Treating Shell Eggs To Maintain Quality

NORTH CENTRAL REGIONAL PUBLICATION NO. 62

Agricultural Experiment Stations of Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin and U. S. Department of Agriculture, cooperating.

UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION

J. H. LONGWELL, *Director*

BULLETIN 659 COLUMBIA, MISSOURI AUGUST, 1955

NORTH CENTRAL REGIONAL COMMITTEE ON POULTRY PRODUCTS TECHNOLOGY RESEARCH

Cooperating Stations and Representatives

Indiana	William J. Stadelman
Illinois	L. E. Card
Iowa	Frances Carlin
	Owen Cotterill
Kansas	R. E. Clegg
Michigan	L. E. Dawson
Minnesota	M. H. Swanson
Missouri	E. M. Funk
Nebraska	R. E. Feeney
North Dakota	R. L. Bryant
Ohio	A. R. Winter
South Dakota	C. W. Carlson
Wisconsin	D. L. Hussemann

U. S. Department of Agriculture Representatives
Bureau of Animal Industry

A. W. Brant
E. H. McNally

Administrative Adviser

Sam B. Shirky, Associate Director,
Missouri Agricultural Experiment Station
(George F. Stewart, Ia., Former Administrative Adviser)

publication assembled and prepared by
E. M. Funk
University of Missouri

FOREWORD

The North Central Region produces annually very large quantities of eggs and poultry meat. Maintenance of quality of poultry products during the time they are in market channels is of utmost importance to both consumers and producers.

The North Central Region has designed a project to study the causes of deterioration in quality of eggs and poultry while they are in market channels; and to discover methods by which such losses can be eliminated or reduced.

This project is entitled NCM-7 "Minimizing Quality Losses in Shell Eggs and Dressed Poultry in Market Channels". It has been financed from funds made available by Section 9b3 of the Bankhead-Jones Act, by funds supplied by the various state agricultural experiment stations, and by funds of the United States Department of Agriculture.

The results reported in this publication "Treating Shell Eggs to Maintain Quality" are based on work conducted at a number of state agricultural experiment stations in the North Central Region and by the United States Department of Agriculture. The data were assembled and coordinated by Professor E. M. Funk and this report is published by the Missouri Agricultural Experiment Station as a regional bulletin.

Sam B. Shirky
Administrative Adviser

TABLE OF CONTENTS

Treating Shell Eggs To Maintain Quality

A major problem of the poultry industry is that of maintaining the quality of shell eggs while in the channels of trade, from the time of production until the eggs are consumed. The chemical, physical, and biological nature of the egg makes this a problem that requires the attention of all handlers. There are methods, processes, and treatments that help maintain the keeping quality of shell eggs while in market channels.

A study of changes in egg quality made by the North Central Poultry Marketing Research Committee, (NCM-6) and reported as North Central Regional Publication 15 (Mich. Spec. Bul. 361) showed that one-third of the eggs examined in this region were below Grade A when received at the first buying station. There was a further decline of 13.1 percent by the time the eggs reached the central plant. Projecting these data to the consumer it is evident that less than one-half of such eggs are of Grade A quality when they reach the consumer.

Processes for Minimizing Losses in Quality

Processes or treatments that minimize the decline in egg quality are of value to the poultry industry. The following methods have been developed.

By Proper Cleaning

Soiled eggs should be cleaned before they are offered to the consumer or before they are used for breaking stock. North Central Regional Publication No. 41 (Missouri Agri. Exp. Sta. Bulletin 607) discussed the problems involved in cleaning soiled shell eggs and made recommendations as to the best procedures to follow in cleaning soiled shell eggs for current use.

In 1953 Forsythe, Ayres, and Radlo reported that the bacterial count of the shell surface and the contents of the egg was greatly reduced by washing dirty eggs. Winter et al., 1955, reported similar results. (See Table 1)

Soiled shell eggs can be cleaned sufficiently to present, under natural light, as pleasing an appearance as naturally clean eggs. The Missouri Station (1954) reported a process whereby stains could be removed from white-shelled eggs by dipping the eggs in a warm water solution containing 0.5 percent of sodium perborate. See Figure 1.

Soiled eggs that have been surface cleaned either by buffing or washing and then stored may show heavy losses unless they are pasteurized. Table 2 shows what happens when eggs are stored that have been cleaned by different methods. These results are typical of many other trials made at the Missouri Station. They show that dry-cleaned eggs will not keep satisfactorily in storage. They also show that washing with detergents and germicides does not protect eggs against spoilage in all cases. Surface cleaning, alone,

TABLE 1 -- BACTERIA ON EGG SHELLS AND IN EGG MEATS (WINTER, 1955)
Ohio Agricultural Experiment Station

Product and treatment	No. of trials	Bacteria (thousands) Average	High	Low
Clean eggs (per shell)				
Not washed	3	87	117	52
Washed in cold water	3	36	43	27
Egg meats from clean eggs				
Not washed (per gram)	2	0.1	0.2	0.0
Soiled eggs (per shell)				
Not washed	2	2063	2162	1965
Washed in detergent sanitizer (200 p.p.m.)	2	272	293	15
Egg meats from soiled eggs (per gram)				
Not washed	3	12.7	22.4	1.0
Washed in detergent sanitizer (200 p.p.m.)	3	1.3	3.3	0.2

TABLE 2 -- A COMPARISON OF THERMOSTABILIZATION WITH OTHER PROCESSES OF CLEANING ON THE KEEPING QUALITY OF SHELL EGGS IN STORAGE.*
Missouri Agricultural Experiment Station

Lot	Kind of Eggs and Treatment	No. Eggs	Percentage of Loss Found by Breaking: By Candl-ing	Green Whites	Sour	Other Rots	Stuck	Musty	Total	Stuck Yolks Not Loss %
A	Clean, Controls	274	0	.36					.36	
B	Soiled Eggs	323	.93	3.09		.31			4.33	.93
C	Soiled Eggs washed in tap water (59° F.) containing quaternary and a detergent.	288	2.78	8.33		1.04			12.15	
D	Soiled eggs washed in tap water (64° F.) containing detergent.	324	9.26	10.49	5.25	14.20			39.20	
E	Soiled Eggs dry cleaned.	313	1.28	3.84	.32	1.28			6.72	
F	Soiled Eggs washed in a spray type machine water 166° F.	324	3.40	6.17		1.54			11.11	.31
G	Same as D plus immersion for 5 minutes in water at 140° F.	324	0	.31					.31	
H	Same as D plus immersion for 3 minutes in water at 145° F.	324	.62	2.16		.31			3.09	2.47
I	Same as D plus immersion for 5 minutes in oil at 144-138° F.	288	2.08						2.08	1.92
J	Same as D plus immersion for 15 minutes in water at 130° F.	324	0	.31	.31	.31	.31		1.24	1.54

*Eggs stored from April 16, 1952, to October 29, 1952. Egg temperature before cleaning, 70° F.

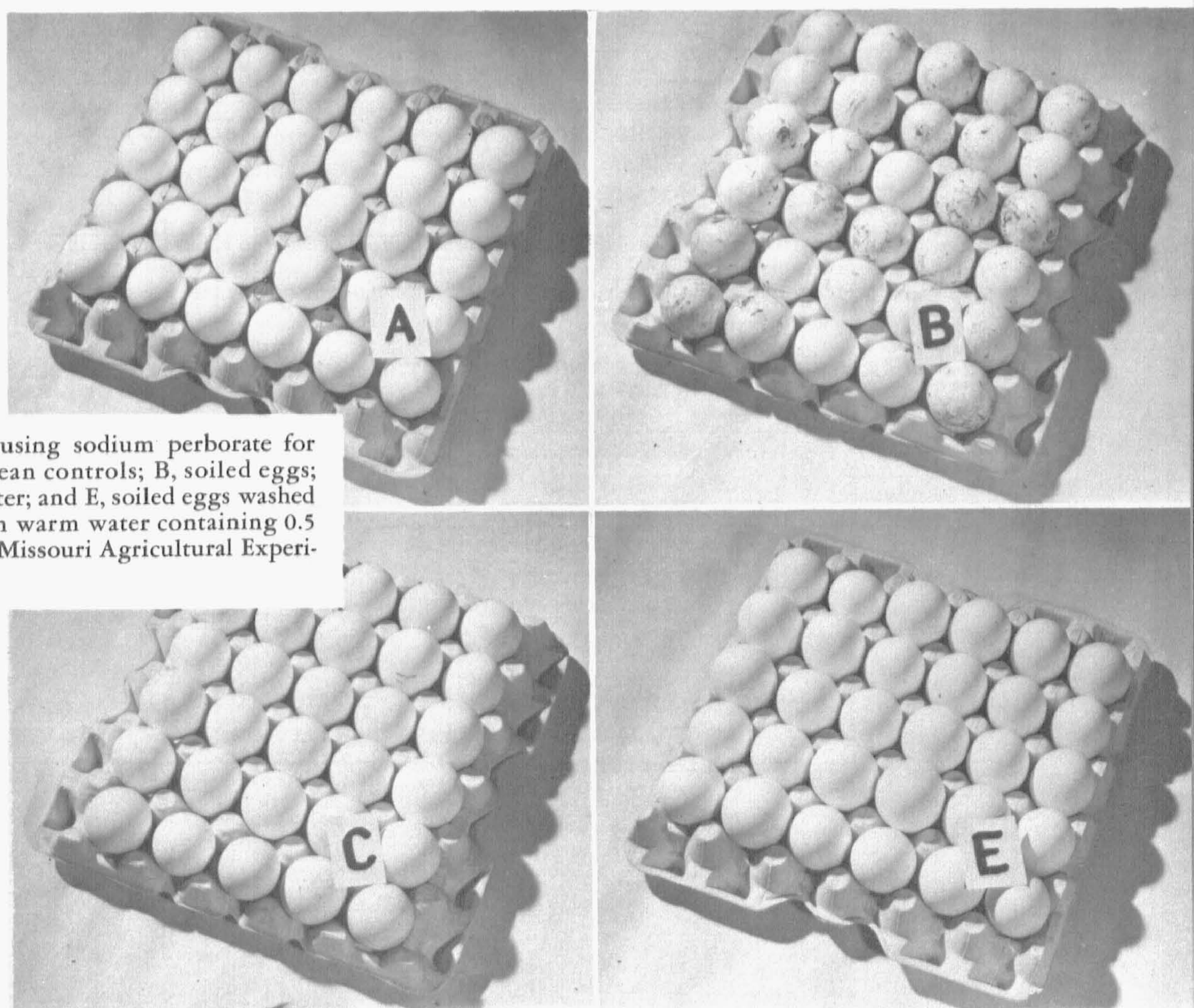


Fig. 1—The effect of using sodium perborate for cleaning soiled eggs. A, clean controls; B, soiled eggs; C, soiled eggs washed in water; and E, soiled eggs washed in water and then dipped in warm water containing 0.5 percent sodium perborate. (Missouri Agricultural Experiment Station.)

cannot protect an egg if the bacteria have already penetrated the shell and such penetration occurs in many soiled eggs either before cleaning or during the cleaning process.

By Sealing the Shell

The common method for partially sealing an egg shell is by oil processing. Such sealing reduces evaporation and otherwise helps maintain egg quality. This practice is commonly used for shell eggs intended for storage. It also has merit for eggs being marketed through the current channels of trade.

Mallman and Davidson (1944) proposed the following treatment for eggs on the farm: "Eggs approximately 24 hours old are dipped into a light paraffin oil (Eureka white oil-viscosity 50 to 60) containing 0.25 percent penta chloro phenol at the prevailing environmental temperature, preferably 70° F." They also reported that dirty eggs could be washed without endangering their keeping quality, provided the eggs were dried and immediately dipped in the oil.

Winter and Cotterill (1949) reported that dipping eggs on the farm in oil held at 55° F., 70° F., 100° F., 130° F. and 160° F. protected such eggs against decline in grade, compared to unoiled eggs. They recommended dipping eggs on the farm, within 24 hours after laying, in egg processing oil held at 55° F. to 70° F.

Data obtained by Carlin and co-workers on the effect of oil processing and thermostabilization on loss of weight in shell eggs stored at different temperatures are shown in Tables 3 and 4 and in Figure 2. The oil used had a Saybolt viscosity at 100° F. of 65-75, Carnation Oil BT-90.

Two studies were conducted to determine weight loss in eggs stored at 34° F. In one experiment all the eggs were stored at 34° F., removed from storage and

TABLE 3 -- EFFECT OF OIL PROCESSING AND HEAT TREATMENT ON WEIGHT LOSS IN SHELL EGGS STORED AT 34° F. FOR SPECIFIED PERIODS
Iowa Agricultural Experiment Station

Storage Time Weeks	Untreated A*	Untreated B**	Oiled A	Oiled B	Thermostabilized in oil A	Thermostabilized in oil B	Thermostabilized in water A	Thermostabilized in water B
	%	%	%	%	%	%	%	%
1	0.7	----	0.4	---	0.4	---	1.1	----
4	1.4	0.8	0.4	0.3	0.3	0.3	1.9	1.3
8	2.6	----	0.6	---	0.5	---	3.4	----
12	3.7	----	0.7	---	0.3	---	4.2	----
16	5.3	----	1.5	---	0.9	---	6.0	----
20	6.7	----	1.8	---	1.4	---	6.7	----
24	7.8	----	2.5	---	1.7	---	8.1	----
26	----	7.1	---	1.5	---	1.2	----	8.0
28	8.9	----	2.8	---	2.1	---	9.2	----
30	----	8.1	---	1.4	---	1.4	----	10.2
32	10.3	----	3.9	---	2.6	---	10.5	----
35	11.3	9.3	4.4	1.7	2.9	1.5	11.5	----
37	----	10.2	---	1.6	---	1.2	----	11.3

* Three dozen of each treatment were removed from storage, brought to room temperature, weighed, and then returned to storage each month.

** Eggs removed from storage, weighed, and then broken for interior quality measurements.

TABLE 4 -- EFFECT OF OIL PROCESSING AND HEAT TREATMENT ON WEIGHT LOSS IN SHELL EGGS STORED AT 50° F. AND AT 70° F. FOR SPECIFIED PERIODS
Iowa Agricultural Experiment Station

Storage Time Weeks	Weight Loss: Untreated 50° F.	Untreated 70° F.	Oiled 50° F.	Oiled 70° F.	Thermostabilized in Oil 50° F.	Thermostabilized in Oil 70° F.
	%	%	%	%	%	%
0	----	----	0.13*	0.05*	0.50*	0.51*
1	0.93	1.55	0.02	0.11	0.37	0.16
2	1.84	3.45	0.12	0.42	0.29	0.46
3	----	5.20	----	0.50	----	0.37
4	3.20	6.40	0.25	0.70	0.31	0.63
5	----	7.86	----	0.99	----	0.90
6	4.57	----	0.33	----	0.54	----
7	----	----	----	----	----	----
8	6.43	----	0.68	----	0.64	----

*Weight loss during treatment.

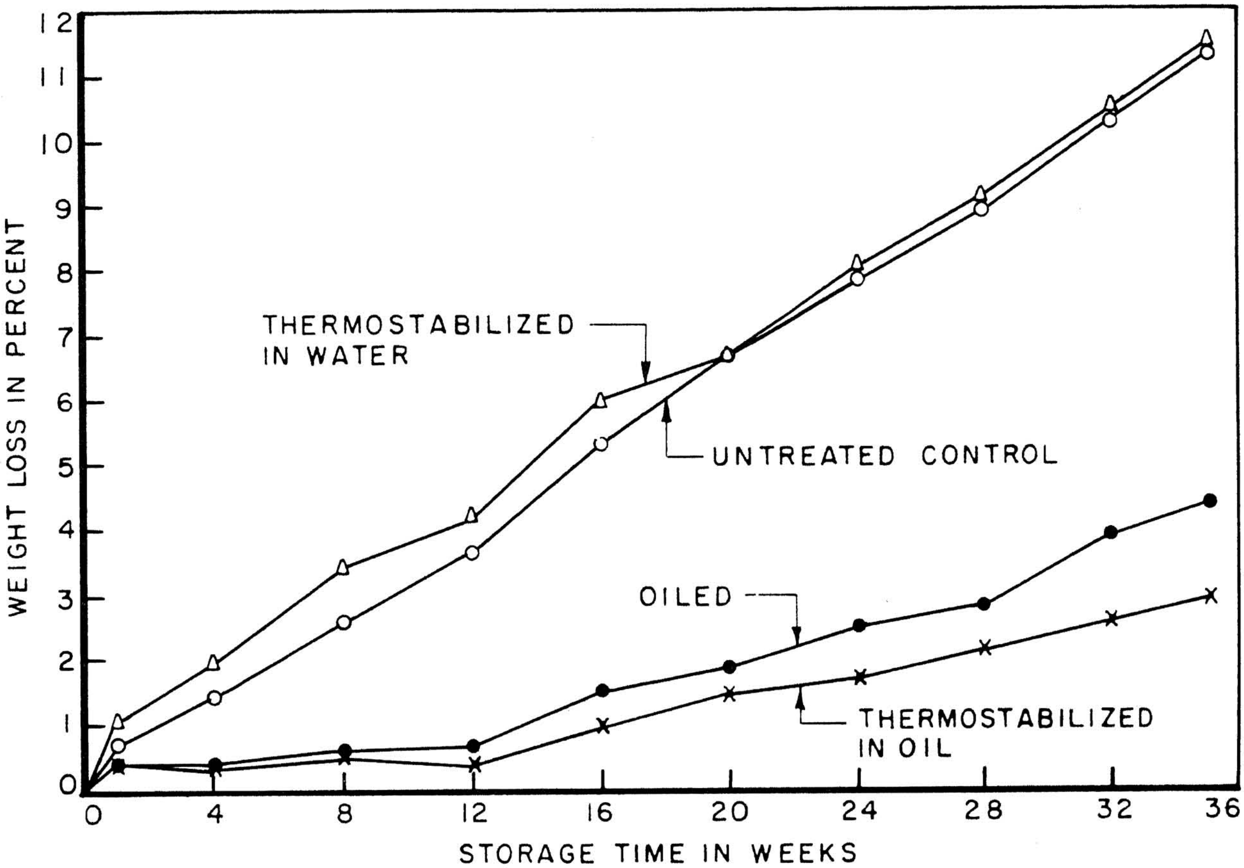


Fig. 2—Cumulative weight loss, in percent, on treated and untreated eggs stored at 34° F. and determined at 4-week intervals. (Iowa Agricultural Experiment Station.)

brought to room temperature and weighed. Then the eggs were put back into storage and the weighing procedure was repeated each month. An examination of these data (Table 3, column A) reveals that under conditions in which eggs are subjected to repeated cooling and warming, thermostabilization in oil is most effective (3%) in preventing weight loss and oiling is next (4%) in efficiency. Both untreated eggs and those thermostabilized in water lost approximately 11 percent of their original weight after 8 months storage. However, when eggs are stored at 34° F. for 8 months and then removed from storage and used immediately, oiling and thermostabilization in oil are equally effective in holding moisture losses to 1.5 percent as compared with 10 to 11 percent for untreated eggs or eggs thermostabilized in water (Table 3, column B). In addition, oil processing and thermostabilization in oil appeared to be equally effective in preventing weight losses in eggs stored at 50° F. and at 70° F. (Table 4). Treated eggs lost less than 1 percent of their original weight, whereas untreated eggs lost 6 to 7 percent after storage for 8 weeks at 50° F.

Evidence obtained at the Iowa Agricultural Experiment Station indicates that eggs processed in oil may develop more off-flavor than untreated eggs when both are stored for 6 months or longer at 34° F. The results of organoleptic tests that were conducted by Carlin and co-workers to determine the effect of shell treatment on the flavor of stored eggs are presented in Tables 6, 7, 8, and 9. Foss and Carlin (1954) reported indications of slight off-flavor in oiled eggs stored for 5 months in egg cartons at 34° F. and definite off-flavors in oiled eggs stored 6 months. (Tables 6, 7, column 1). In later experiments by Carlin and Hansuld, eggs were stored in egg cases at 34° F. and detection of definite off-flavors was not obtained in the oil treated eggs until they had been stored 7 months or longer. (Tables 6, 7, column 2). Another study by these same workers in which the eggs were stored for 6 months at 34° F. in different types of containers confirmed the results obtained previously, showing that oiled eggs developed more off-flavor than untreated eggs during cold storage, and that it appeared sooner in eggs stored in one dozen cartons than in 30 dozen cases (Table 8).

TABLE 5 -- THE EFFECT OF OIL PROCESSING AND HEAT TREATMENTS ON EVAPORATION IN SHELL EGGS.*
Missouri Agricultural Experiment Station

Lot	Treatment	Loss in Weight (%). Ten Egg Samples: Range	Average	Percentage of the loss in controls
A.	Controls	3.32-6.16	4.86	100.0
B.	Immersed for 10 Seconds in Egg Processing Oil Held at 130° F.	0.58-3.24	1.67	34.4
C.	Same as B at 70° F.	0.29-2.43	0.65	13.4
D.	Immersed for 5 Seconds in Water Held at 212° F.	3.96-5.61	4.67	96.1
E.	Immersed for 10 Seconds in Water Held at 212° F.	4.08-5.66	4.72	97.1
F.	Immersed for 15 Seconds in Water Held at 212° F.	3.20-5.27	4.39	90.2
G.	Immersed for 15 Minutes in Water Held at 130° F.	4.39-6.30	5.00	102.7
H.	Immersed for 15 Minutes in Egg Processing Oil Held at 130° F.	0.23-0.92	0.37	7.5
I.	Dipped in Vinegar and Then Immersed for 15 Minutes in Water (130° F.) containing Sodium Metasilicate (5 oz. in 15 gal. water).	2.67-5.63	4.84	99.5

*Eggs held 10 days at room temperature after laying and treatment. White Leghorn eggs laid March 6, 1954.

TABLE 6 -- AVERAGE SCORES* FOR FLAVOR OF SCRAMBLED EGGS MADE WITH UNTREATED AND TREATED EGGS STORED AT 34° F. FOR SPECIFIED PERIODS
Iowa Agricultural Experiment Station

Storage Time	Untreated		Oiled		Thermo-oil		Thermo-water	
	I	II	I	II	I	II	I	II
Months								
1	8.9	8.6	8.8	8.3	9.2	9.1	---	8.4
2	8.8	---	8.1	---	8.4	---	---	---
3	8.0	---	7.2	---	7.6	---	---	---
4	7.8	---	6.6	---	6.7	---	---	---
5	6.5	---	5.7	---	6.0	---	---	---
6	6.2	7.8	4.5	7.5	5.5	7.5	---	7.5
7	6.3	6.8	4.8	4.3	4.9	5.8	---	6.8
8	5.6	5.6	4.2	---	4.1	4.5	---	4.5
8 1/2	---	5.1	---	3.6	---	4.2	---	---

* For six judges with at least six replications. A score of 10 was most desirable.
I = Summer eggs put in storage every week from May 14 to July 17, 1953.
II = Spring eggs put in storage on March 31 and April 22, 1954.

TABLE 7 -- AVERAGE SCORES OF SIX JUDGES FOR FLAVOR OF SOFT-COOKED YOLKS AND WHITES OF UNTREATED AND TREATED EGGS STORED AT 34° F. FOR SPECIFIED PERIODS
Iowa Agricultural Experiment Station

Storage Time		Untreated		Oiled		Thermo-oil		Thermo-water	
		I	II	I	II	I	II	I	II
Months									
1	yolks	8.9	9.0	8.5	8.5	9.0	8.6	---	---
	whites	9.3	9.3	7.5	8.9	8.3	8.6	---	---
2	yolks	9.0	---	9.2	---	8.8	---	---	---
	whites	9.3	---	8.4	---	7.8	---	----	---
3	yolks	8.1	---	7.1	---	8.0	---	---	---
	whites	8.1	---	6.6	---	6.8	---	---	---
4	yolks	7.9	---	7.4	---	7.5	---	---	---
	whites	8.0	---	6.1	---	6.4	---	---	---
5	yolks	7.1	---	6.3	---	6.7	---	---	---
	whites	7.1	---	5.3	---	5.9	---	---	---
6	yolks	5.5	8.2	5.5	7.7	5.5	7.6	---	7.5
	whites	6.2	7.6	4.9	6.3	4.9	6.1	---	6.9
7	yolks	5.7	7.1	4.4	6.7	5.3	7.5	---	6.6
	whites	5.9	6.2	4.7	5.6	4.9	5.8	---	6.9
8	yolks	6.2	6.0	4.9	---	5.0	6.8	---	6.8
	whites	6.5	5.9	4.3	---	4.8	5.8	---	6.1
8 1/2	yolks	---	5.4	---	5.8	---	6.1	---	---
	whites	---	5.5	---	4.0	---	4.8	---	---

TABLE 8 -- EFFECT ON THE QUALITY OF OILED AND UNTREATED EGGS OF THE TYPE OF CONTAINER USED TO STORE EGGS AT 34° F. FOR SIX MONTHS

Iowa Agricultural Experiment Station

Treatment		pH Albumen	Weight Loss	Haugh Units*	Flavor Score**
			%		
Untreated	egg carton	8.9	9.4	66.0	5.8
	egg case	8.9	7.5	68.4	6.2
	tin can #10	8.8	6.9	64.3	6.3
	desiccator (10% K_2CO_3)	8.7	5.2	58.3	5.6
Oiled	egg carton	8.3	3.1	69.7	3.5
	egg case	8.1	2.0	69.3	5.1
	tin can #10	8.0	0.7	69.2	5.3
	desiccator (10% K_2CO_3)	8.0	2.2	66.5	7.9

* Average for 18 eggs. Haugh units of 45 - 67 = B grade eggs and 68 - 93 = A grade eggs, weighing 2 oz. each.

** Average for seven judges and 3 replications.

TABLE 9 -- AVERAGE SCORES FOR FLAVOR OF SCRAMBLED EGGS MADE WITH UNTREATED AND TREATED EGGS STORED AT 50° F. AND AT 70° F. FOR SPECIFIED PERIODS.

Iowa Agricultural Experiment Station

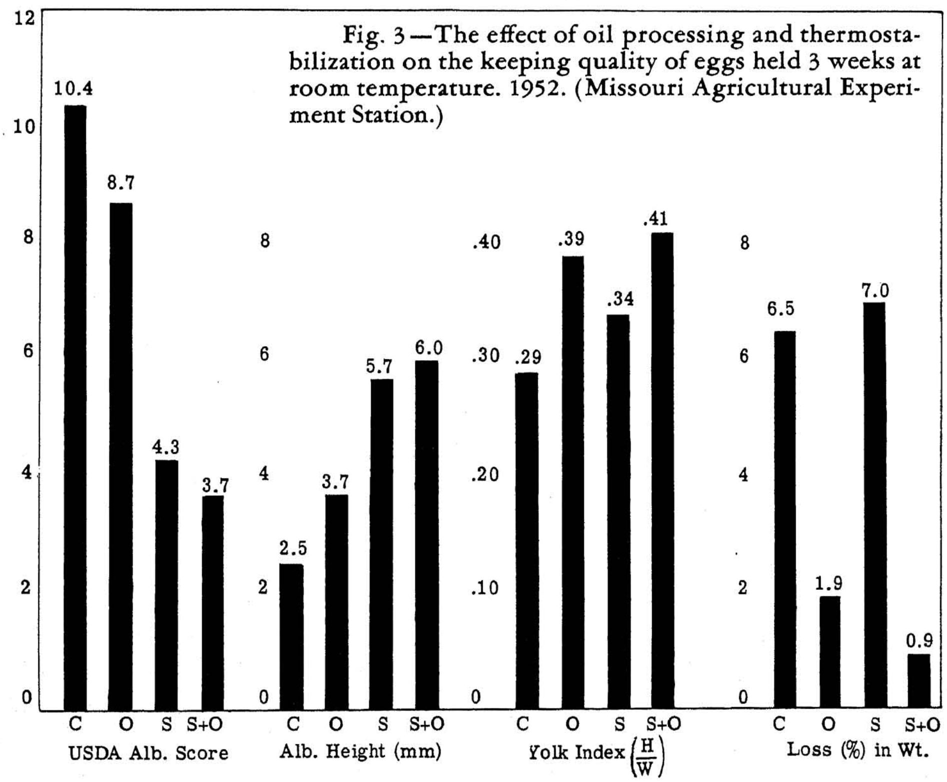
Storage Time	50° F. Untreated	50° F. Oiled	50° F. Thermo-oil	70° F. Untreated	70° F. Oiled	70° F. Thermo-oil
Weeks						
1	8.8	9.8	9.6	9.2	9.6	9.6
3	---	---	---	8.9	9.2	9.3
4	8.9	9.4	9.1	---	---	---
5	---	---	---	8.3	9.4	9.1
6	6.8	8.3	7.7	---	---	---
8	7.4	8.2	8.4	---	---	---

In contrast, when untreated and treated eggs were stored at 50° F. for 8 weeks and at 70° F. for 5 weeks, it was the untreated eggs that declined in flavor most rapidly; whereas the oiled eggs had the lowest flavor score when the eggs were stored at 34° F. for 6 months or longer (Tables 6 and 9).

There does not appear to be any correlation between pH of egg albumen and flavor score (Table 8).

The effect of oil processing on loss of weight in shell eggs is shown in Table 5 and Figure 3. This Missouri data showed that evaporation in 10 days at room temperature was reduced from 4.86 percent to 0.37

Fig. 3—The effect of oil processing and thermostabilization on the keeping quality of eggs held 3 weeks at room temperature. 1952. (Missouri Agricultural Experiment Station.)



C = Controls, O = Oil Processed, S = Thermostabilized and S+O = Stabilized and Oil Processed, 1952 percent in the eggs immersed in oil for 15 minutes at 130° F. Loss in weight when shell eggs were dipped for 10 seconds in oil held at 70° F. was 13.4 percent of the evaporation (weight loss) that occurred in the controls (natural eggs, untreated). If the same oil was heated to 130° F., the amount of evaporation was increased to 34.4 percent of the loss in controls. The oil used had a viscosity of 50/60 Saybolt Seconds at 100° F.

The Ohio Station (Winter and Cotterill, 1949) reported that in storage tests (6 months at 30° F.) oiled eggs were superior to unoiled eggs for poaching, custards, and angel cakes. Their results were:

	Oiled	Unoiled
Palatability score for hard cooked eggs	85	77
Custard score	93	91
Poached properties	Good	Slightly lower
Angel cake score	Good	Slightly lower

Investigations reported in 1954 from the Washington Agricultural Experiment Station (McLaren and Stadelman) showed that oil treatment maintained the functional properties of eggs for angel cakes better than in eggs without oil treatment, but their work showed no value of oil treatment in maintaining flavor during storage.

Their results also showed that eggs which were oil treated the day they were laid retained their physical quality and functional properties better than eggs held 7 days at 85° F. before oiling.

The protection of quality in shell eggs obtained by oil processing at the Missouri Station is shown in Figure 2. Albumen score was affected but little by oil processing, but this process did reduce loss in weight and improve the yolk index. Thermostabilization protected albumen quality. The two processes complemented each other and resulted in greatly improved keeping quality.

Contamination of oil. It is important when treating eggs with oil to keep the oil reasonably clean and thereby prevent contamination. Mold frequently

TABLE 10 -- THE EFFECT OF OIL PROCESSING, WRAPPING CARTONS IN PLASTIC AND ADDING CO_2 TO WRAPPED CARTONS ON THE KEEPING QUALITY OF SHELL EGGS.
From the Minnesota Agricultural Experiment Station
(Poultry Science 32:369-71, 1953)

Trial 1 -- Eggs held 7 days at 80° F.

Group	Treatment	No. Eggs	Egg wt. (gm.)	Alb. ht. (mm.)	Haugh Units	USDA Score	USDA Grade	No. of Eggs by grade: High	Med.	Low	%
1	Controls	240	59.1	3.35	51.0	7.2	AA	0	1	4	2.1
							A	8	17	36	25.4
							B	69	56	34	66.3
							C	11	4	0	6.3
2	Oiled	240	59.2	3.86	57.0	6.5	AA	0	0	3	1.3
							A	21	44	60	52.1
							B	60	27	15	42.5
							C	8	1	1	4.2
3	Plastic bag overwrap	240	59.3	3.72	55.0	6.7	AA	0	0	1	0.1
							A	17	37	59	47.1
							B	61	37	20	49.2
							C	5	3	0	3.3
4	Plastic bag overwrap plus CO_2	240	59.2	5.23	71.0	4.7	AA	0	12	37	20.4
							A	71	58	34	67.9
							B	15	11	0	10.8
							C	2	0	0	0.1

USDA scores range from 1.0 (eggs in which the albumen appears perfect) to 12.0 (eggs in which all albumen is thin)

Trial 2 -- Eggs held 10 days at 60° F.

Group	Treatment	No. Eggs	Egg wt. (gm.)	Alb. ht. (mm.)	Haugh Units	USDA Score	USDA Grade	No. of Eggs by grades: High	Med.	Low	%
1	Controls	116	62.4	4.05	57	6.4	AA	0	1	0	0.9
							A	11	21	29	52.6
							B	28	17	6	44.0
							C	2	0	1	2.6
2	Oiled	118	61.2	4.34	61	6.0	AA	1	0	4	4.2
							A	19	24	25	57.6
							B	24	12	8	37.3
							C	1	0	0	0.9
3	Plastic bag overwrap plus CO_2	118	62.1	5.27	70	4.8	AA	0	2	14	13.6
							A	38	32	23	78.8
							B	7	1	1	7.6
							C	0	0	0	0

causes heavy losses in shell eggs in storage, and such organisms may be carried to the eggs in the oil used in processing. To minimize contamination and to assure proper oiling, the following recommendations are made:

1. Eggs to be oiled should be at a temperature of 50° to 70° F. The oil should be about 70° F.

2. Eggs showing any moisture on the surface should not be oiled.

3. Viscosity of oil for room temperature work; 55-60.

4. Excess oil (beads) should be removed before casing.

5. Case and put in coolers.

6. Clean all equipment thoroughly each day.

7. Filter and sterilize oil daily. (a) Filter through cotton and cheese cloth. (b) Sterilize at 180° F. for 15 minutes. (c) The flash point of oil is near 280° F. for most oils.

By Sealing the Package

At one time case liners (moisture proof bags) were inserted in cases to reduce evaporation and otherwise help maintain the quality of shell eggs shipped long distances. They were of value in maintaining shell egg quality.

Another approach to this problem of reducing evaporation has been to seal the egg carton. Pyke (1945) reported that by sealing egg cartons (dozen) with moisture proof plastic film, the broken out appearance of normal fresh eggs was maintained, and the volume of cakes made from such eggs was superior to that of cakes made from untreated eggs. Swanson (1953) reported (See Table 10) results which showed that the interior quality of shell eggs held in cartons overwrapped with plastic bags was maintained much better than in the controls.

The Use of Heat

For a review of literature of the use of heat for preserving egg quality, see Missouri Agricultural Experiment Station Research Bulletin 467.

Work first reported by the Missouri Station, and later confirmed by workers at the U. S. D. A., Ohio and Iowa Stations, has shown that heat, if properly applied to shell eggs, may be used to:

(1) Stabilize the thick albumen so that the egg retains its fresh appearance longer than if untreated.

(2) Devitalize fertile eggs by stopping all embryonic development at the time of heating and,

(3) Pasteurize the egg against most of the bacteria that cause spoilage in storage.

Stabilizing the Albumen. One of the problems in maintaining quality in shell eggs is to prevent or minimize breakdown of thick albumen into thin albumen. By thermostabilization this breakdown may be slowed down as shown in Figure 4. These results are

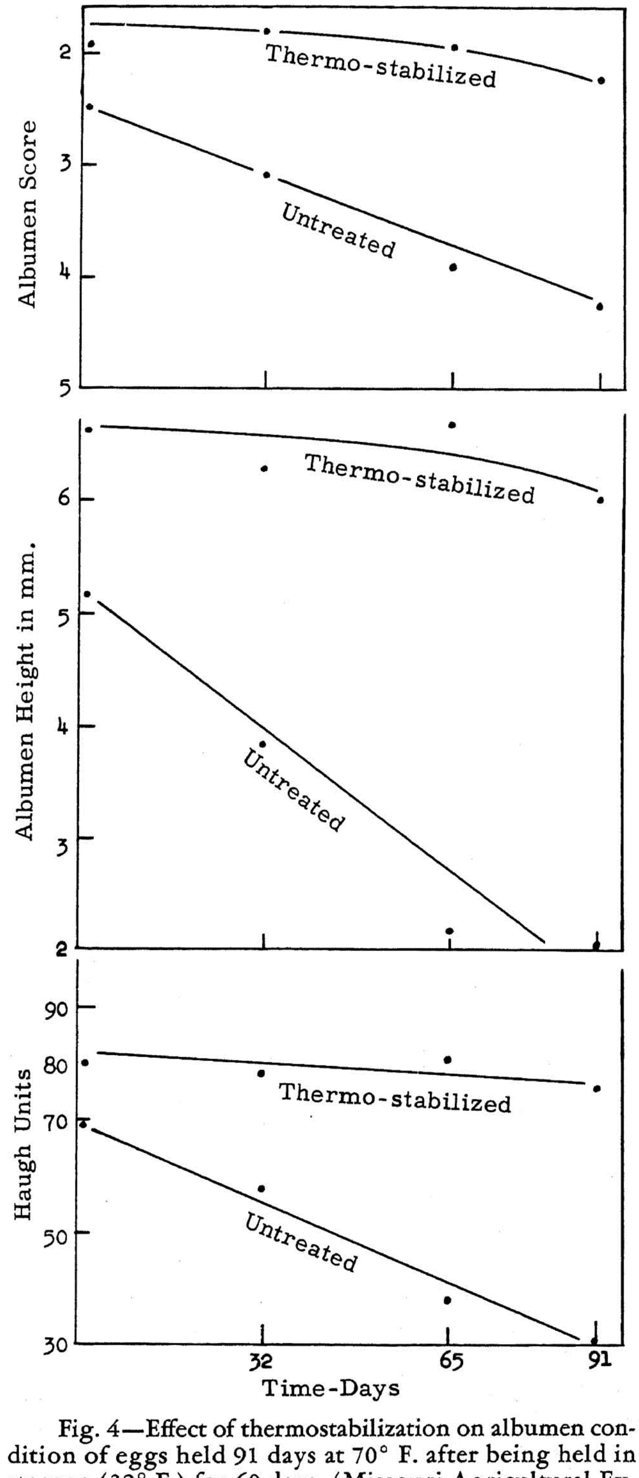


Fig. 4—Effect of thermostabilization on albumen condition of eggs held 91 days at 70° F. after being held in storage (32° F.) for 60 days. (Missouri Agricultural Experiment Station.)

typical of what may be expected from thermostabilization.

Devitalizing Fertile Eggs. Table 11 and Figure 5 show some time and temperature relationships that will devitalize fertile eggs. The most practical heat treatment for devitalizing shell eggs is to immerse them for 15 minutes in water or oil held at 130° F.

Pasteurizing Shell Eggs. Results reported in Missouri Agricultural Experiment Station Research Bulletin 364 showed that *Pseudomonas fluorescens* and many other bacteria that cause spoilage in shell eggs during storage could be destroyed by heating without injuring the marketability of the egg. Under NCM-7 sponsored research, the application of pasteurization to shell eggs passing through the channels of trade has been investigated in comparison with other processes at the Missouri and Ohio Stations.

TABLE 11 -- DEVITALIZING FERTILE CHICKEN EGGS BY HEATING IN WATER*
Missouri Agricultural Experiment Station

Treatment	Diameter (mm) of the Blastoderm After 2-6 Days at 100° F.
Untreated infertile controls	2.5 to 3.1
Untreated fertile controls	Live embryos
20 minutes at 130° F.	4.6
15 minutes at 130° F.	6.3
5 minutes at 140° F.	4.7
7½ minutes at 140° F.	6.0
10 minutes at 140° F.	4.9
10 minutes at 138° F.	4.7
35 minutes at 120° F.	5.9

*Data from Research Bulletin 362

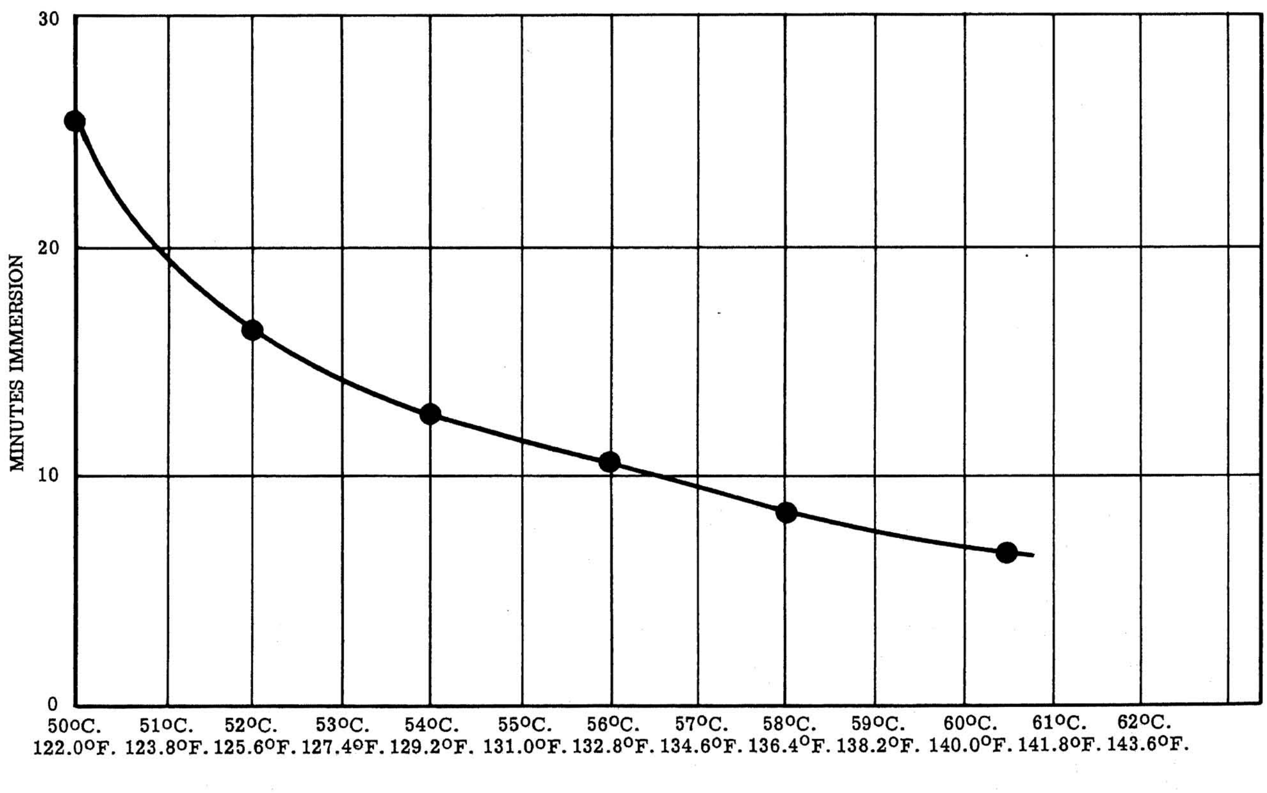


Fig. 5—Time required at different temperatures to devitalize fertile eggs. (Courtesy U.S.D.A. and the U. S. Egg and Poultry Magazine.)

Dry Cleaning Compared to Pasteurization in Preventing Spoilage

Heat treatment (thermostabilization), when compared to dry cleaning (see Table 12) and other methods used in cleaning soiled shell eggs, was found to be the most effective. Table 12 shows the results of six replications of experiments designed to compare dry cleaning with washing plus heat treatment. In each test the losses in dry-cleaned eggs were too high for any practical use whereas the losses in the soiled eggs that were cleaned by washing and then thermostabilized were comparable to the losses normally encountered in clean eggs.

TABLE 12 -- A COMPARISON OF LOSSES IN SHELL EGGS, DRY CLEANED AND WASHED, AND THERMOSTABILIZED BY IMMERSING FOR 15 MINUTES IN WATER AT 130° F. STORED FOR 6-7 MONTHS IN COMMERCIAL COLD STORAGE*
Missouri Agricultural Experiment Station

Storage Date	Treatment	Percentage Loss in Storage
1948, April 8	Soiled eggs dry cleaned with emery cloth.	9.3
1948, April 8	Soiled eggs washed and thermostabilized.	0.6
1948, April 15	Soiled eggs dry cleaned with emery cloth.	8.2
1948, April 15	Soiled eggs washed and thermostabilized.	0.6
1948, April 22	Soiled eggs dry cleaned with emery cloth.	9.1
1948, April 22	Soiled eggs washed and thermostabilized.	2.3
1952, April 16	Soiled eggs dry cleaned.	6.7
1952, April 16	Soiled eggs washed and thermostabilized.	1.2
1952, April 23	Soiled eggs dry cleaned.	2.5
1952, April 23	Soiled eggs washed and thermostabilized.	0.3
1952, April 30	Soiled eggs dry cleaned.	8.3
1952, April 30	Soiled eggs washed and thermostabilized	0.6

*Data from Missouri Agricultural Experiment Station Research Bulletins 426 and 550.

Wet Cleaning With and Without Heat Treatment

It is generally conceded that some method of wet-cleaning of soiled eggs is more practical than dry-cleaning. There is a common belief, however, that washing results in much more spoilage than dry cleaning. In general, this is true but in some lots losses in dry-cleaned eggs may be as high as those in washed eggs.

Research to date indicates that there is only one way to wash soiled eggs and keep the losses low and comparable with those in clean eggs. That is to combine the washing with heat treatment, either at the time of washing or soon thereafter. Table 1 shows the comparative losses in soiled eggs cleaned by different methods of washing and by washing combined with pasteurization or heat treatment. These results show that washing alone may result in heavy losses but if combined with the proper heat treatment, the losses may be very low and compare favorably with losses in clean eggs.

Amount of Heat to Use

The amount of heat to use in treating shell eggs to maintain quality depends upon the purpose of the treatment.

If only shell surface pasteurization is desired, 5 seconds in boiling water may accomplish such a purpose. If pasteurization of the contents against the more common organisms causing spoilage in shell eggs is desired, heat treatments in water, such as 1½ minutes at 150° F., 3 minutes at 145° F., 5 minutes at 140° F. and 15 minutes at 130° F., are necessary.

Heat will reduce lysozyme activity in egg albumen, but Cotterill and Winter (1954) reported that standard thermostabilization of shell eggs (15 minutes in water held at 130° F.) did not affect lysozyme. However, when the temperature was raised to 134° F. to 138° F. or higher lysozyme activity was decreased. They also reported that lysozyme activity was reduced in shell eggs immersed in water for 1 minute at 165°

F., 3 minutes at 148° F., 5 minutes at 144° F., 7 minutes at 140° F. and 10 minutes at 138° F.

Flash Heat Treatment. Romanoff and Romanoff (1944) reported that flash heat treatment (5 seconds in boiling water) of shell eggs was effective in maintaining egg quality. Funk (1950) compared the flash heat treatment with thermostabilization. His results showed that immersing shell eggs in water for 5 seconds gave very little protection against albumen breakdown and none against embryonic development. In 1953 , Feeney, MacDonnell, and Lorenz reported that dipping shell eggs that were infected within 24 hours previously with *Pseudomonas* bacteria for two or three seconds in boiling water was effective in preventing spoilage in such eggs. However, if infection had occurred more than 24 hours before such flash treatment the treatment could only be effective with organisms on or in the shell and was not effective against the bacteria that had penetrated the shell.

Value of Heat Treatment

Anyone can easily demonstrate the value of heat treatment such as thermostabilization by taking some fresh laid fertile eggs and treating one-half of them and then holding both lots at room temperature for several weeks or in an incubator for three days. The real differences show when such eggs are broken out. See Figure 6.

Gorseline, Hayes, and Otte (1952) reported results with thermostabilized eggs in market channels including storage. Table 13 shows that the percentage of Grade A eggs remaining in lots stored for 7½ months was more than doubled (83 percent compared to 37.8 percent) by thermostabilization as compared to oil processing. It should be mentioned that egg candlers are confused by thermostabilized eggs and do not grade them as high as their interior quality justifies. The grading reported here was done by those who knew the characteristics of thermostabilized eggs.

TABLE 13 -- EFFECT OF THERMOSTABILIZATION ON RETAINING THE GRADE OF SHELL EGGS IN COMMERCIAL STORAGE.*

Treatment	Percentage of Grade A Eggs after $7\frac{1}{2}$ Months Storage
Thermostabilization in Oil	Percentage Grade A Eggs
130o F., 16 minutes	83.3
132° F., 16 minutes	83.9
134° F., 16 minutes	85.0
136° F., 16 minutes	83.9
144° F., 8 minutes	78.9
Oiled only	37.8

*From U.S.D.A., Circular 898

Probably the most spectacular effect of thermostabilization can be seen in the appearance of the thick white and in the albumen height measurement of heat treated eggs. These eggs have a high percentage of thick white even after storage for 8 months. An examination of the data on Haugh Units in Table 14 reveals that heat treatment in oil at 130° F. for 16 minutes or at 152° F. for 2 minutes raises the initial quality of eggs 4 to 6 units above the control eggs. Also after storage for 8 months at 34° F., eggs thermostabilized at 130° F. for 16 minutes have Haugh units from 13 to 15 units higher than the untreated control eggs (Table 14). However, this beneficial stabilizing effect is not so pronounced when eggs are thermostabilized in water. In fact, such eggs exhibit decreases in Haugh units similar to those found in oiled eggs (Table 14).

TABLE 14 -- AVERAGE HAUGH UNITS FOR EGGS UNTREATED, OILED, THERMOSTABILIZED IN OIL AND THERMOSTABILIZED IN WATER, AFTER SPECIFIED STORAGE PERIODS AT 34° F.

Iowa Agricultural Experiment Station

Storage Time	Untreated		Oiled		Thermo*-oil			Thermo*-water	
	I	II	I	II	I	II	III	I	II
Months									
0	72.0	80.8	75.7	82.9	76.7	86.3	80.0	----	81.3
1	72.1	----	71.3	----	78.8	----	----	----	----
2	67.3	----	68.9	----	77.1	----	----	----	----
3	65.0	----	69.8	----	73.3	----	----	----	----
4	61.6	----	68.0	----	73.3	----	----	----	----
5	63.9	----	66.6	----	72.5	----	----	----	----
6	61.5	59.8	67.7	69.3	70.9	72.6	70.3	----	69.9
7	59.1	59.8	64.4	67.1	70.6	73.0	----	----	69.9
8	55.9	56.5	63.6	62.2	68.8	71.5	----	----	66.7

I = Summer eggs put in storage in one dozen egg cartons every week from May 14 to July 17, 1953
II = Spring eggs put in storage in 30 dozen egg cases on March 31 and April 22, 1954.
* Eggs in lots I and II were thermostabilized at 130° F. for 16 minutes.
Eggs in lot III were thermostabilized at 152° F. for 2 minutes.

Eggs that were heat treated for 2 minutes at 152° F. in oil and stored for 6 months at 34° F. had interior quality, as measured by Haugh units, very similar to eggs treated for 16 minutes in oil at 130° F. and stored under similar conditions.

Gorseline, Moser, and Hayes (1950) reported studies of changes in quality of shell eggs during storage in which thermostabilized eggs were compared with natural eggs and oil processed eggs. They summarized their results as follows:

1. The thermostabilization process markedly stabilized egg white against the normal deteriorative changes causing thinning of egg white during storage.
2. Thermostabilized eggs retained their interior quality during storage to a better degree than "natural" or "oiled" eggs, as demonstrated by the candling procedure.
3. The percentage of thick white was greater in stabilized eggs than in "natural" or "oiled" eggs after 4, 5, and 8 months of storage.
4. Thermostabilization increased the albumen index, and it remained higher during all storage periods than the indexes of "natural" and "oiled" eggs.
5. The whipping properties of egg white were altered by the stabilization process. A marked increase in whipping time was necessary to obtain foam of value comparable to that of untreated eggs.
6. There was less moisture or weight loss in the thermostabilized eggs than in the untreated eggs.

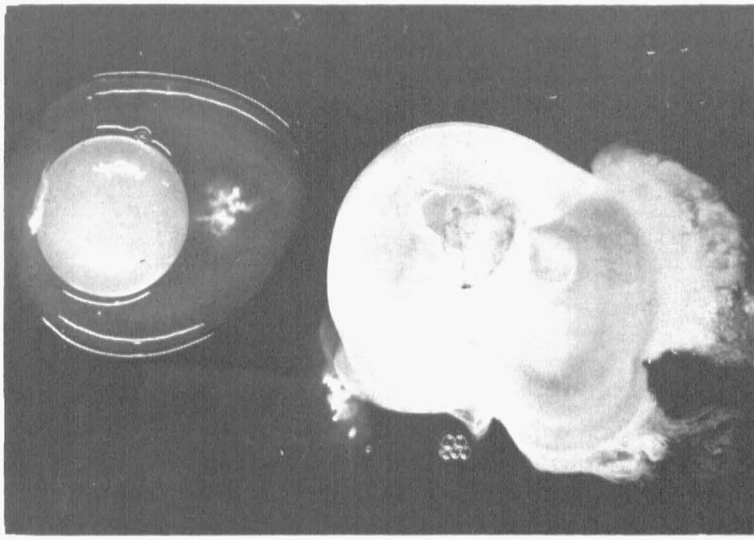


Fig. 6—Eggs laid by the same hen held for 3 days at 100° F. The egg on the left was thermostabilized (15 minutes at 130° F. in water). Note retention of thick white and lack of embryonic development. (Missouri Agricultural Experiment Station.)

7. Thermostabilization had no marked influence on the yolk index. There was a slight increase in the index, but not enough to be of significance.
8. Thermostabilization brought about no significant change in the pH of either the white or the yolk of eggs.

Heat Treatment and Bacterial Count of Shell Eggs

Funk (1943) reported that shell eggs previously inoculated with bacterial cultures of *Aerobacter aerogenes, Alcaligenes bookeri, Alcaligenes faecalis, Eberthella oedematiens, Eberthella oxyphila, Escherichia coli, Flavobacterium aurescens, Proteus ichthyosmus, Proteus mirabilis, Proteus vulgaris, Pseudomonas fluorescens, Serratia marcesens, Staphylococcus albus,* and *Staphylococcus aureus,* when immersed for 10 minutes in egg processing oil held at 140° F., were found to be negative when cultured for these organisms.

Murphy and Sutton (1947) reported that they effectively pasteurized shell eggs to prevent rotting by immersing them in water held at 54° C. (129° F.) for either 15, 22½, or 30 minutes.

Results substantiating his earlier work which showed shell eggs could be pasteurized to prevent spoilage in storage were reported by Funk in 1950.

Salton, Scott, and Vickery (1951) reported that they were able to prevent rotting in shell eggs by heating them in water held at temperatures below 65° C. (149° F.); 57.5° C. for 800 seconds, 60.0° C. for 320 seconds, 62.5° C. for 128 seconds, and 65.0° C. for 64 seconds. The lowest temperature they used was 57.5° C. (135° F.) for 800 seconds. They were unable to prevent rotting at 70° C. (158° F.) for 22 seconds or higher temperature because coagulation occurred near the shell before the inner contents could be pasteurized.

After examining (bacteriologically) 5,724 individual eggs used in experiments in which he compared dirty eggs treated chemically with similar eggs thermostabilized, Miller (1954) reported that thermostabilized eggs showed fewer spoilage bacteria compared with chemically treated eggs in the same group.

Winter (1954) found that the keeping quality of washed eggs was greatly improved by agitating such eggs soon after washing for 2 minutes in water held at 144° F. or in oil held at 152° F. (See Figure 7.)

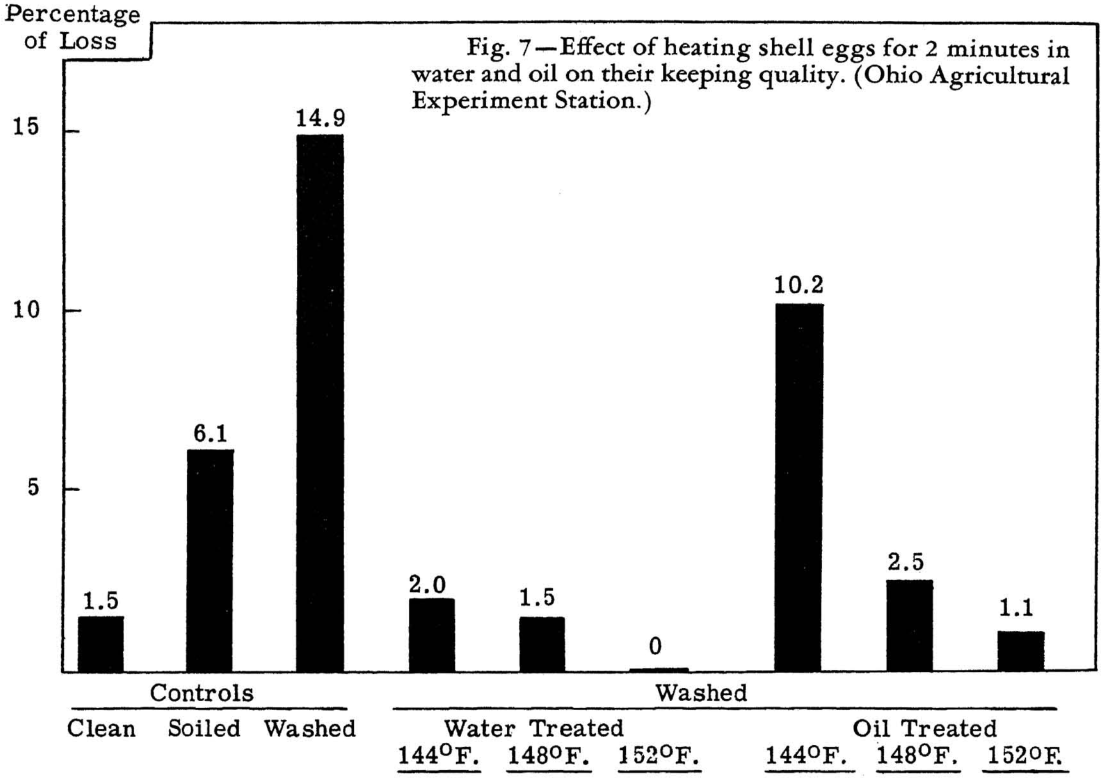


Fig. 7—Effect of heating shell eggs for 2 minutes in water and oil on their keeping quality. (Ohio Agricultural Experiment Station.)

Heat Treatment and Functional Properties of Eggs

Slosberg et al. (1948) reported that the leavening power of egg albumen was impaired at temperatures as low at 105° F. when held 6 hours or more.

In 1950 Funk again reported that the whipping properties of the albumen were impaired by thermostabilization. See Table 15.

Carlin and Foth (1952) reported research on the interior quality and functional properties of current receipt eggs that were oiled and thermostabilized and stored in a commercial warehouse at 34° F. They concluded that oiling and thermostabilization had no deleterious effects on sponge cakes, plain cakes, or cus-

TABLE 15 -- EFFECT OF THERMOSTABILIZATION ON THE WHIPPING PROPERTIES OF EGG ALBUMEN.*
Missouri Agricultural Experiment Station
Duplicate samples of 165 cc of albumen whipped with a kitchen aid (electrical beater) on speed 8, 1946.

	Lots	Whipping Time to Bring Egg Foam to a Soft Peak	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 min. in water held at 130° F.	80 sec.	2.00
		135 sec.	3.00
C.	Fresh eggs immersed for 90 min. 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 min. at 130° F. and 7 min. at 136° F.	230 sec.	2.50
		210 sec.	2.50
F.	Fresh eggs stabilized for 15 min. in water held at 130° F.	195 sec.	2.63
		180 sec.	2.63

*Data from Missouri Agricultural Experiment Station Research Bulletin 467.

tards made with the treated eggs. However, foaming properties of the thermostabilized eggs were impaired. This was evident in the increase in whipping time and the slight decrease in cake volume (10 to 20%) of angel cakes made from the heat treated eggs. Results of more recent research by Carlin and Foss (1954) indicated that the impairment of whipping properties might not be as great in eggs thermostabilized (at 130° F. for 16 minutes) 18 hours after laying and stored in a small walk-in refrigerator since angel cakes made with such eggs were only 5 to 10 percent lower in volume than the control cakes.

Similar results have been obtained when eggs thermostabilized at 152° F. for 2 minutes were tested in angel cakes. The cakes made with these eggs were reduced 5 to 10 percent in volume.

Hayes, Gorseline, and Moser (1952) reported on a study of consumer acceptance of thermostabilized, oil-processed, and natural eggs, They found that the percentages of consumers liking eggs of each kind for all uses were: natural, 99.6 percent; oil processed, 93.6 percent; and thermostabilized, 92.4 percent. Only 1 percent of the eggs were used for making angel cakes where whipping properties of the albumen would be a factor. The percentage of consumers liking these eggs for angel cakes were: natural eggs, 87.5 percent; oil processed, 100.0 percent; and thermostabilized (two tests), 100.0 percent and 92.9 percent.

From these results it appears evident that for eggs going to retail stores, the whipping property of the albumen is not of great importance. The consumers used few eggs for products where whipping properties of the albumen were of importance, and few consumers detected anything objectionable about these eggs for making angel cakes.

Effect of Heat Treatment on Yield of Liquid Egg

It is evident upon examining shell eggs that have been thermostabilized (15 minutes at 130° F.) or exposed to more heat that the albumen tends to adhere to the shell. Funk (1943) reported four trials in which the liquid egg yield from untreated and treated (thermostabilized at 130° F.) eggs was determined as follows:

	(1)	(2)	(3)	(4)	Avg.
Untreated	86.0	85.7	86.6	85.6	86.0
Treated	85.7	85.8	85.7	85.1	85.6

More recently Carlin and Foth (1952) reported the percentage yield of egg white, shell, and yolk from oiled and stabilized lots stored for 8 months as follows:

	% Egg White	% Shell	% Yolk
Oiled, 100° F.	56.3	12.1	31.6
Oiled, 180° F.	55.4	12.0	32.5
Thermostabilized			
15 minutes at - 130° F.	51.0	12.8	36.5
15 minutes at - 134° F.	50.8	13.6	35.6
15 minutes at - 136° F.	48.4	14.2	37.5
8 minutes at - 144° F.	46.0	17.2	36.8

These results show the shift of water from the albumen to the yolk. The decrease in yield of egg meat in eggs stabilized at 130° F. would be the difference in egg shell weight, which would be 0.7 or 0.8 percent. When higher temperatures were used for thermostabilization, the differences were greatly increased.

Maintaining Quality by Chemical Treatments

Carbon Dioxide

It has been shown that by increasing the CO_2 content of the air surrounding shell eggs, the quality and grade of such eggs can be retained much longer than in untreated eggs. Results at Minnesota, as shown in Table 4, indicated that eggs sealed in cartons in which solid carbon dioxide (pea size) had been added retained their thick white USDA score and USDA grade much better than untreated controls or oil processed eggs. Eggs in sealed cartons may develop mold growth.

Fungicides

Mallman and Michael (1940) of the Michigan Station reported that by impregnating cases, flats, and fillers with mycostatic agents the development of mold on shell eggs in storage could be minimized. They used sodium 2, 4, 5 trichlorophenate, sodium 2, 4, 5, 6 tetrachlorophenate and sodium pentachlorophenate.

Mallman and Davidson (1944) reported that shell eggs dipped in paraffin oil containing 0.25 percent penta chlorophenol were protected against mold development.

Lorah et al. (1954) reported that mold growth on shell eggs could be prevented effectively by using the following substances in egg processing oil: 1.0 percent to 0.1 percent zinc dimethyl dithiocarbamate, 1 percent tetra-ethylthiuram monosulfide, 1.0 percent to 0.25 percent Thiourea, 0.1 percent to 0.01 percent alkyl dimethyl benzyl ammonium chloride.

A 4.0 percent aqueous solution of sodium propionate was also effective when used as a dip before oil processing. This substance is used to prevent mold growth in bread.

Conclusions

The maintenance of quality in shell eggs is important, and much can be done to maintain quality by treating the eggs.

Oil processing can be used to prevent evaporation and otherwise protect shell egg quality. There is evidence that oil processing affects flavor in eggs that have been stored at 34° F. for more than 4 months.

Sealing egg cartons with plastic and enclosing solid carbon dioxide in the carton helps maintain egg quality.

Heating shell eggs sufficiently to pasteurize them results in:

1. Retention of thick albumen.
2. Devitalizing of embryonic development.
3. Destruction of many of the bacteria that cause spoilage in eggs.

Either dry-cleaning or wet-cleaning of eggs may result in heavy losses in storage unless the eggs are heat treated.

The foaming properties of albumen are disturbed by heating. More time is required for whipping, and there is a slight reduction in angel cake volume.

The development of mold in shell eggs may be prevented by the use of mycostatic agents.

REFERENCES

Barott, H. G. and E. H. McNally. 1943. Heat Treating Shell Eggs. U. S. Egg and Poultry Magazine 49:320.

Bose, S. and G. F. Stewart. 1948. Comparative and Complementary Effects of Heat Treating and Oiling Shell Eggs on Their Keeping Quality. Poultry Science 27:228-33.

Brown, Helen J. and N. E. Gibbons. 1954. Air Cell Mold in Oiled Eggs. Food Techol. 8:307-11.

Carlin, Agnes Frances and Janice Foth. 1952. Interior Quality and Functional Properties of Oiled and Thermostabilized Shell Eggs Before and After Commercial Storage. Food Technology 6:443-450.

Carlin, F. and S. Foss. 1954. Quality of Baked Products Prepared from Untreated, Oiled and Thermostabilized Eggs Stored 6 and 8 Months at 34° F. Poultry Science 33:1047 (abstract)

Conner, J. W., E. S. Snyder, and H. L. Orr. 1953. The Influence of Washing and Oiling on Grade and Bacteria Content of Eggs Stored for a Nine Month Period. Poultry Science 32:228-235.

Cotterill, O. J. and A. R. Winter. 1954. Egg White Lysozyme, 2. Effect of Thermostabilization. Poultry Science 33:1185-1191.

Evans, R. J. 1942. Shell Treatment of Eggs by Oiling. U. S. Egg and Poultry Magazine 48:596-99.

Feeney, R. E., L. R. MacDonnell, and F. W. Lorenz. 1953. High Temperature Treatment of Shell Eggs. Poultry Science 32:899.

Feeney, R. E., L. R. MacDonnell, and F. W. Lorenz. 1954. High Temperature Treatment of Shell Eggs. Food Technology 8:242-45.

Forsythe, R. H., J. C. Ayres, and J. L. Radlo. 1953. Factors Affecting The Microbiological Populations of Shell Eggs. Food Technology 7:49-56.

Foss, S., F. Carlin, and O. Cotterill. 1954. Flavor of Untreated, Oiled, and Thermostabilized Eggs After Storage at 34° F. Food Technology 8: No. 5, 19 (abstract)

Funk, E. M. 1937. Factors Influencing the Production of Clean Eggs. Missouri Agricultural Experiment Station, Bulletin 384.

Funk, E. M. 1938. Improving the Keeping Quality of Eggs by Cleaning with Sodium Hydroxide. Missouri Agricultural Experiment Station, Research Bulletin 277.

Funk, E. M. 1943. Stabilizing Quality in Shell Eggs. Missouri Agricultural Experiment Station, Research Bulletin 362.

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

Funk, E. M. 1948. Experiments in Cleaning Soiled Eggs for Storage. Missouri Agricultural Experiment Station, Research Bulletin 426.

Funk, E. M., H. L. Kempster, and M. F. Dendy. 1950. Influence of Nesting Materials on the Production of Clean Eggs. Missouri Agricultural Experiment Station, Research Bulletin 463.

Funk, E. M. 1950. Maintenance of Quality in Shell Eggs by Thermostabilization. Missouri Agricultural Experiment Station, Research Bulletin 467.

Funk, E. M., James Forward, and Martha Lorah. 1954. Minimizing Spoilage in Shell Eggs by Thermostabilization. Poultry Science 33:532-538.

Funk, E. M., J. Forward, and Martha Lorah. 1954. Maintaining Quality in Shell Eggs by Heat Treatment. Missouri Agricultural Experiment Station, Research Bulletin 550.

Gorseline, Harry E., Roy E. Moser, Jr., and Kirby M. Hayes. 1950. A Pilot Scale Study of Shell Egg Thermostabilization. Food Technology 4:426-430.

Gorseline, Harry E., Kirby M. Hayes, and Alfred W. Otte. 1952. Thermostabilization of Shell Eggs: Quality Retention in Storage. Circular 898. U. S. D. A.

Hayes, Kirby M., Harry F. Gorseline, and Roy E. Moser, Jr. 1952. Consumer Acceptance of Thermostabilized, Oil-Processed and Natural Shell Eggs. Circular 902, U. S. D. A.

Kahlenberg, O. J., J. W. Gorman, H. E. Gorseline, M. A. Howe, and E. R. Baush. 1952. A Study of the Washing and Storage of Dirty Eggs. U. S. D. A. Circular 911.

Lorenz, F. W. and P. B. Starr. 1952. Spoilage of Washed Eggs. Effect of Sprayed Versus Static Water Under Different Washing Temperatures. Poultry Science 31:204-214.

Lorah, Martha E., E. M. Funk, and James Forward. 1954. Reducing Spoilage in Shell Eggs from Mold by the Use of Fungicides. Missouri Agricultural Experiment Station, Research Bulletin 573.

Mallman, W. L. and C. E. Michael. 1940. The Development of Mold on Cold Storage Eggs and Methods of Control. Michigan Agricultural Experiment Station, Technical Bulletin 174.

Mallman, W. L. and J. A Davidson. 1944. Oil-Protected Shell Eggs. U. S. Egg and Poultry Magazine 50:113-15, 133, 169-71 and 189-191.

Miller, W. A. 1954. The Microbiology of Dirty Eggs Treated in Various Ways and Stored at Different Temperatures and Humidities. Poultry Science 33:735-742.

Murphy, T. W. and W. S. Sutton. 1947. The Pasteurization of Shell Eggs to Prevent Storage Rot and Maintain Quality. Agri. Gazette, New South Wales, Misc. Publ. 3317.

McLaren, Barbara E. and W. J. Stadelman. 1954. Relationship Among Physical, Functional, and Flavor Properties of Eggs. Washington Agricultural Experiment Station, Technical Bulletin 14.

North Central Poultry Marketing Research Committee. 1949. Changes in Egg Quality During Marketing. North Central Regional Publication 15. Michigan Agricultural Experiment Station, Special Bulletin 361.

North Central Regional Committee on Poultry Products Technology Research. 1953. Quality Losses in Market Eggs. North Central Regional Publication No. 41. Missouri Agricultural Experiment Station, Bulletin 607.

Pyke, W. E. 1945. Packaging is Means of Preserving Eggs: Treatments with Egg Cartons are Helpful. Colorado Farm Bulletin Colorado Agricultural Experiment Station May-June, 1945.

Romanoff, Alexis L. and Anastasia J. Romanoff. 1944. A Study of Preservation of Eggs by Flash Heat Treatment. Food Research 9:358-366.

Salton, M. R. J., W. J. Scott, and J. R. Vickery. 1951. Studies in the Preservation of Shell Eggs, VI. The Effect of Pasteurization on Bacterial Rotting. J. Applied Science, 2 (1):205-222.

Slosberg, H. M., H. L. Hanson, G. F. Steward, and B. Lowe. 1948. Factors Influencing the Effects of Heat Treatment on the Leavening Power of Egg White. Poultry Science 27:294-301.

Stuart, L. S. and E. H. McNally. 1943. Bacteriological Studies on the Egg Shell. U. S. Egg and Poultry Magazine 49:28-31, 45-47.

Swanson, M. H., 1953. A Proposal for the Use of Carbon Dioxide in Retail Egg Cartons. Poultry Science 32:370-71.

Winter, A. R. and Owen J. Cotterill. 1949. The Preservation of Shell Egg Quality by Oil Dipping Right on the Farm. American Egg and Poultry Review, March 1949.

Winter, A. R., Patricia Shields, Lois MacDonald, and Inez Prudent. 1954. Improving the Keeping Quality of Eggs During Marketing by Hot Oil Treatment. Food Technology. Volume 8:515-17.

Winter, A. R., Blanche Burkart, and Charles Wettling. 1952. Cleaning Eggs for Market. Ohio Agricultural Experiment Station, Research Bulletin 710.

Winter, A. R., Blanche Burkart, Patricia Clements, and Lois MacDonald. Cleaning Eggs With Detergents and Detergent-sanitizers. Ohio Agricultural Experiment Station, Research Bulletin (in press) 1955.

Wolk, J., E. H. McNally, and N. H. Spicknall. 1950. The Effect of Temperatures on the Bacterial Infection of Shell Eggs. Food Technology 4:316-318.