shown by Table 9 and Figure 8. But in this connection it should be observed that the lower grade eggs are more likely to develop such defects as stuck yolks and watery yolks.

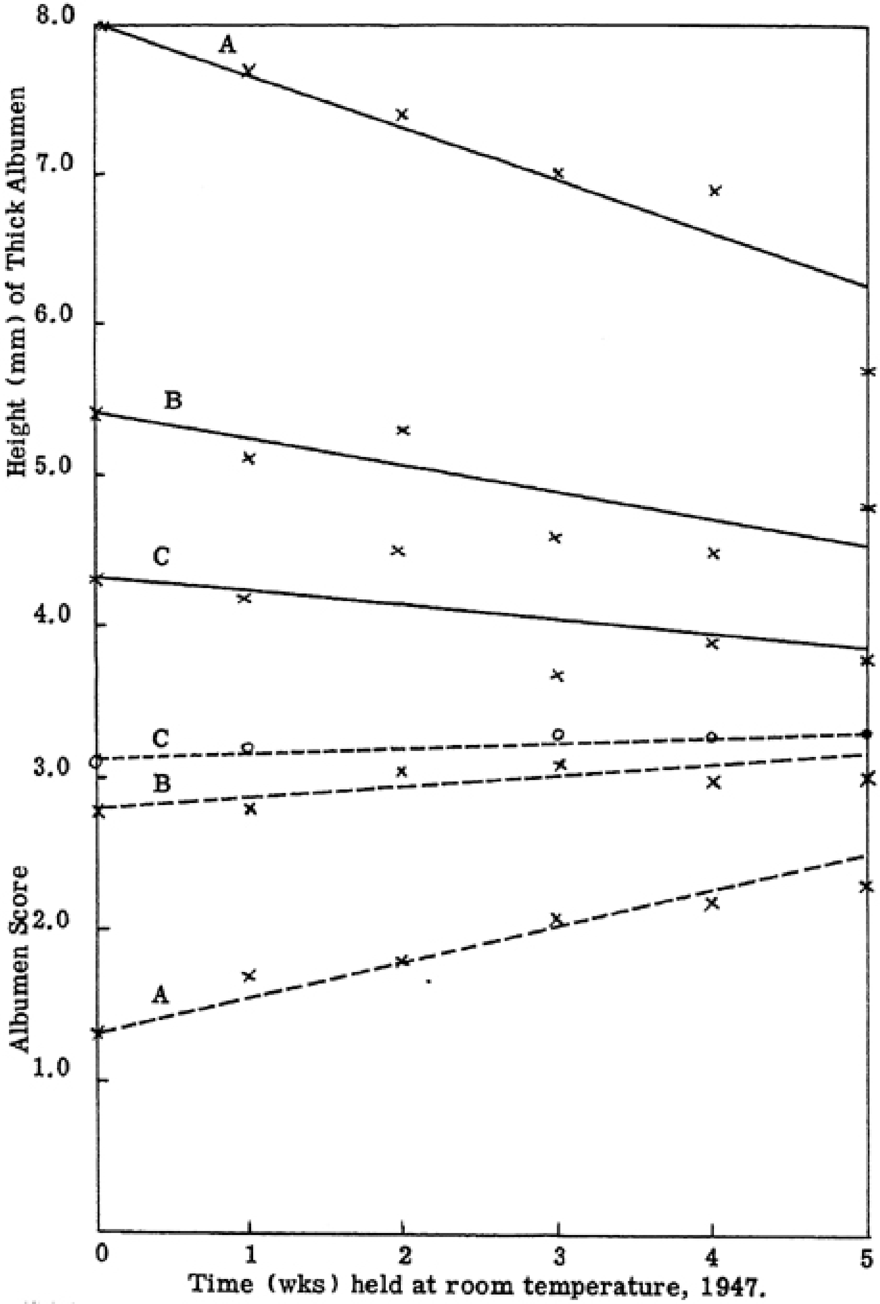

Figure 8.—The effect of thermostabilization on maintaining the quality of grade A, B and C eggs.

Table 9.--Results From Stabilizing A, B, and C Grade Eggs Held at Room Temperature. 10 Egg Samples.

Date Examined	Albumen Score: Stabilized	Albumen Score: Controls	Albumen Height (mm.): Stabilized	Albumen Height (mm.): Controls	Yolk Index: Stabilized	Yolk Index: Controls
			Results with A Grade Eggs			
Dec. 8, 1947	1.3	1.3	8.0	8.4	.44	.46
Dec. 15, 1947	1.7	2.3	7.7	5.4	.42	.43
Dec. 22, 1947	1.8	3.1	7.4	4.4	.41	.39
Dec. 29, 1947	2.1	3.4	7.0	4.1	.41	.40
Jan. 5, 1948	2.2	3.5	6.9	3.9	.35	.33
Jan. 12, 1948	2.3	3.7	5.7	3.5	.30	.28
			Results With B Grade Eggs			
Dec. 20, 1947	2.8	3.0	5.4	4.5	.34	.37
Dec. 27, 1947	2.8	3.1	5.1	4.0	.37	.37
Jan. 3, 1948	3.1	3.4	5.3	3.8	.34	.34
Jan. 10, 1948	3.1	3.8	4.6	3.3	.31	.31
Jan. 17, 1948	3.0	3.6	4.5	3.6	.29	.29
Jan. 24, 1948	3.0	3.9	4.8	3.0	.28	.26
			Results With C Grade Eggs			
Dec. 29, 1947	3.1	3.1	4.3	4.1	.30	.38
Jan. 5, 1948	3.2	3.3	4.2	3.7	.31	.31
Jan. 12, 1948	3.0	3.9	4.5	3.1	.28	.26
Jan. 19, 1948	3.3	3.7	3.7	2.8	.25	.26
Jan. 26, 1948	3.3	4.1	3.9	2.4	.26	.22
Feb. 2, 1948	3.3	4.1	3.8	2.3	.24	.22

Table 10.--A Comparison of Methods of Cleaning Soiled Eggs on the Keeping Quality of Such Eggs. Internal Temperature of the Eggs Varied From 56°F. to 76°F. and the Wash Water Temperature From 0 to 13°F. Above the Temperature of the Eggs. Eggs Stored Weekly From April 19 to June 28 and Held Until November 19, 1946.

			Percentage of Loss Found By								
				Breaking							
Lot	Kind of Eggs	No. Eggs	Can-dling	Other Rots	Green Whites	Sour	Musty	Mold	Total Loss	Stuck Yolks No.	Stuck Yolks %
A	Clean, unwashed	3204	.01						.01		
B	Soiled, unwashed	3168	1.3	3.03	1.8	.40	.8	.06	7.4	6	.2
C_1	Soiled, washed in water	906	13.0	9.9	6.8	.8	.7		31.2		
C_2	Soiled, washed in 1% lye water	1306	3.2	3.3	2.6	.4	.3		9.8	4	.3
D	Soiled, washed and then Thermostabilized in water (15 Min. at 130°F.)	2882	.9	.3	.1	.1		.06	1.5	16	.6
E_1	Same as D plus pasteurized (20 seconds at 160°F.) in oil	1547	.8	.4	.2	.3	.06		1.8	9	.6
E_2	Same as E_1 (pasteurized but not thermostabilized)	1215	8.1	11.0	6.1	2.3	1.8		29.3		

The Use of Thermostabilization as an Adjunct to Cleaning Soiled Eggs to Minimize Storage Losses.—From the pasteurizing effects noted early in experimenting with the process of thermostabilization an experiment was suggested to determine the effectiveness in preventing loss in eggs held in cold storage. Table 10 summarizes the results of a series of such experiments, made in 1946. The results showed that average losses were reduced from 31.2 per cent and 29.3 per cent to 1.5 per cent and 1.8 per cent by using this process. The incidence of stuck yolks was increased by thermostabilization. The losses in washed eggs immersed in oil for 20 seconds at 160° F. were approximately the same (29.3 as compared to 31.2 per cent) as those washed and not heated. Rots, green whites, sour and musty eggs were greatly reduced by thermostabilization (15 minutes at 130° F. in water).

The effectiveness of thermostabilization in reducing storage losses in washed eggs is shown in Figure 9. In five repeated trials it will be observed that losses were reduced by more than 90 per cent. Figure 10 shows that the effectiveness of stabilization against loss in storage may be lost if more than two days time elapses after the soiled eggs are washed before they are heated. These results would indicate that the heat used (immersion for 10 minutes in egg processing oil held at 140° F.) was not effective against the organisms which had penetrated the egg.

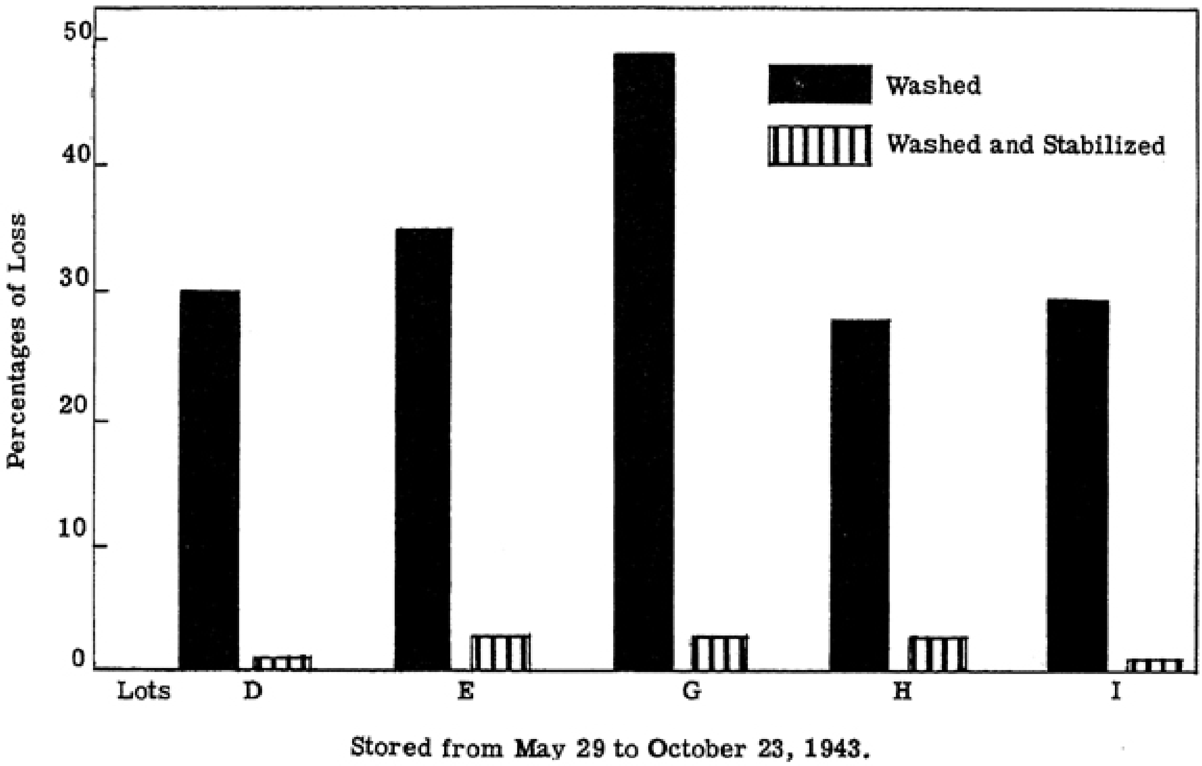

Figure 9.—The effect of thermostabilization in preventing loss in the storage of shell eggs. 1943.

Factors Related to the Occurrence of Stuck Yolks in Thermostabilized Eggs.—Difficulties experienced in commercial practice of thermostabilization with stuck yolks prompted an investigation at the University of Missouri, of the factors related to this condition. Table 11 shows the incidence of stuck yolks in both natural and oil processed eggs which were stabilized and held in cold storage for 29 to 37 weeks, then held at 40° F. for 54 days and finally held at 70° F. for 22 days. It was evident from these results that thermostabilization increased stuck yolks in natural eggs but decreased their incidence in oil processed eggs. The occurrence of stuck yolks in eggs which were both thermostabilized and oil processed was relatively low.

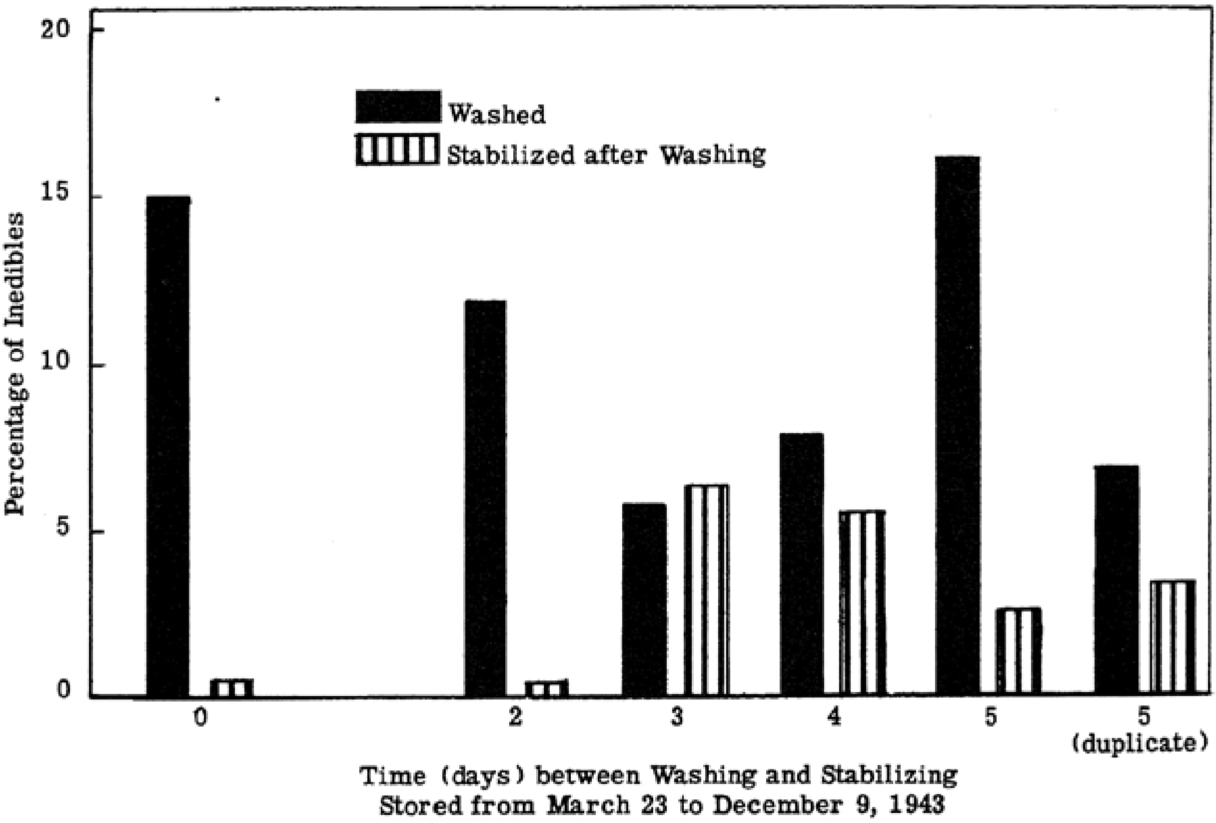

Figure 10.—The relation of time between washing and thermostabilization on the effectiveness of the process in preventing storage loss. 1943.

Table 11.--Effect of Thermostabilization and Oil Processing on the Occurrence of Stuck Yolks in Shell Eggs, 1947-48.

	Clean Eggs				Clean Eggs, Stabilized			
	Natural		Oil Processed		Natural		Oil Processed	
Lot	No. Eggs Exam-ined	Per Cent Stuck Yolks	No. Eggs Exam-ined	Per Cent Stuck Yolks	No. Eggs Exam-ined	Per Cent Stuck Yolks	No. Eggs Exam-ined	Per Cent Stuck Yolks
A. Eggs showing stuck yolks after 29 to 37 weeks of commercial storage	1432	0	1428	0.28	2792	0.14	2798	0.07
B. Stuck yolks found by samples broken each week during subsequent storage for 54 days at 40°F.	69	0	71	4.22	141	8.51	142	0.70
C. Stuck yolks found in samples broken each week from eggs from the above lots in group B held at 70°F. for 22 days.	70	7.14	65	4.62	140	12.14	140	1.43

Temperature of the Medium (Water) Used in Thermostabilization as a Factor Causing Stuck Yolks in Storage.—From earlier observations when comparing eggs stabilized in water for 15 minutes at 130° F. with those stabilized for 7 minutes at 130° F. plus 7 minutes at 136° F., it was suspected that the temperature of the water used in stabilizing eggs was a factor in the occurrence of stuck yolks. A quintuplicated storage experiment was conducted in 1948 for the purpose of determining if such a relationship existed. The results of that experiment as presented in Table 12 showed that stabilized eggs contained more stuck yolks than eggs which were not heated and that heating eggs for 3 minutes in water held at 145° F. more than doubled (6.36 per cent as compared to 2.98, .78 and 1.68) the incidence of stuck yolks caused by regular thermostabilization (15 minutes at 130° F.).

Table 12.--Effect of Methods of Stabilizing and Cleaning Shell Eggs on the Occurrence of Stuck Yolks During Storage. Eggs Stored From April 8 to May 20, and Removed From Storage and Broken November 17, 1948. Figures in Table are Percentages of 180 Egg Lots.

Lot	Kind of Eggs	Date Stored Apr. 8	Apr. 15	Apr. 29	May 13	May 20	Avg.
A.	Clean, controls	0	0	0	0	0	0
1 B.	Soiled	0	0	.6	----	0	.15
2 B.	Soiled, washed in tap water	.6	0	0	----	0	.15
1 C.	2 B + 15 min. in 130°F. H_2O	3.3	1.1	4.4	3.3	2.8	2.98
2 C.	2 B + 5 min. in 140°F. H_2O	1.1	0	3.3	5.6	5.0	3.00
1 D.	2 B + 3 min. in 145°F. H_2O	4.6	.6	8.3	7.2	11.1	6.36
2 D.	Soiled eggs washed in roccal (10%) one ounce per gallon water	0	.6	0	0	0	.15
1 E.	2 D + 15 min. in 130°F. H_2O	1.1	0	2.2	0	.6	.78
2 E.	Soiled eggs washed in 1.0% lye water	1.1	0	.6	0	0	.34
1 F.	2 E + 15 min. in 130°F. H_2O	1.1	0	4.5	1.1	1.7	1.68
	Average	1.19	.23	2.39	1.72	2.12	

Cooling After Thermostabilization.—Some experiences suggested that stuck yolks might be resulting from failure to cool the eggs soon after stabilizing. Grade A eggs were stabilized and cooled shortly thereafter while other eggs of similar grade were kept warm (100° F.) for 24 hours before cooling. The results (Table 13) showed that stabilized eggs kept warm for 24 hours developed 6.0 per cent stuck yolks and 7.5 per cent inedible eggs as compared to 1.6 per cent of stuck yolks found in eggs cooled soon after stabilizing.

Table 13.--Effect of Cooling and Oil Processing on the Keeping Quality of Shell Eggs. Case Lots of Grade A Eggs Purchased From a Missouri Egg Packing Plant and After Processing Held at 55°F. From July 11 to August 29, 1949.

Lot	Processing	Percentage of Loss Found Aug. 29: Stuck	Inedible
A.	Clean eggs, stabilized in water 15 minutes at 130°F., not oiled	2.0	1.2
B.	Clean eggs, stabilized, oiled and cooled soon after stabilization	1.6	0
C.	Clean eggs, stabilized, oiled and held at 100°F. for 24 hours before cooling	6.0	7.5
D.	Natural clean eggs	0	2.7
E.	Soiled eggs, washed	10.4	22.7
F.	Soiled eggs, washed and stabilized	6.8	3.6

Original Egg Quality.—In testing the relation of original quality of the eggs stabilized to occurrence of stuck yolks, it was found (Table 14) that when high quality fresh laid eggs were stabilized stuck yolks developed only under the most adverse conditions (eggs held for 12 weeks at 55° F.).

Table 14.--The Effect of the Quality of Eggs Stabilized on the Occurrence of Stuck Yolks. Eggs Stabilized as Indicated Below. Eggs Held at 55°F. From October 21, 1948, to January 22, 1949. Each x in Table Indicates a Stuck Yolk.

	LOT A Fresh Laid Eggs						LOT B Grade A & B Commercial Eggs						LOT C Grade B & C Commercial Eggs					
			Stabilized						Stabilized						Stabilized			
	Controls		15 Min. at 130°F		7 Min. at 130°F & 7 Min. at 136°F		Controls		15 Min. at 130°F		7 Min. at 130°F & 7 Min. at 136°F		Controls		15 Min. at 130°F		7 Min. at 130°F & 7 Min. at 136°F	
	Not Oiled	Oiled	Not Oiled	Oiled	Not Oiled	Oiled	Not Oiled	Oiled	Not Oiled	Oiled	Not Oiled	Oiled	Not Oiled	Oiled	Not Oiled	Oiled	Not Oiled	Oiled
No. of Eggs	12	12	12	11	11	12	22	22	22	23	22	22	29	28	29	29	28	28
Candled Oct. 29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov. 5	0	0	0	0	0	0	0	0	0	0	0	0	0	x	0	xx	0	x
Nov. 12	0	0	0	0	0	0	0	0	0	0	0	x	0	x	0	xx	xxx	xx
Nov. 19	0	0	0	0	0	0	0	0	x	xxx	0	x	0	x	x	xxx	x	xx
Nov. 26	0	0	0	0	0	0	0	0	x	xx	0	x	x	x	x	xxx	x	xx
Dec. 3	0	0	0	0	0	0	0	0	0	xxx	xx	xx	x	x	xxx	xxxx	xx	xx
Dec. 11	0	0	0	0	0	0	0	0	xx	xx	xxx	xx	x	x	xxx	xxx	xx	xx
Dec. 17	0	0	0	0	0	0	0	x	xx	xxx	xxxx	xxxx	x	xx	xxx	xxx	xxx	xxx
Dec. 31	0	0	0	0	0	0	xxx	x	xxxx	xxx	xxxxx	xxxx	0	0	xxxx	xxxx	xxxxx	xx
Jan. 7	0	0	0	0	0	0	xx	xx	xxx	xx	xxxx	x	x	x	xxx	xxxx	xx	xx
Jan. 14	0	0	0	0	0	0	xx	xx	xxxx	xx	xxxxx	xx	x	xx	xxx	xxxx	xxx	xx
Jan. 21	x	0	0	0	0	0	xxx	xxxx	xxxx	xxx	xxxx	xxx	xxxx	xx	xxx	xxxxx	xxx	xx
Jan. 22 Broken Out	0	x	xx	0	0	0	xxxx	x	xx	x	xxxx	xx	xxx	0	xxx xxx	x	xxx	x

Stuck yolks appeared in commercial grade A and B eggs as early as the third week; in grade B and C eggs as early as one week.

In another test designed to determine the relation of the quality of eggs when stabilized to the incidence of stuck yolks a very close relationship was noted (Table 15) between low quality and stuck yolks. Eggs held 7 days at 80° F. before stabilizing developed 20 stuck yolks in 24 eggs as contrasted to no stuck yolks in eggs stabilized as fresh eggs.

Table 15.--Relation of Age and Quality When Thermostabilized (15 x 130°F.) on the Incidence of Stuck Yolks. 24 Egg Samples Stabilized 12/27/48.

	Stuck Yolks Observed			
	By Candling			By Breaking
Kind of Egg Stabilized	1/3/49	1/10/49	1/17/49	1/24/49
1. Fresh eggs stabilized day laid	0	0	0	0
2. Fresh eggs held 3 days at 80°F. before stabilizing	0	1	1	3
3. Fresh eggs held 7 days at 80 F. before stabilizing	8	15	20	20

That stabilization may in some cases reduce the development of stuck yolks was shown by the results presented in Table 16. The untreated controls developed fewer stuck yolks but it will be observed that when higher temperature (140° F.) was used for stabilizing the eggs more stuck yolks developed than when 130° F. was used.

Table 17 presents results which showed that egg quality can be maintained much better when more heat is used in thermostabilization. Eggs heated for 20 minutes at 130° F. were superior in keeping quality than those heated less. The author, however, is of the opinion that if eggs are

Table 16.--The Relation of the Amount of Heat Used in Thermostabilization and the Occurrence of Stuck Yolks in Pullet Eggs Held at Room Temperature. 24 Egg Samples.

Treatment--12/27/48	Stuck Yolks Observed: By Candling 1/3/49	1/10/49	1/17/49	By Breaking 1/24/49
1. Controls, untreated	0	8	8	11
2. Held for 10 minutes in H_2O at 130°F.	0	0	0	0
3. Stabilized for 15 minutes in H_2O at 130°F.	0	0	0	2
4. Stabilized for 10 minutes in H_2O at 140°F.	0	2	5	6

Table 17.--Relation of the Degree of Thermostabilization to the Maintainance of Quality at High Temperature. Eggs Held for 85 Hours at 100°F. September 27 to October 1, 1948. 10 Egg Samples.

Treatment	Albumen Score	Ht. Thick Albumen mm	Albumen Index
Immersed in H_2O held at 130°F.			
A. 20 minutes	1.50	7.95	.1205
B. 15 minutes	2.25	6.32	.0887
C. 10 minutes	2.25	6.69	.0921
D. 5 minutes	2.50	4.56	.0777
E. 0 minutes	2.58	5.77	.0772

stabilized for 15 minutes in water or rapidly circulating oil held at about 130° F. the most acceptable market egg will result.

Additional tests were made to determine the relation of the original quality of the egg and cooling following thermostabilization to the development of stuck yolks. The results (Table 18) showed as reported above that eggs of lower quality (grade B) developed stuck yolks earlier and more of them than did grade A eggs. The beneficial effects of cooling soon after stabilizing were again demonstrated.

Table 18.--Relation of the Original Candling Grade and Cooling After Stabilization to the Occurrence of Stuck Yolks (Percentage) in Stabilized Eggs as Observed by Candling Case Lots of Eggs Held at 55°F. From July 11, 1949, to September 12, 1949.

Kind of Eggs and Treatment	July 12	July 23	July 29	August 3	August 10	August 29	September 5	September 12
Grade A natural controls	0	0	0	.9	1.1	2.8	0	0
Grade B natural controls	0	0	0	0	1.1	2.7	1.9	0
Grade A, stabilized and cased warm	0	.9	0	.3	1.1	2.0	3.1	4.0
Grade B, stabilized and cased warm	0	3.9	3.1	4.4	3.2	7.0	7.6	11.6
Grade A, stabilized, oiled and cooled before casing	0	0	0	0	1.9	1.6	1.8	4.0
Grade B, stabilized, oiled and cooled before casing	0	7.9	4.7	5.5	7.1	10.7	14.1	13.6
Grade A, stabilized, oiled and held at 100°F. for 24 hours	0	0	5.0	5.6	5.7	6.0	4.4	8.7
Grade B, stabilized, oiled and held at 100°F. for 24 hours	3.5	2.8	4.0	6.7	9.5	13.8	26.7	48.0

Watery Yolks.—Another problem in commercial application of the process not occurring in experiments with fresh-laid eggs was that of watery or "ballooned" yolks where apparently the yolk had absorbed an excessive amount of water from the albumen. Table 19 presents the results obtained in an experiment designed to determine the relation of thermostabilization, the quality of eggs when stabilized and cooling subsequent to this treatment to the occurrence of watery yolks. It was apparent from the results that this process did cause some watery yolks but that the number was very small in grade A eggs. Grade B eggs developed more watery yolks than grade A eggs. Cooling soon after stabilizing tended to minimize the development of watery yolks.

Table 19.--The Relation of Thermostabilization, Cooling, and the Original Candling Grade of Shell Eggs to the Occurrence of Watery Yolks (Number) Observed in 20-Egg Samples. Eggs Held at 55°F. From July 11, 1949, to September 12, 1949.

Kind of Eggs and Treatment	July 12	July 23	July 29	August 3	August 10	August 29	September 5	September 12	Total
Grade A natural controls	0	0	0	0	0	0	0	0	0
Grade B natural controls	0	1	0	1	1	0	0	0	3
Grade A, stabilized and cased warm	0	0	0	1	0	0	0	2	3
Grade B, stabilized and cased warm	0	1	1	4	3	6	1	11	27
Grade A, stabilized, oil processed and cooled before casing	0	0	0	0	0	1	0	1	2
Grade B, stabilized, oil processed and cooled before casing	0	4	0	0	0	3	0	0	7
Grade A, stabilized, oil processed and held 24 hours at 100°F. before casing	1	2	0	0	1	0	0	1	5
Grade B, stabilized, oil processed and held 24 hours at 100°F. before casing	3	2	0	1	3	2	1	8	20

Commercial Experiments and Observations

Since some commercial companies, notably Swift & Company, evidenced interest in this process for maintaining quality in shell eggs it was deemed advisable to investigate the keeping quality of eggs thermostabilized, commercially. Table 20 presents the results of observations made on eggs

Table 20.--Storage Losses in Eggs Commercially Thermostabilized in Water for 7 Minutes at 130°F. Plus 7 Minutes at 136°F. Eggs Stored July 20, 1946.

Lots	No. Eggs Examined	% Losses Found By: Candling	% Losses Found By: Breaking	% Losses Found By: Total	Kind of Loss (No.): Rots	Kind of Loss (No.): Green Whites	Kind of Loss (No.): Sour	Kind of Loss (No.): Musty	Stuck Yolk %
	Removed From Storage November 19, 1946								
Clean eggs	1512	0	.73	.73	3	1	7		0
Clean eggs, stabilized	1512	0	.20	.20	2		1		1.32
Dirty eggs, washed	1692	0.24	3.50	3.74	16	20	22	1	.30
Dirty eggs, washed and stabilized	1692	0.06	.06	.12	1				.71
	Removed From Storage December 16, 1946								
Clean eggs	3600	0.06	.30	.36	3				
Clean eggs, stabilized	1800	.33	0	.33					1.22
Dirty eggs, washed	3600	.75	3.61	4.36	63	28	37	1	.06
Dirty eggs, washed and stabilized	3600	.33	.53	.86	12	7			.33
	Removed From Storage January 16, 1947								
Clean eggs	1800	0	.40	.40		2			0
Clean eggs, stabilized	3600	.14	.06	.20	2				.94
Dirty eggs, washed	1800	.89	1.44	2.43	21	5			.17
Dirty eggs, washed and stabilized	1800	.44	.06	.50	1				1.50

procured from Swift & Company which were stabilized in water by a two-temperature process (7 minutes at 130° F. and 7 minutes at 136° F.). Losses in storage were greatly reduced.

Table 21.--The Relation of Time of Production to Storage Losses (Eggs Per Case) in Eggs Commercially Thermostabilized in Water for 7 Minutes at 130°F. Plus 7 Minutes at 136°F. 1946.

Storage Period (Months)	2	4	6	8	10
	Stored in February				
Lot					
Clean eggs	0	1	0	5	10
Clean eggs, stabilized	0	0	3	1	4
Dirty eggs, washed	1	5	41	19	35
Dirty eggs, washed and stabilized	0	1	4	4	29
	Stored in April				
Clean eggs	0	0	0	1	7
Clean eggs, stabilized	0	0	0	0	6
Dirty eggs, washed	10	9	11	29	137
Dirty eggs, washed and stabilized	0	1	3	0	7
	Stored in June				
Clean eggs	0	2	19	4	71
Clean eggs, stabilized	0	4	30	7	5
Dirty eggs, washed	11	8	19	8	79
Dirty eggs, washed and stabilized	1	2	64	7	12

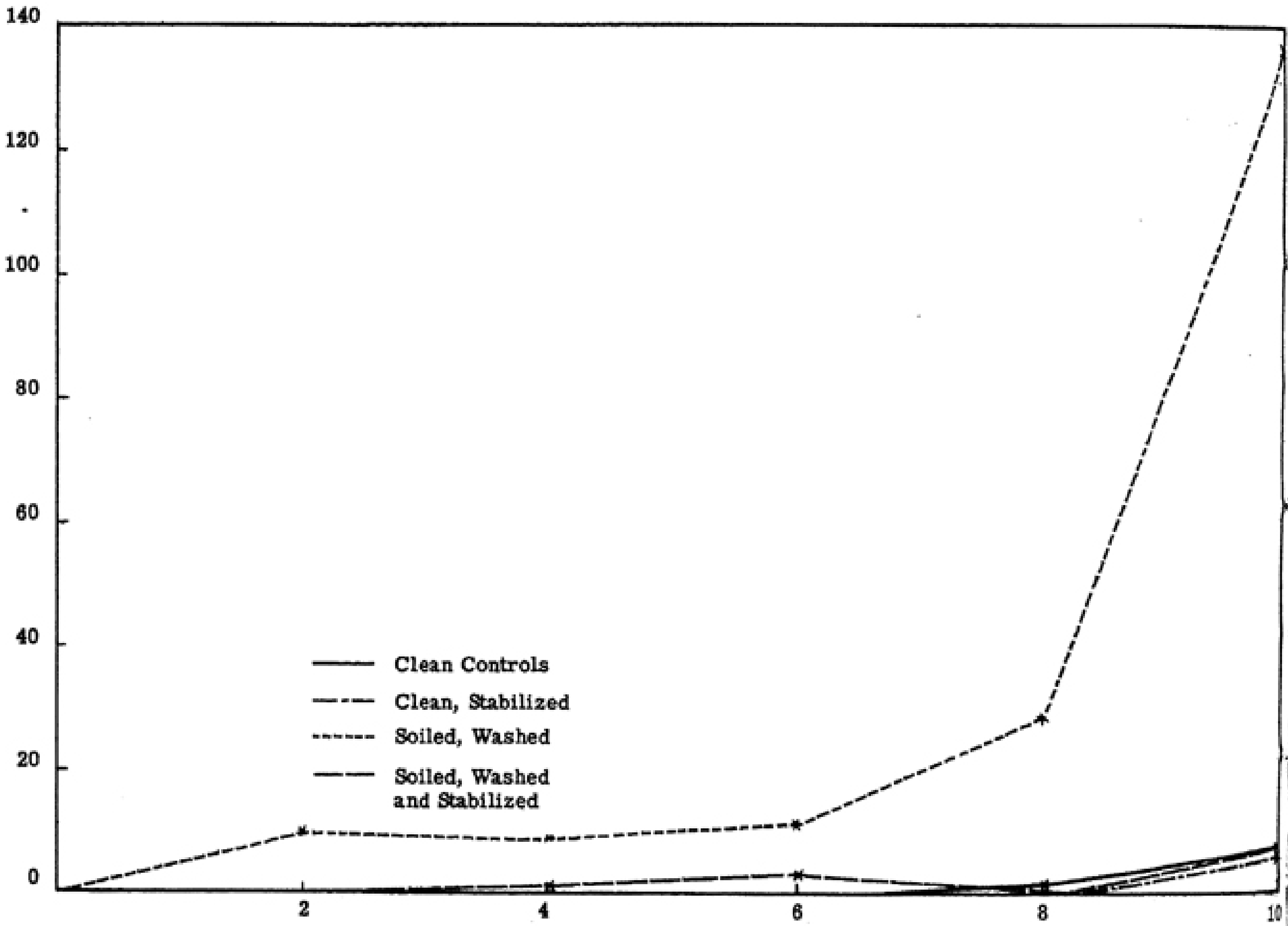

Figure 11.—Storage losses (eggs per case) in eggs stored 2, 4, 6, 8 and 10 months. April eggs. 1946.

Sour eggs were eliminated and green whites materially reduced by the thermostabilization of soiled eggs contaminated by washing. Stuck yolks were increased by the process. Other observations made after 2, 4, 6, 8 and 10 months of storage by Swift & Company (Table 21) of eggs thermostabilized by the two-temperature process showed that losses in storage were significantly reduced by stabilization with the exception of the June eggs held 6 months. No explanation of these losses in June eggs can be made. The results with the April eggs are shown in Figure 11.

That the two-temperature process used by Swift & Company was effective in stabilizing the albumen was shown by the results presented in Table 22 and Figure 12. After 74 days at room temperature thermostabilized eggs were scored 2.3 for albumen and the thick albumen was 5.3 mm. high as compared to control eggs having an albumen score of 3.3 and thick albumen averaging 2.9 mm. in height.

Table 22.--Effect of Commercial Thermostabilization (7 Minutes at 130°F. Plus 7 Minutes at 136°F.) on the Albumen Score and Albumen Height of Shell Eggs. Eggs Stabilized at Clinton, Iowa, February 8, 1947, and Shipped by Railway Express to Columbia, Missouri, for Observation. 10 Egg Samples.

Time Held (Days)	Albumen Score		Albumen Height (mm.)	
	Thermostabilized	Controls	Thermostabilized	Controls
4	2.2	2.1	6.6	6.6
11	2.1	2.4	7.0	6.2
18	2.2	2.8	6.6	4.6
25	2.1	2.9	6.6	4.0
32	2.2	3.0	6.6	4.4
39	2.1	2.8	6.3	4.4
46	2.1	2.9	6.3	4.0
53	2.1	3.3	6.4	3.2
60	2.1	3.6	6.7	2.7
67	2.3	3.5	5.7	2.9
74	2.3	3.3	5.3	2.9

Table 23.--Observations on the Quality (Albumen Score) of Stabilized Eggs in the Channels of Trade (Retail Stores). Eggs Examined at Columbia, Missouri, March 29, 1949, for Albumen Score.

University of Missouri Eggs*		Commercial Lots Purchased in Retail Stores				
		New Orleans			Tampa, Fla.	
Natural Controls	Stabilized March 12	Stabilized	Grade A	Candled Current Receipts	Stabilized	Grade A
3.5	2.0	2.5	2.0	3.5	2.0	2.0
3.5	2.0	2.5	2.5	3.0	1.5	2.5
4.0	1.5	2.0	3.0	3.0	2.5	3.5
3.0	1.5	2.0	2.0	2.5	2.5	3.0
4.0	2.0	2.5	3.5	3.5	2.0	3.0
3.5	1.5	2.0	3.0	2.5	2.0	3.0
3.0	2.0	2.0	1.5	2.5	2.5	2.5
3.0	1.5	1.5	3.0	3.0	2.5	2.5
4.0	1.5	2.0	2.5	2.5	2.0	2.5
4.0	2.0	2.0	3.0	3.0	2.5	3.0
4.0	1.5	2.0	3.0	3.0	3.0	3.0
3.5	1.5	2.0	3.0	2.0	2.0	3.0
Avg. 3.58	1.70	2.08	2.66	2.83	2.25	2.79

* The University of Missouri eggs were produced on the University Poultry Farm March 11, 1949. They were transported to Tampa, Florida, and returned to Columbia, Missouri, by car. The commercial lots were purchased in grocery stores in Tampa and New Orleans.

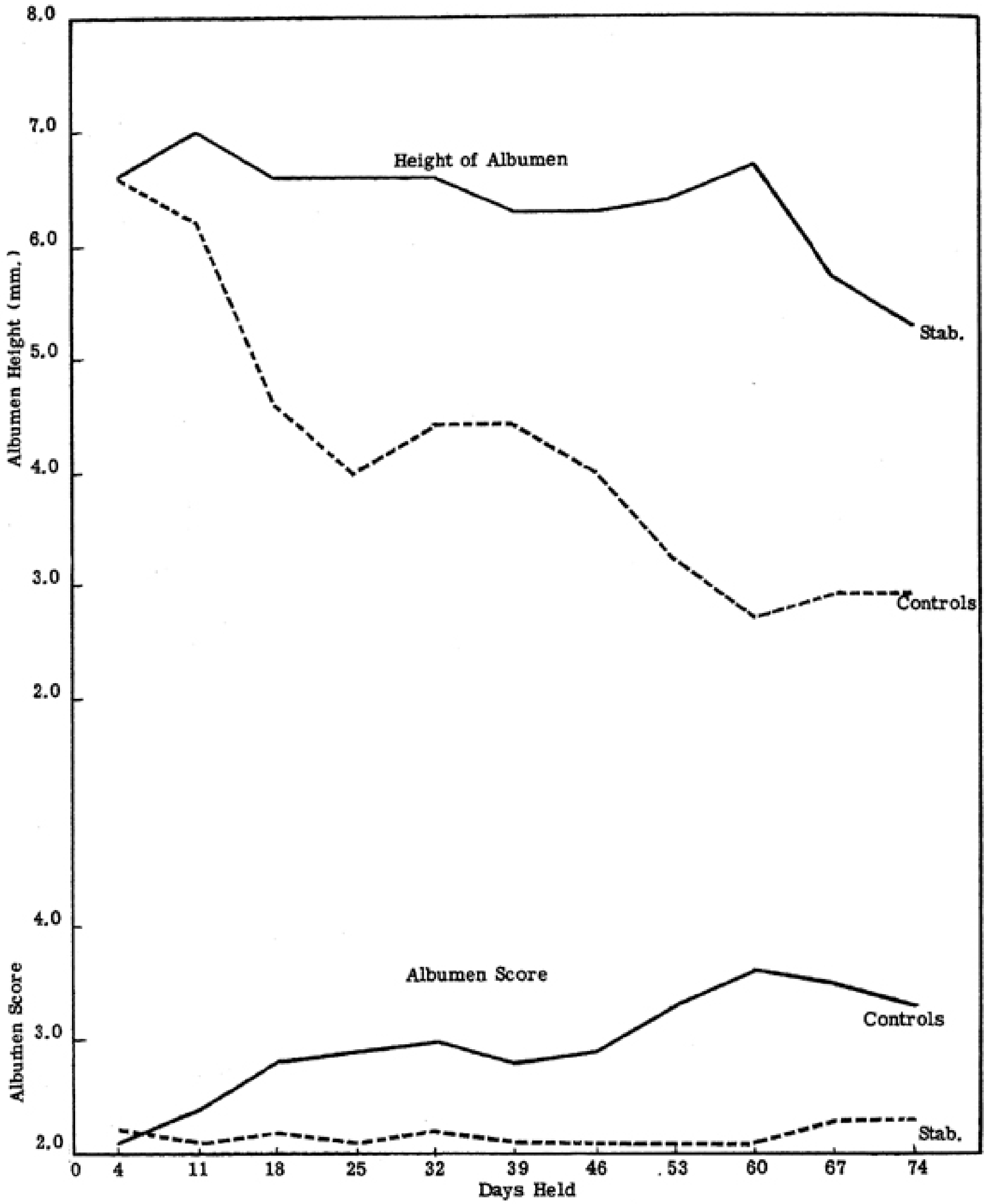

Figure 12.—The effect of commercial thermostabilization on maintaining albumen quality. See Table 22 for data.

Observations made (Table 23) of eggs transported and handled through the regular channels of trade showed that thermostabilization made possible a better quality egg for consumers. The very remarkable protection given high quality shell eggs by this process was shown by the albumen scores of the eggs transported by passenger car from Columbia, Missouri to Tampa, Florida and return. The stabilized eggs showed an average albumen score of 1.70 as compared to 3.58 for control eggs.

In another test made to determine the effectiveness of this process as used commercially (two-temperature, water method) on maintaining egg quality, eggs were thermostabilized at Beatrice, Nebraska by Swift & Company and shipped by railway express to Columbia, Missouri for observations and measurements. The results (Table 24) showed that the thick albumen was retained by the process but that the yolk condition (index or strength of vitelline membrane) was not affected. The results obtained with other lots shipped from Beatrice to Columbia are shown in Figures 13, 14 and 15.

Table 24.--Effect of Thermostabilization on Maintaining the Quality of Shell Eggs as Measured by the Albumen Height, Yolk Index, and Strength of the Vitelline Membrane. Eggs Stabilized by Swift and Co., at Beatrice, Nebraska, and Shipped to Columbia, Missouri, Arriving December 24, 1947. Held at Room Temperature. 10 Egg Samples.

	Albumen Height		Yolk Index		Strength of the Vitelline membrane. (Grams pressure per 10 square centimeters required to rupture this membrane.)	
Date Examined	Thermostabilized and Oil Processed	Natural Controls	Thermostabilized and Oil Processed	Natural Controls	Thermostabilized and Oil Processed	Natural Controls
Dec. 30	8.31	6.55	.493	.471	182	147
Jan. 6	7.40	4.94	.427	.402	162	129
Jan. 13	7.39	4.02	.413	.386	155	127
Jan. 20	6.33	3.70	.379	.361	147	138
Jan. 27	6.80	3.51	.388	.370	147	126
Feb. 3	6.39	3.26	.353	.334	125	115

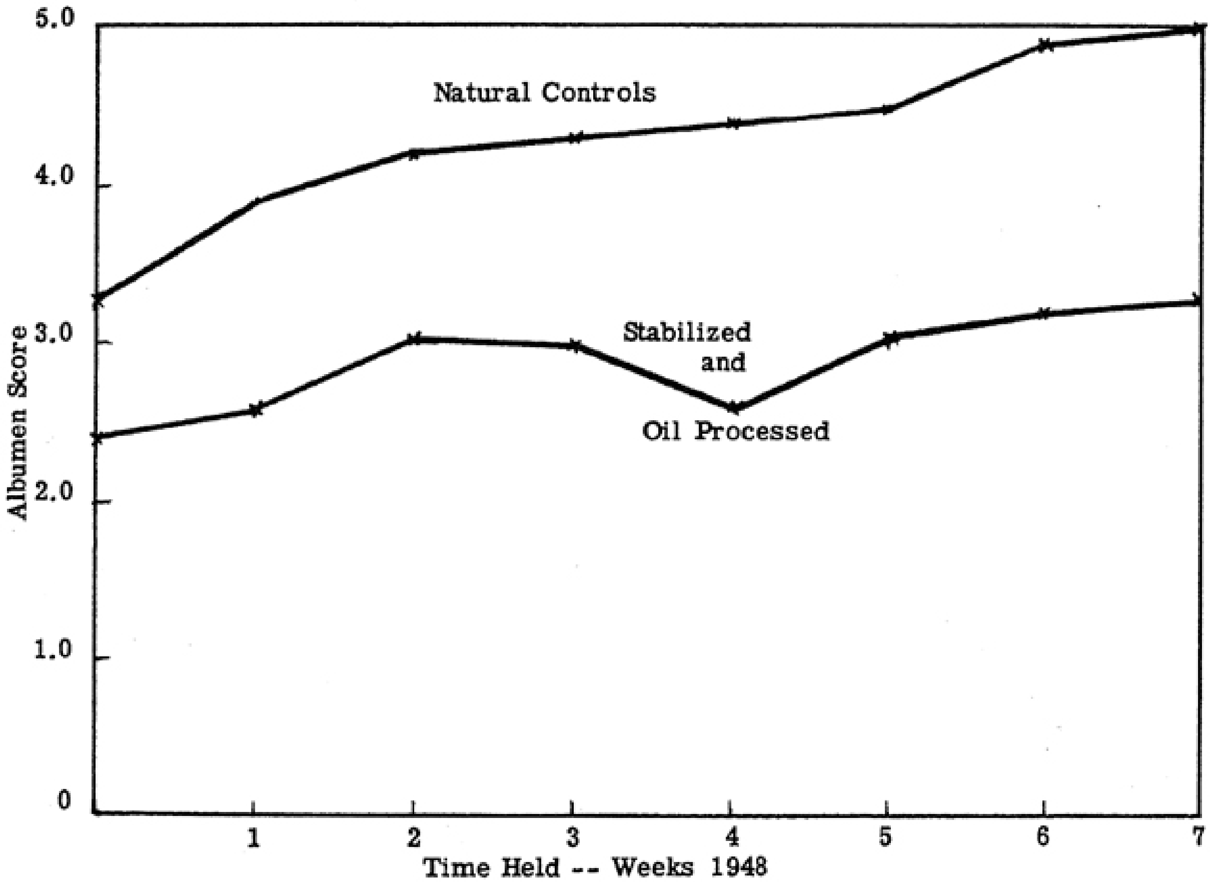

Figure 13.—Changes in the albumen score of eggs commercially thermostabilized at Beatrice, Nebraska, May 20, 1948. Shipped to Columbia, Missouri, and held at room temperature.

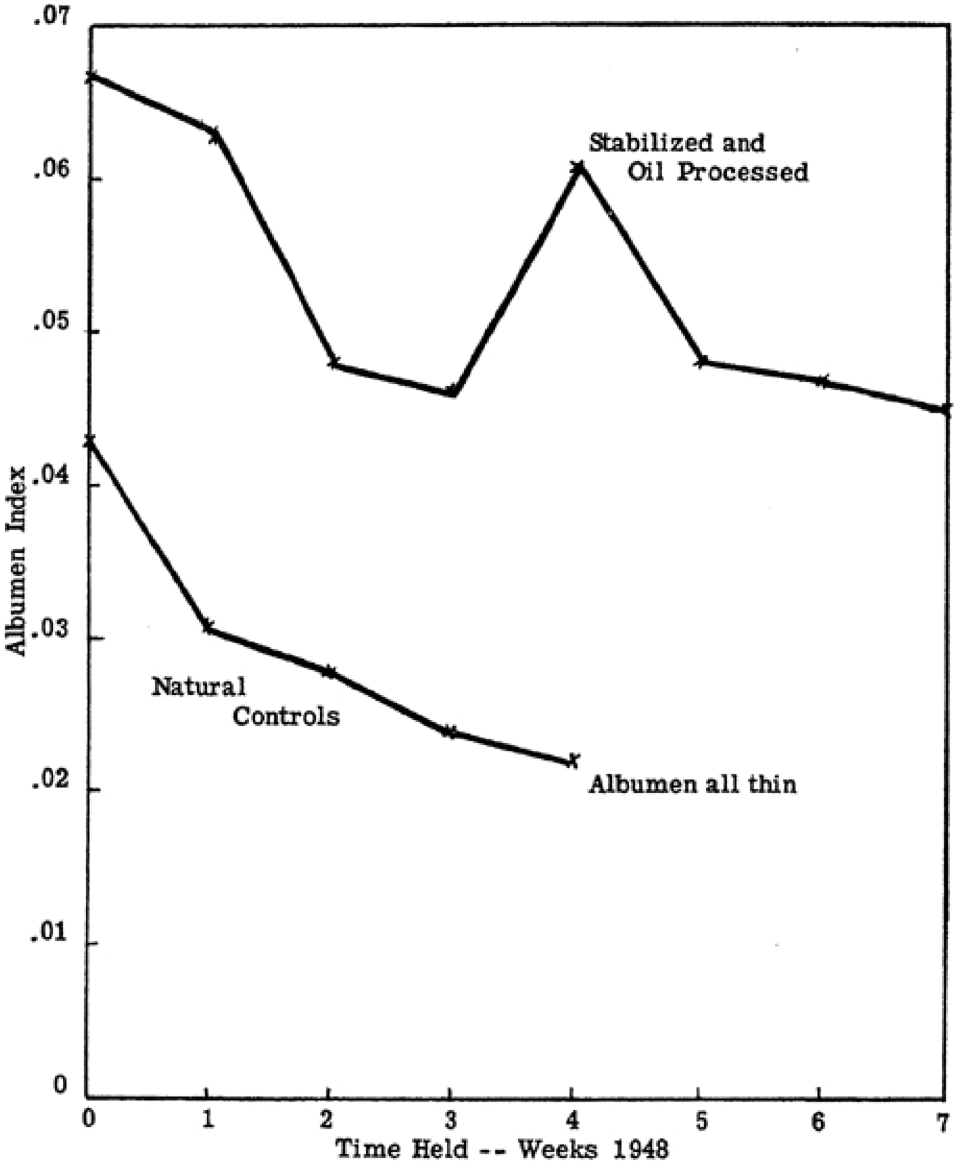

Figure 14.—Changes in the albumen index of eggs commercially thermostabilized at Beatrice, Nebraska, May 20, 1948. Shipped to Columbia, Missouri, and held at room temperature.

An additional test was made on eggs stabilized at Beatrice, Nebraska by shipping them to New Orleans and then returning them by railway Express to the University of Missouri for observation. The results (Table 25) showed that thick albumen was maintained remarkably well but that within one week after the eggs were received at Columbia, Missouri several inedible eggs were found in the stabilized eggs. These were stuck yolks, watery yolks and rots. From experiments conducted in our laboratory, it must be concluded that some eggs of low quality were used and that possibly they were not properly cooled after being stabilized.

In another and more extended test grade A and grade B eggs stabilized on the Johnson machine in Kansas City, Missouri, were shipped by railway express to Madison, Wisconsin for examination. The results

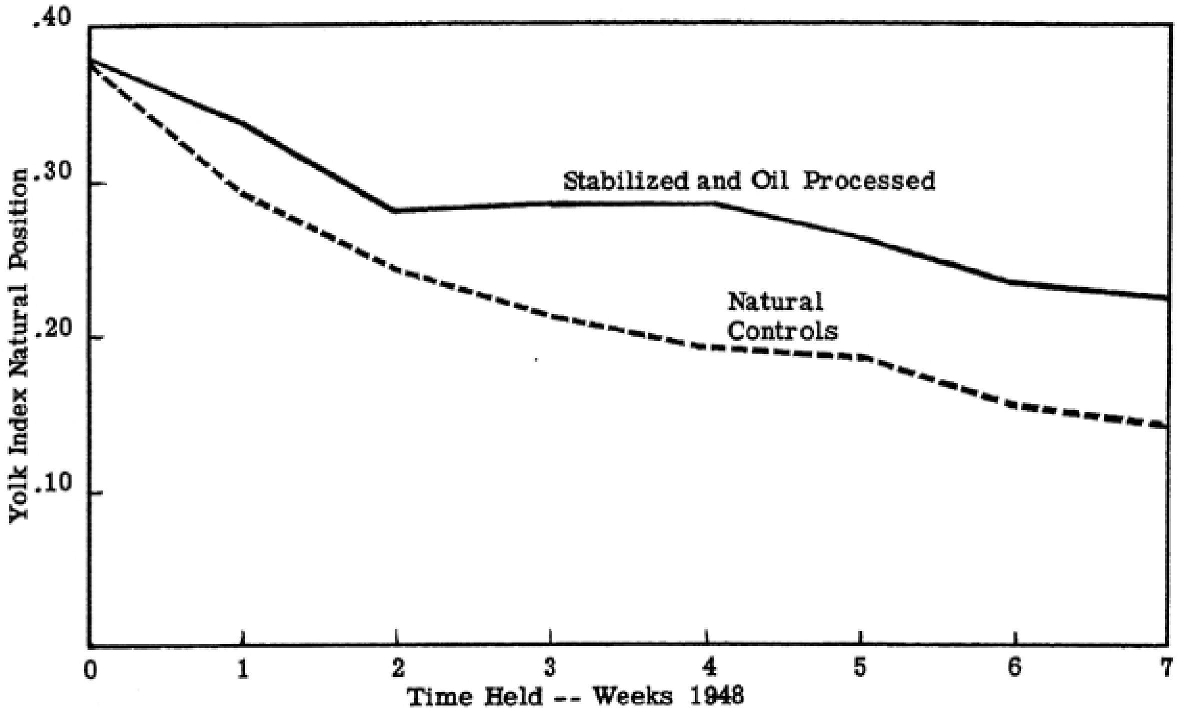

Figure 15.—Changes in the yolk index of eggs commercially thermostabilized at Beatrice, Nebraska, May 20, 1948. Shipped to Columbia, Missouri, and held at room temperature.

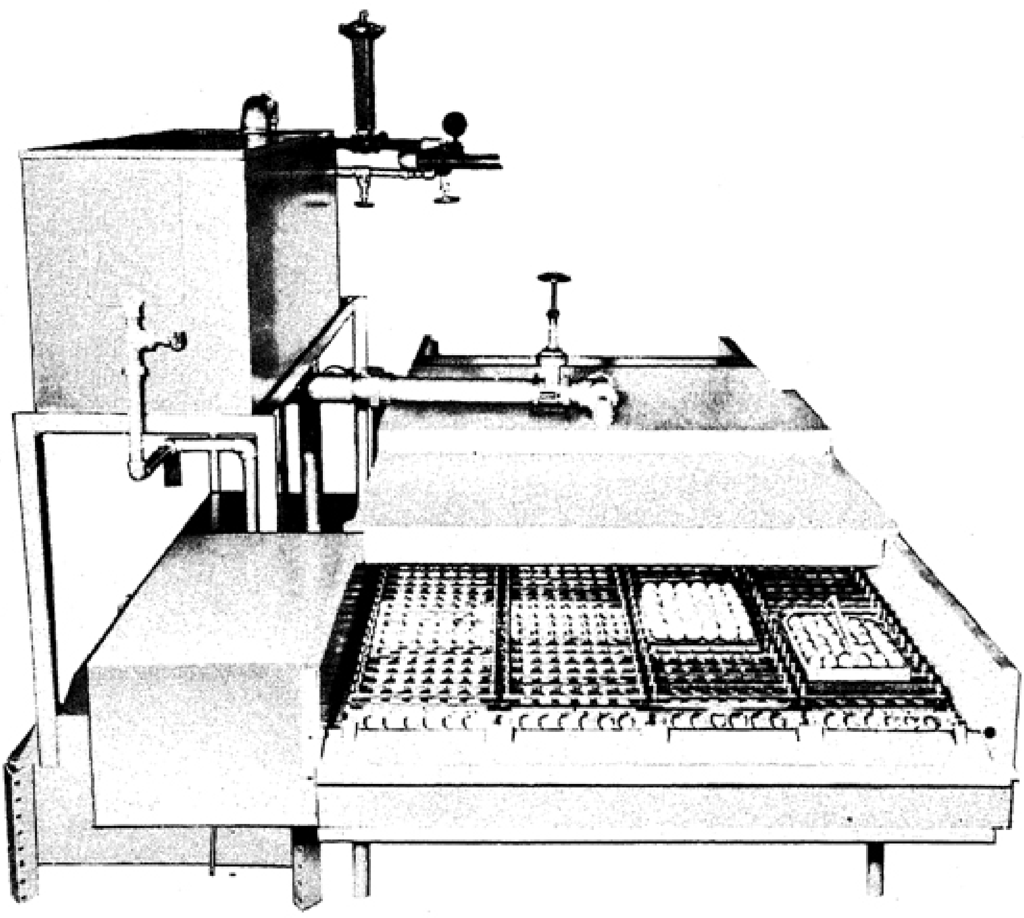

Figure 16.—Commercial machine for stabilizing eggs in oil. The oil, heated by steam coils, flows over the eggs as they are conveyed through the machine. Car-pro lifters are used for placing the eggs on the conveyors and for removing the eggs. (Courtesy, Gordon Johnson Company, Kansas City, Missouri.)

Table 25.--Effect of Commercial Thermostabilization on the Keeping Quality of Eggs. Eggs Shipped September 24, 1948, From Beatrice, Nebraska, to New Orleans by Rail (Carlot) and From New Orleans to Columbia, Missouri, by Express Arriving September 29. Held at Room Temperature (70°F.-80°F.) Thereafter. Lot A, Controls and Lot B, Stabilized.

Date Examined	No. Eggs	Albumen Score A	Albumen Score B	Ht. (mm.) of Albumen A	Ht. (mm.) of Albumen B	Albumen Index A	Albumen Index B	Inedible (%) A	Inedible (%) B
September 30	20	3.1	2.5	3.7	6.0	.0433	.0733	0	0
October 7	20	3.5	2.6	3.5	5.7	.0318	.0687	0	10
October 14	20	4.0	2.7	2.9	5.1	.0223	.0598	0	5
October 21	20	4.0	2.9	2.6	5.1	.0218	.0534	0	35
October 28	30	4.1	3.0	2.4	4.7	.0191	.0497	7	33
November 4	30	4.3	3.0	2.1	4.7	.0180	.0532	29	43

(Table 26) showed that grade A eggs thermostabilized on this machine retained their quality unusually well at 60° F. to 64° F. It was quite interesting that fewer stuck yolks developed in the stabilized lots and also fewer yolks in these lots were ruptured when the eggs were broken for examination. Only two watery yolks were found and these were in grade B stabilized eggs.

Table 26.--The Relation of Thermostabilization and the Original Candling Grade of Shell Eggs to the Subsequent Grade of Such Eggs Held at 60-64°F. Eggs Were Commercially Stabilized in Kansas City, Missouri, November 10, 1949, and Shipped by Express to Madison, Wisconsin, Where Observations Were Made.

Dates observed	Nov. 15			Nov. 22			Nov. 29			Dec. 6			Dec. 13			Jan. 3				
Candling grade	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	I*	S*
Grade A, stabilized in oil	79	7		76	10		63	22	1	57	27	2	53	28	2	36	37	10		
Grade A, natural	81	9		67	23		25	55	10	10	60	20	9	55	23	1	18	67	1	10
Grade B, stabilized in oil		89			75	14		60	27		57	28		56	29		43	41		
Grade B, natural		88			63	25		42	46		37	51		30	58		2	86		9

Dates observed	Jan. 10					Jan. 17					Jan. 18, Broken Out Condition					
Candling grade	A	B	C	I*	S*	A	B	C	I*	S*	Alb. Score	Ined.	Stuck Yolks	Rup't Yolks	Mottled Yolks	
Grade A, stabilized in oil	24	45	14			21	40	21	1		3.04	2	0	3	7	
Grade A, natural	1	16	68	2	13	1	8	76	2	24	4.78	3	10	15	3	
Grade B, stabilized in oil		31	53		1		25	57	2	2	3.73	1	6	6	21	2**
Grade B, natural		1	84	3	14		1	83	4	20	4.90	4	15	17	15	

* I (inedible eggs) and S (stuck yolks) observed by candling.
** Two eggs contained enlarged and watery yolks.

1950 Storage Experiments

The 1950 storage experiments were designed to test some theories with respect to the occurrence of stuck yolks; (1) the grade of eggs, (2) the time of storage, (3) cooling after thermostabilization, (4) oil processing, and (5) movement of eggs during stabilization.

Grade A and grade B eggs were purchased from an egg packing plant and prepared for storage February 8, 15, 22, April 12, 19, 26 and June 14, 21, 28 and 29. These eggs were all held until October 10-13, 1950, when they were removed from storage, and broken for inspection.

Lots were cooled soon after thermostabilization for comparison with eggs held for 12 hours at 100° F. after thermostabilization before casing. Oil processed lots were prepared for comparison with natural eggs. Eggs were stabilized while in motion while others were stabilized without movement.

Summaries of the results of these storage tests are presented in Tables 27 and 28.

Comparison of Grade A and Grade B Eggs.—Under the conditions of this experiment the incidence of stuck yolks was not greater in grade B than in grade A eggs; the respective percentages of stuck yolks being 0.52 per cent and 0.50 per cent.

Previous tests (Table 18) showed that the incidence of stuck yolks may be much higher in grade B than in grade A eggs. But the conditions which prevailed there were different in that they were more prolonged and more severe.

Time of Storage.—The results obtained this year with eggs stored in February, April and June which were removed from storage in October did not reveal any significant differences in stuck yolks. However, it should be noted that the June eggs were in storage approximately two months less than the April eggs and four months less than the February eggs.

Cooling vs. Casing Eggs Warm.—To test the effect of keeping eggs warm after stabilization on the occurrence of stuck yolks, lots of eggs were cooled immediately after being stabilized, other lots were cased warm, while others were held at 100° F. and then cased. Previous work had shown that eggs kept warm for 24 hours (Tables 13 and 18) before casing developed more stuck yolks than eggs cooled soon after stabilization. These (1950) tests did not reveal any difference in the incidence of stuck yolks in eggs held at 100° F. for 12 hours before casing as compared to eggs cooled immediately after stabilizing and then cased; the respective percentages of stuck yolks being for grade A eggs 0.52 per cent and 0.89 per cent, and for grade B eggs 0.82 per cent and 0.37. These percentages are quite small and the differences insignificant. However, when compared to no stuck yolks in 2988 eggs stored in lots A4a and B4a (natural eggs) it again becomes evident that this process does increase stuck yolks but they may be held to a very low incidence.

Oil Processing.—To test the effect of oil processing on the occurrence of stuck yolks lots of similar eggs were oil processed for comparison with natural eggs (lot 4a, natural eggs and lot 4b, oil processed). In the grade A eggs no stuck yolks were found in the natural eggs and 9 stuck yolks in the oil processed eggs; each lot consisting of 1848 eggs. In the grade B eggs no stuck yolks were found in 1140 natural eggs and 10 stuck yolks occurred in 1158 oil processed eggs. Under the conditions which prevailed in this experiment oil processing increased the incidence of stuck yolks in both grade A and grade B eggs.

Movement of Eggs During Stabilization.—Some preliminary tests suggested that eggs kept in motion during stabilization developed fewer stuck yolks than eggs stabilized in a stationary position. Eggs of similar quali-

Table 27.--Summary of 1950 Egg Storage Experiments in Which Grade A Eggs Were Used. Eggs Stored in February, April, and June. All Eggs Removed From Storage October 10-13, 1950, and Broken for Inspection.

Lot	Treatment	No. Eggs	Loss Found By: Can-dling	Mold	Green	Sour	Rots	Stuck	Musty	Total Loss: No.	Per Cent
A1a	stabilized in circulating oil (15 x 130°F.), and cased at room temperature.	1675	0		2		2	14		18	1.07
A1b	stabilized in oil (15 x 130°F.), eggs in motion; cased at room temperature.	1692	0		1			16		17	1.00
A2a	stabilized in circulating oil (15 x 130°F.), cooled at 32°F. 12 hours before casing.	1692	0			2	1	11		14	.83
A2b	stabilized in oil (15 x 130°F.), eggs in motion; cooled at 32°F. 12 hours before casing	1692	2		3	1		9		15	.89
A3a	stabilized in circulating oil (15 x 130°F.), and held 12 hours at 100°F. before casing	1837	1		5	1	1	11		19	1.03
A3b	stabilized in oil (15 x 130°F.), eggs in motion; held 12 hours at 100°F.	1834	1		3	2	1	8		15	.82
A4a	natural eggs not oiled	1848	2		1		2	0		5	.27
A4b	natural eggs oiled	1848	9	2		3	9	9		32	1.73
A5	soiled eggs washed with an egg-washing machine.	3695	26		80	16	16	6	4	147	3.98
A6	soiled eggs washed with an egg-washing machine, and stabilized in water (15 x 130°F.)	3581	10	1	9	0	6	22	0	47	1.31
	Totals	21,394	51	3	104	25	38	106	4	329	
	Percent Loss		.24	.01	.49	.12	.18	.50	.02	1.54	

Table 28.--Summary of 1950 Egg Storage Experiments in Which Grade B Eggs Were Used. Eggs Stored in February, April, and June. All Eggs Removed From Storage October 10-13, 1950, and Broken for Inspection.

Lot	Treatment	No. Eggs	Loss Found By: Can-dling	Mold	Green	Sour	Rots	Stuck	Musty	Total Loss: No.	Per Cent
B1a	stabilized in circulating oil (15 x 130°F.), and cased at room temperature.	1344	1			1	1	5		8	.59
B1b	stabilized in oil (15 x 130°F.), eggs in motion; cased at room temperature.	1344	4		2		6	5	1	18	1.34
B2a	stabilized in circulating oil (15 x 130°F.), and cooled at 32°F. 12 hours before casing.	1340	2				1	10		13	.97
B2b	stabilized in oil (15 x 130°F.), eggs in motion; cooled at 32°F. for 12 hours before casing.	1342	4		1		1	4		10	.75
B3a	stabilized in circulating oil (15 x 130°F.), and held 12 hours at 100°F. before casing.	1344	0		5		2	11		18	1.34
B3b	stabilized in oil (15 x 130°F.), eggs in motion; held 12 hours at 100°F. before casing.	1344	1		2			11		14	1.04
B4a	natural eggs not oiled.	1140	2		1		2	0		5	.44
B4b	natural eggs oiled.	1158	7		1	2	5	10		25	2.16
B5	soiled eggs washed with egg washing machine.	2780	47		66	5	16	7	6	147	5.29
B6	soiled eggs washed with an egg washing machine, and stabilized in water (15 x 130°F.).	2779	7		2	1	1	19	0	30	1.08
	Totals	15,915	75		80	9	35	82	7	288	
	Percent Loss		.47		.50	.06	.22	.52	.04	1.81	

ties were divided into two lots; one lot being kept in constant motion while being stabilized while the other lot remained stationary with the oil being circulated around the eggs. The results of these tests were as follows:

	Stuck Yolks found in Eggs			
	Stationary		In Motion	
Grade	No. Eggs	No. Stuck Yolks	No. Eggs	No Stuck Yolks
B	1344	5	1344	5
	1340	10	1342	2
	1344	11	1344	11
A	1675	14	1692	16
	1692	9	1692	11
	1837	11	1834	8
Total	9232	60	9248	53

Minimizing Storage Loss by Thermostabilization.—Previous work showed losses in shell eggs held in cold storage could be reduced by thermostabilization, especially, if the eggs had been previously exposed to excessive contamination. Another test of this effect was made in this experiment by washing soiled eggs with an egg washing machine in water held at about 100° F. and containing Kleneg (a commercial germicidal compound used for cleaning soiled eggs). The results were as follows:

		Average Storage Loss	
	No. Eggs	No.	Per Cent
Grade A soiled eggs washed	3695	147	3.98
Grade A soiled eggs washed and Thermostabilized	3581	47	1.31
Grade B soiled eggs washed	2780	147	5.29
Grade B soiled eggs washed and Thermostabilized	2779	30	1.08

These results again demonstrated the pasteurizing effect of this process.

It was interesting to observe the kind of loss found on breaking these eggs which was as follows:

Lot	Kind of Loss Found on Breaking						
	No. Eggs	Mold	Green Whites	Sour	Other Rots	Stuck	Musty
A 5 Grade A soiled eggs washed	3965	0	80	16	16	6	4
A 6 Grade A soiled eggs washed and stabilized	3581	1	9	0	6	22	0
B 5 Grade B soiled eggs washed	2780	0	66	5	16	7	6
B 6 Grade B soiled eggs washed and stabilized	2770	0	2	1	1	19	0

Green whites, sour eggs, musty eggs and other rots were very greatly reduced but stuck yolks were increased by thermostabilization.

CONCLUSIONS

Thermostabilization as a process for maintaining egg quality has very definite merit but there are some disadvantages to the process.

The process devitalizes fertile eggs, stabilizes the thick albumen and pasteurizes shell eggs. Fertile eggs reacted as infertile eggs after thermostabilization. The thick albumen was retained remarkably well in thermostabilized eggs. Pasteurization was accomplished as evidenced by the reduction in spoilage of shell eggs in storage caused by microorganisms.

The process can be used to supply consumers with eggs showing more of their fresh-laid condition than eggs which have not been thermostabilized.

The disadvantages found for this process were:

1. The albumen of thermostabilized eggs required more time for whipping and the volume of foam was reduced.

2. The incidence of stuck yolks was increased by the process.

By using high quality eggs and reasonable cooling and handling the process can be used throughout the year to give the consumer a better quality egg. Lower grade eggs, especially during hot weather, if not properly cooled may cause trouble (stuck yolks and spoilage).

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