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FACTORS AFFECTING THE QUALITY OF PROCUREMENT GRADE SHELL EGGS

by

G. C. Walker, E. A. Braden,

C. L. Hicks and J. M. Tuomy

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UNITED STATES ARMY
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13. ABSTRACT

Federal Specification C-E-271 entitled Eggs, Shell requires that not more than 5% can be packed with the small end of the egg up. The inability of some egg packers to consistently comply with the tolerance prompted an investigation to determine the importance of the position of the egg on quality after shaking to simulate transportation and long term storage.

Three experiments were conducted. In each experiment one-half of the eggs were stored with the small end down and one-half with the small end up. For experiment 1 the eggs were stored quiescently for up to 6 months. For experiment 2 one-half of the eggs were shaken for 3.5 hours prior to storage. The eggs were stored for up to 7 weeks. For experiment 3 one-third of the eggs were stored quiescently, one-third were shaken for 2.5 hours and one-third were shaken for 7.5 hours prior to storage for up to 14 weeks.

Results show that without shaking the storage time influences the deterioration of the quality of the eggs to a greater extent than the position of the egg does. Results of experiments 2 and 3 indicate that shaking is, in general, the most important factor and storage time and position of the eggs assume a less important place in influencing changes in egg weight, albumen height and quality score. However, the interior quality, as measured by the amount of deterioration found, was better maintained in the eggs stored small end up. Shaking of the eggs resulted in more deterioration than in eggs not shaken.

Based upon the results of this study the requirement restricting the percentage of eggs that may be packed small end up will be disregarded and will be deleted from the specification in future revisions of the document.

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Food Laboratory

U. S. ARMY NATICK LABORATORIES

Natick, Massachusetts

FOREWORD

Shell eggs are an important item of subsistence for the Armed Forces wherever they serve. The study reported herein was undertaken to determine the effect of the position of the small end of the egg (down or up), shaking of the eggs to simulate motor truck transportation and the time in storage on the quality of procurement grade shell eggs. The study resulted from a military supply problem concerning the percentage of "upside down" eggs allowed in a case of eggs. The literature yielded little pertinent information.

This study was performed under Production Engineering Task 107-42-460.

We appreciate the help of Mr. Fredrick A. Costanza, General Equipment and Packaging Laboratory, in setting up the apparatus used in the shaking of the eggs.

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ABSTRACT

Federal Specification C-E-271 entitled Eggs, Shell requires that not more than 5% can be packed with the small end of the egg up. The inability of some egg packers to consistently comply with the tolerance prompted an investigation to determine the importance of the position of the egg on quality after shaking to simulate transportation and long term storage.

Three experiments were conducted. In each experiment one-half of the eggs were stored with the small end down and one-half with the small end up. For experiment 1 the eggs were stored quiescently for up to 6 months. For experiment 2 one-half of the eggs were shaken for 3.5 hours prior to storage. The eggs were stored for up to 7 weeks. For experiment 3 one-third of the eggs were stored quiescently, one-third were shaken for 2.5 hours and one-third were shaken for 7.5 hours prior to storage for up to 14 weeks.

Results show that without shaking the storage time influences the deterioration of the quality of the eggs to a greater extent than the position of the egg does. Results of experiments 2 and 3 indicate that shaking is, in general, the most important factor and storage time and position of the eggs assume a less important place in influencing changes in egg weight, albumen height and quality score. However, the interior quality, as measured by the amount of deterioration found, was better maintained in the eggs stored small end up. Shaking of the eggs resulted in more deterioration than in eggs not shaken.

Based upon the results of this study the requirement restricting the percentage of eggs that may be packed small end up will be disregarded and will be deleted from the specification in future revisions of the document.

INTRODUCTION

Shell eggs form an important part of the diet of the U.S. military man in whatever part of the world he is serving. The length of the military supply line and the perishable nature of the egg require that the product receive the best care possible from production to consumption. The time between procurement by the Department of Defense (DoD) and serving to the consumer in overseas areas is estimated at up to four months.

The DoD purchases procurement grade eggs in accordance with the requirements stated in Federal Specification C-E-271 entitled Eggs, Shell. One of the requirements in the specification states that not more than 5% of the eggs can be packed with the small end of the egg up. The tolerance is necessary because some mechanical egg grading and packing equipment cannot at times differentiate the small end from the large end of the egg. The inability of some egg packers to consistently comply with the tolerance for "upside down" eggs prompted an investigation to determine the importance of the position of the egg, small end down or up, on quality after simulated transportation and during long term storage. The literature of the field yielded little information applicable to this military supply situation.

The admonition to pack eggs with the small end down has been echoed from the earliest shipment of eggs to the present time. Pennington _et al._ (1933) discuss the changes in the practice of delivery of eggs to the consumer. When the producer and consumer were close to each other, direct delivery of eggs was the custom. As producer and consumer moved farther and farther apart the eggs were shipped, handpacked, small end down, in hogsheads with straw or grain used as a buffer against shock and breakage. The method of handling eggs has changed from hand-packing to mechanical sizing and packing. However, even as revolutionary changes have occurred in methods of handling eggs, packing eggs with the small end down has been advised (Benjamin and Pierce, 1937; Winter and Funk, 1946; Dawson and Hall, 1954; Orel and Musil, 1956; Goodwin et al., 1962).

The basic reason for packing eggs with the small end down is economic. Eggs are sold by their candled quality. The candled quality is better maintained when eggs are kept small end down during handling. Dawson and Hall (1954) found an average decrease in the candled index of 0.55 for eggs packed with the small end down, but for eggs packed with the small end up the candled index decreased 1.6 points during 14 days of storage. They found the albumen quality to be slightly, but not significantly, better in eggs packed with the small end up after the storage period. Goodwin et al. (1962) reported that the albumen condition of eggs stored with the small end up was significantly better than eggs stored with the small end down. Candling of the eggs, however, revealed more off-centered yolks in the eggs stored small end up. Brant and Sanborn (1963) found just the opposite i.e. that holding eggs large end up resulted in the poorest centering of the yolk. Orel and Musil (1956) noted that albumen index was 6 to 7% lower for eggs stored with the small end down. Analysis of variance of the results showed this difference to be significant.

Few studies have been reported on the effect of transportation on quality changes in shell eggs. Gwin (1952) found quality loss to be related to time in transit, distance in miles traveled and season of the year. Adams and Milam (1960) shipped selected eggs from Lincoln, Nebraska to Rio de Janeiro, Brazil. The average Haugh score changed from 84.6 to 72.4 during the 30 days in transit. Adams and Skinner (1962, 1963) found that the position of the cases of eggs in the truck influenced the Haugh score to a greater extent than did a 10 day difference in the age of the eggs at the time of shipment. The eggs in the study were shipped from Lincoln, Nebraska to Hastings, Nebraska, (100 miles; non-refrigerated truck) then to Tucson, Arizona (1200 miles; refrigerated egg trucks). Aho et al., (1967) found no significant influence contributed by the orientation of the small end of the egg when eggs were subjected to short length transportation and holding for 10 days.

The eggs used in the research reviewed above were generally selected according to factors such as breed of the hen, the age of the hen, and the season in which the egg was laid. These factors are not considered in the specification for shell eggs. The experiments were generally of short duration. Usually eggs were stored for periods not exceeding 30 days.

EXPERIMENTAL METHODS

Three experiments were conducted. The eggs used in the experiments were fresh production, shell protected, Procurement Grade I (U.S.D.A. 1969). Large size eggs were used in experiment 1 and medium size eggs in experiments 2 and 3. All eggs were obtained from a local vendor supplying procurement grade eggs to the military. New commercial 30 dozen egg cases and 5 x 6 egg trays were used in each experiment. The eggs were prepared for storage in a room maintained at 50F to prevent sweating. All eggs were examined initially and cracks, checks and leakers were discarded.

Experiment 1. Six cases (30 dozen eggs per case) of eggs were packed with the small end of the egg down and six cases with the small end of the egg up. Six eggs from each tray, one egg from each corner and two from the center, were weighed prior to storage. The eggs were stored at 40 to 45F and 80 to 85% relative humidity for up to 6 months. One case of eggs was used for the initial examination. Two cases of eggs, one case with the eggs small end down and one case with the eggs small end up, were examined each month.

Experiment 2. Fifteen cases of eggs were used in experiment 2. One case was used for the initial examination. One-half of each of the remaining 14 cases was packed with the eggs small end down and the other half of each case with the eggs small end up. Six eggs from each tray, one from each corner and two from the center, were weighed and candled. Only grade A eggs were used in the six positions.

Seven cases of eggs were shaken for 30 minutes by the procedure described below. The eggs were then placed into storage at 40 to 45F. After one week the 7 cases were removed from storage, one case was used for examination and the remaining 6 cases were shaken for 30 minutes and returned to storage. This procedure was repeated at each withdrawal.

The remaining 7 cases of eggs were shaken for 3.5 hours prior to storage. One case was examined at each weekly withdrawal.

Experiment 3. Forty-five cases of eggs were prepared for storage as described for experiment 2. Fifteen cases of eggs were stored without further treatment, 15 cases were shaken for 3.5 hours and 15 cases were shaken for 7.5 hours. The initial examination was made on 3 cases of eggs, one case from each treatment. The remaining cases were stored at 40 to 45F and one case of each treatment was examined at each weekly withdrawal.

Procedure used for shaking the eggs. The eggs from experiments 2 and 3 were shaken to simulate motor truck transportation. The apparatus used was a Vibrating Package Testing Machine, Type 1000, manufactured by the L.A.B. Corporation, Summit, New Jersey. The test was made on this apparatus because it closely duplicates freight car and motor truck destructive forces. The eggs were subjected to a synchronous circular motion in vertical plane, at a speed of 200 r.p.m. The eggs were subjected to a force calculated to be 0.8 G. The test procedures were based upon the Standard Method for Vibration Testing for Shipping Containers, D-999-68 (A.S.T.M., 1969). Procedure A of the method was used i.e. the cases of eggs were not fastened to the bed of the tester.

Examination of the eggs. At each examination the eggs that had been weighed prior to storage were reweighed and the eggs from experiments 2 and 3 were recandled and graded A. B. C or Loss. All eggs were examined for mold growth on the shell and for cracks, checks and leakers.

Each egg was broken out and the interior quality examined by two methods: (1) graded according to the U.S. Department of Agriculture (U.S.D.A.) chart "Interior Quality of Eggs" and (2) the content of each egg was examined for the interior quality factors outlined in the U.S.D.A. Agriculture Handbook No. 75 "Egg Grading Manual". The height of the albumen of each of the eggs that had been weighed was measured with a dial micrometer gauge.

The effect of the position of the egg, the time in storage and shaking the egg were evaluated by (1) the change in weight, (2) the candled grade, (3) the internal grade, (4) the change in the height of the albumen, (5) the internal quality and (6) the change in the calculated quality score. The quality score was calculated from the data for weight of the egg and the height of the albumen. The equation presented by Brant et al. (1951) was used to calculate the quality score:

$$Q.\ S. = 13.25 - 12.5 \text{Log} (H - 1.7\ W^{0.37} + 7.6)$$

where: H is the height of the albumen in millimeters and W is the weight of the egg in grams.

The data were tested by an analysis of variance procedure. The analysis of variance results were tested by the method of Hicks (1956) to determine the components of variance.

RESULTS AND DISCUSSION

Initial quality of the eggs. Two to 8% of the eggs were candled at the suppliers plant, prior to delivery, by the resident U.S.D.A. grader. The eggs graded 93 to 98% A; 1 to 5% B; and 1 to 2% dirties and checks. The quality of the eggs is well within the tolerance set for [illegible] ment grade eggs by the U.S.D.A.

Experiment 1. Gradual deterioration in the internal grade occurred during the first 4 months of storage. Table 1 shows, however, that between the 4th and 6th months of storage the eggs declined precipitately in quality. The initial average quality as determined by internal grade indicated 93% A quality. After 4 months of storage 74% of the eggs were A quality. After 6 months the quality had declined to 26 and 23% A grade eggs for eggs stored small end down and up, respectively. A concomitant increase in the percentages of B and C quality eggs was noted. Table 2 shows the type of deterioration and the number and percent of eggs showing deterioration during the 6 months of storage. Only 0.15% of the eggs were classified as loss.

The average weight loss was 0.1 g. after 1 month and 2.3 g. after 6 months of storage. The height of the albumen decreased from an average value of 4.1 mm. at the initial examination to 3.6 and 3.7 mm. after 6 months for eggs stored small end down and up respectively. The quality score changed during storage from an initial value of 6.0 to 6.5 and 6.4 for eggs held small end down and up respectively. Results indi[illegible] the position of the egg, small end down or up, is not an important factor in the decline of quality when measured by the height of the albumen and the quality score when eggs are stored quiescently. The time in storage is the dominant factor. Table 2 shows that a slightly greater percentage of eggs stored small end down showed deterioration than eggs stored small end up. The difference was not statistically significant.

Table 3 shows the results of the analysis of variance and the calculated percentages of the variance attributable to storage time and position of the egg. The table confirms that the position of the egg has no significant influence on the quality factors: weight loss, quality score, and internal grade. The position of the egg was a significant influence ($p > 0.005$) on the change in the height of the albumen.

Experiment 2. Examination of the eggs out of storage revealed 0.1% cracks and 0.8% leakers for the total experiment. When the data were examin... according to the shaking pattern 0.1% cracks and 0.5% leakers were found in the eggs shaken intermittently during storage but only 0.1% each cracks and leakers were found in the eggs shaken prior to storage.

The effect of shaking on the grade of shell eggs as measured by candled (Table 4) and internal (Table 5) grade could not be determined. The results were erratic and no pattern of quality change could be delineated. Larzelere (1951) observed somewhat the same behavior when he followed eggs from their source on the farm to the retail store. He found that for every 100 grade A eggs on the farm 28 to 96 eggs were still grade A at the retail store.

Table 6 shows the type of deterioration and the percent of eggs showing deterioration in experiment 2. Comparison of the deterioration factors observed in experiment 2 with those in experiment 1 (Table 2) shows that a greater variety of serious defects were found in experiment 2. However, the data show that while 15.7% of the eggs had some kind of defect only 0.7%

were classified as loss. The effect of the pattern of shaking was noted. When eggs were shaken intermittently during storage 6.8% deterioration was found, whereas when eggs were shaken prior to storage 25.9% showed deterioration.

Table 7 presents the results of the analysis of variance and the percentage of variation for experiment 2. The table shows that the position of the egg was not a significant influence. The time in storage became less important than shown in experiment 1 when shaking was introduced as a factor, except for the change in weight where it contributed over 1/5 of the variance. The importance of shaking is shown in the table. However, Table 8 shows very little change in the average values for weight, albumen height and the calculated quality score from the initial examination to the 7 week withdrawal.

Experiment 3. The eggs were examined for condition of the shell at each withdrawal. For the total experiment 0.3% of the eggs had mold growth, 0.7% were classified as cracks.

The candled (Table 9) and internal (Table 10) grades showed erratic results and no statistical analysés were conducted.

Table 11 shows the type of deterioration and the number and percent of eggs showing deterioration during 14 weeks of storage. The table clearly shows that eggs stored small end down deteriorate to a greater extent than eggs stored small end up under the same conditions.

The effect of shaking on egg loss was determined. For the total experiment 2.6% were classified as loss. When the eggs were stored without shaking 0.3% were loss; the position of the egg showing no influence. After shaking for 2.5 hours the eggs stored small end down and up had 3.5 and 1.6% loss, respectively, during the storage period. After 7.5 hours of shaking 6.4 and 3.3% loss was found for eggs stored small end down and up, respectively.

An abnormal odor was noted in 0.05% of the eggs when they were broken out.

Little change was noted in the quality score during the 14 week storage period for eggs not shaken prior to storage. The quality score changed from 5.2 to 6.3 for eggs shaken for 2.5 hours and from 6.1 to 6.9 for eggs shaken for 7.5 hours prior to storage. Examination of the data for quality score by position of the egg shows that when eggs were stored small end down the quality score changed from 5.3 to 6.3. When the eggs were stored small end up the quality score changed from 6.0 to 6.3.

At the time of initial examination a 0.14 and 0.11 gram weight loss was noted for eggs shaken for 2.5 and 7.5 hours respectively. After 14 weeks of storage the average weight loss ranged from 1.1 to 1.4 grams.

The height of the albumen had an initial average value of 4.3 mm. During storage the height decreased to 3.9, 3.3 and 3.0 for eggs stored without shaking and eggs shaken for 2.5 and 7.5 hours, respectively.

Table 12 shows the results of the analysis of variance and the calculated percentages of the variance attributable to storage time, shaking and position of the egg, down or up, for the quality factors of weight loss, height of the albumen and quality score. In addition, the data for weight los were analysed for the influence of the place of the egg in the tray and the place of the tray in the case. The table clearly shows the influence of shaking on the height of the albumen and quality score. The position of the egg exerts considerable influence on the results, whereas the time in storage contributes only a small part of the variance. The place of the tray in the case showed a marked influence on the weight loss contributing about 2/3 of the variance. The table shows that the position of the egg was not a significant factor in the data for weight loss, and the place of the egg in the tray contributed only a small part of the variance.

In general, a greater percentage of defects occurred in eggs stored small end down than in eggs stored small end up (Tables 2, 6 and 11). It would seem logical from the consumer's standpoint to pack eggs with the small end up to aid in extending their storage life. A problem arises, however, because the egg distribution industry is geared to packing eggs with the small end down, and because the candled quality, the basic quality determinant to commerce, is better maintained when eggs are packed small end down. A solution would be to invert the eggs in the case or package by inverting the entire unit after final candling and prior to placing into storage or distribution. A modification in the design of the egg tray and carton would be required to make the egg cup bigger to accommodate the large end of the egg.

SUMMARY AND CONCLUSIONS

The inability of some egg packers to consistently comply with a tolerance of 5% for "upside down" eggs prompted an investigation to determine the importance of the position of the egg small end down or up, on quality during simulated transportation and long term storage. The literature of the field yielded little information applicable to this military supply problem.

Three experiments were conducted. In each experiment one-half of the eggs were stored small end down and one half were stored small end up. For experiment 1 the eggs were stored quiescently for up to 6 months at 40 to 45F. For experiment 2 one lot of eggs was shaken for 2.5 hours prior to storage and one lot was shaken for 2.5 hours in 30 minute increments during storage for 7 weeks at 40 to 45F. For experiment 3 one-third of the eggs were stored quiescently, one-third were shaken for 2.5 hours and one-third were shaken for 7.5 hours then stored for up to 14 weeks. Shaking was done on an apparatus designed to simulate motor truck transportation. Data were obtained on changes in weight, candled grade, internal quality, height of the albumen and quality score.

The results show that when eggs are stored quiescently as in experiment 1 the time in storage is the most important factor influencing quality changes in the eggs. The position of the egg is not a significant influence in the factors of weight loss and quality score and is a significant factor only at the 5% level for changes in the height of the albumen.

When shaking is introduced as a variable (experiments 1 and 3) it becomes the most important factor in influencing quality changes as measured by the height of the albumen and quality score but has less influence on the change in weight. The time in storage is a significant factor but contributes only 1.5 to 3.7% of the variance for the height of the albumen and quality score. Storage time is more important in influencing changes in weight contributing between 16 and 22% of the variance. The position of the egg did not influence the results of experiment 2 for changes in weight, height the albumen and quality score. In experiment 3 the position of the egg was a significant influence on the height of the albumen and quality; contributing about 30% of the total variance.

Shaking of the eggs resulted in more deterioration than in eggs not shaken. About 3.8 times the number of eggs were deteriorated when the eggs in experiment 2 were shaken prior to storage than when eggs were shaken intermittently during storage. The length of shaking prior to storage also influenced the amount of deterioration noted.

The position of the egg was an important influence on the amount of deterioration noted. The eggs stored small end down had about twice as many deteriorated eggs as the eggs stored small end up.

Based upon the results of this study the requirement restricting the percentage of eggs that may be packed small end up will be eliminated from Federal Specification C-E-271 Eggs, Shell.

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Table 1. Changes in the Grade of Shell Eggs as Measured by the Internal Grade. Experiment 1.

MONTHS IN STORAGE	PERCENTAGES OF EGGS STORED SMALL END DOWN GRADING					PERCENTAGES OF EGGS STORED SMALL END UP GRADING				
	AA	A	B	C	LOSS	AA	A	B	C	LOSS
0	2	93	4	1	0					
1	2	88	7	2	<1	2	90	6	<1	<1
2	<1	84	15	<1	0	0	83	14	3	0
3	0	78	16	6	0	0	83	15	2	0
4	<1	74	20	5	<1	1	74	21	4	<1
5	0	38	43	19	0	0	42	39	18	<1
6	0	26	48	25	<1	0	23	46	30	<1

Table 2. Type of deterioration and the number and percent of eggs showing deterioration initially and during storage at 40 to 45F for 6 months. Experiment 1.

Type of Deterioration	360 Eggs Initial	2,160 Eggs Stored Small End Down	2,160 Eggs Stored Small End Up
		%	
Albumen off color	0.0	0.0	0.14
Bloody white	0.0	0.05	0.09
Stuck yolk	0.0	0.14	0.0
Meat or blood spots	0.6	1.39	1.25
Cloudy white	0.0	0.0	0.05
Mottled yolk	2.2	4.49	3.15
Number and percent of eggs showing deterioration (by position)		131 (6.1%)	101 (4.7%)
Number and percent of eggs showing deterioration (Total)		242 (5.2%)	

Table 3. Results of the Analysis of Variance (ANOVA) and the Calculated Percentage of Variation for Experiment 1.

Factor	WEIGHT LOSS		HEIGHT OF ALBUMEN		QUALITY SCORE		INTERNAL GRADE	
	ANOVA	Percentage of Variation	ANOVA	Percentage of Variation	ANOVA	Percentage of Variation	ANOVA	Percentage of Variation
Storage Time	**	99.8	**	72.9	**	97.8	**	99.8
Position of Egg	n.s.	--	*	26.3	n.s.	-	n.s.	-
Interaction	n.s.	--	n.s.	--	n.s.	-	n.s.	-
Not Accounted for	-	0.2	-	0.8	-	1.3	-	0.2

** p > 0.01   * p > 0.05   n.s. - not significant

Table 4. Changes in the Grade of Shell Eggs as measured by Candling. Experiment 2.

Storage Time in	Eggs Shaken Intermittently for 3.5 Hours								Eggs Shaken for 3.5 Hours Prior to Storage							
	Percentage of Eggs Stored with Small End Down Grading				Percentage of Eggs Stored with Small End Up Grading				Percentage of Eggs Stored with Small End Down Grading				Percentage of Eggs Stored with Small End Up Grading			
Weeks	A	B	C	LOSS	A	B	C	LOSS	A	B	C	LOSS	A	B	C	LOSS
0	61	33	6	0	72	25	3	0	1/							
1	78	19	3	0	78	19	3	0	42	58	0	0	14	69	14	3
2	58	42	0	0	42	55	3	0	33	64	3	0	8	92	0	0
3	28	66	3	3	23	69	8	0	28	66	6	0	6	80	14	0
4	3	88	11	0	25	53	22	0	14	64	19	3	0	14	72	14
5	6	86	8	0	6	55	39	0	6	80	11	3	3	80	14	3
6	25	58	17	0	8	58	28	6	0	64	36	0	14	72	11	3
7	22	56	11	11	8	78	11	3	30	64	3	3	14	80	6	0

1/ One case used for initial grading.

Table 5. Changes in the Grade of Shell Eggs as Measured by Internal Grading. Experiment 2.

Storage Time in	Eggs Shaken Intermittently for 3.5 Hours								Eggs Shaken for 3.5 Hours Prior to Storage							
	Percentage of Eggs Stored with Small End Down Grading				Percentage of Eggs Stored with Small End Up Grading				Percentage of Eggs Stored with Small End Down Grading				Percentage of Eggs Stored with Small End Up Grading			
Weeks	A	B	C	LOSS	A	B	C	LOSS	A	B	C	LOSS	A	B	C	LOSS
0	72	24	4	0	76	22	1	1	1/							
1	89	9	1	1	88	10	2	1	73	22	4	1	66	25	6	3
2	89	9	2	0	97	3	0	0	92	6	1	1	81	16	3	0
3	89	10	0	1	90	8	1	1	76	17	6	1	68	30	20	0
4	94	6	0	0	64	30	5	1	22	52	19	7	13	50	19	17
5	75	23	1	1	71	24	4	1	34	58	5	3	21	60	16	3
6	65	30	4	1	68	22	2	8	31	56	4	9	23	69	6	2
7	67	19	1	13	76	22	0	2	23	63	12	2	5	74	20	1

1/ One case used for initial grading.

Table 6. Type of deterioration and the number and percent of eggs showing deterioration initially and during storage at 40 to 45F for 7 weeks. Experiment 2.

Deterioration factor	360 eggs initial	2,520 eggs stored small end down: 1,260 eggs shaken during storage	2,520 eggs stored small end down: 1,260 eggs shaken before storage	2,520 eggs stored small end up: 1,260 eggs shaken during storage	2,520 eggs stored small end up: 1,260 eggs shaken before storage
	%	%	%	%	%
Albumen off-color	0.0	0.1	3.1	0.3	2.1
Bloody white	0.0	0.1	0.0	0.1	0.0
White rot	0.0	0.0	0.0	0.0	0.4
Green rot	0.0	0.0	0.1	0.1	0.2
Black rot	0.0	0.0	0.1	0.0	0.1
Mixed rot	0.0	0.1	0.1	0.0	0.0
Sour	0.6	0.1	0.0	0.0	0.8
Meat or blood spots	0.3	0.4	0.3	0.2	0.1
Cloudy white	0.0	0.0	0.2	0.3	0.2
Mottled yolk	6.0	8.4	28.9	3.3	14.9
No. and percent of eggs showing deterioration (by position and shaking pattern)		115 (9.2%)	414 (32.8%)	56 (4.3%)	239 (11.7%)
No. and percent of eggs showing deterioration (by position)		529 (21.0%)		295 (11.7%)	
No. and percent of eggs showing deterioration (total)		849 (15.7%)			

Table 7. Results of the analysis of variance (ANOVA) and the calculated percentage of variation for experiment 2.

Factor	Change in weight		Height of albumen		Quality score	
	ANOVA	Percentage of variation	ANOVA	Percentage of variation	ANOVA	Percentage of variation
Storage time	**	22.2	**	1.5	**	3.2
Shaking	**	76.0	**	97.4	**	94.3
Position of egg	n.s.	-	n.s.	-	n.s.	-
Storage time X shaking	**	1.7	**	0.5	**	1.0
Storage time X position of egg	n.s.	-	**	0.5	**	1.3
Shaking X position of egg	n.s.	-	n.s.	-	n.s.	-
3-factor interaction	n.s.	-	**	0.1	**	0.2
Not accounted for	-	< 0.1	-	< 0.1	-	< 0.1

** p > 0.01   n.s. not significant

Table 8. The average weight, height of albumen and quality score initially and after 7 weeks of storage. Experiment 2.

Conditions	Weight (g)		Height of Albumen (mm)		Quality score	
	Initial	7 weeks	Initial	7 weeks	Initial	7 weeks
Eggs stored small end down; intermittent shaking	52.9	52.1	3.2	4.2	6.9	6.4
Eggs stored small end up; intermittent shaking	52.9	50.9	3.9	3.9	5.7	7.2
Eggs stored small end down; shaken prior to storage	52.6	52.2	3.2	2.7	6.9	6.3
Eggs stored small end up; shaken prior to storage	52.9	52.1	3.9	2.9	5.7	7.3

TABLE 9. Changes in the grade of shell eggs as measured by candling. Experiment 3.

Storage time	Eggs not shaken								Eggs shaken for 2.5 hours at 200 r.p.m.								Eggs shaken for 7.5 hours at 200 r.p.m.							
	Percentage of eggs stored with small end down grading				Percentage of eggs stored with small end up grading				Percentage of eggs stored with small end down grading				Percentage of eggs stored with small end up grading				Percentage of eggs stored with small end down grading				Percentage of eggs stored with small end up grading			
(weeks)	A	B	C	Loss	A	B	C	Loss	A	B	C	Loss	A	B	C	Loss	A	B	C	Loss	A	B	C	Loss
0	100	0	0	0	100	0	0	0	100	0	0	0	100	0	0	0	86	14	0	0	78	19	3	0
1	92	8	0	0	92	5	0	3	36	56	8	0	3	80	17	0	36	64	0	0	36	47	17	0
2	81	19	0	0	83	17	0	0	94	6	0	0	92	8	0	0	33	64	3	0	28	58	14	0
3	100	0	0	0	97	3	0	0	36	44	17	3	22	61	17	0	75	25	0	0	55	42	0	3
4	100	0	0	0	94	6	0	0	94	6	0	0	86	14	0	0	86	14	0	0	89	11	0	0
5	94	6	0	0	94	3	3	0	97	3	0	0	78	19	3	0	47	47	3	3	25	69	6	0
6	94	6	0	0	89	11	0	0	78	22	0	0	42	58	0	0	47	47	6	0	31	58	11	0
7	89	8	0	3	97	3	0	0	92	5	0	3	61	39	0	0	89	11	0	0	78	22	0	0
8	75	25	0	0	92	5	0	3	85	17	0	-	39	61	0	0	28	58	3	11	44	28	28	0
9	86	14	0	0	89	11	0	0	75	17	3	5	28	67	5	0	86	14	0	0	56	44	0	0
10	75	25	0	0	58	42	0	0	33	17	0	0	58	42	0	0	89	11	0	0	64	36	0	0
11	78	22	0	0	47	53	0	0	33	61	3	3	6	94	0	0	78	22	0	0	58	42	0	0
12	72	28	0	0	86	14	0	0	44	53	3	0	25	72	3	0	20	50	11	19	11	69	17	3
13	78	22	0	0	81	19	0	0	42	55	3	0	25	69	3	3	19	42	6	33	3	67	30	0
14	94	6	0	0	97	3	0	0	17	61	14	8	3	83	14	0	42	47	8	3	17	58	19	6

TABLE 10. Changes in the grade of shell eggs as measured by internal grading. Experiment 3.

Storage Time (Weeks)	Eggs not shaken								Eggs shaken for 2.5 hrs at 200 r.p.m.								Eggs shaken for 7.5 hours 200 r.p.m.							
	Percentage of eggs stored with small end down grading				Percentage of eggs stored with small end up grading				Percentage of eggs stored with small end down grading				Percentage of eggs stored with small end up grading				Percentage of eggs stored with small end down grading				Percentage of eggs stored with small end up grading			
	A	B	C	Loss	A	B	C	Loss	A	B	C	Loss	A	B	C	Loss	A	B	C	Loss	A	B	C	Loss
0	92	6	2	0	93	7	0	0	84	14	2	0	83	9	8	0	82	12	6	0	87	10	3	0
1	85	13	2	0	82	15	3	0	58	25	17	0	51	34	15	0	79	18	2	1	67	19	14	0
2	91	9	0	0	88	10	2	0	82	15	3	0	92	7	1	0	42	33	18	7	48	27	19	6
3	83	16	1	0	87	10	1	0	40	41	14	5	53	30	16	1	61	35	3	1	51	46	2	1
4	68	31	1	0	86	12	2	0	61	37	1	1	68	31	1	0	69	30	1	0	76	23	1	0
5	65	34	1	0	82	17	1	0	61	34	4	1	69	30	1	0	41	34	21	4	59	22	18	1
6	65	32	1	2	61	35	4	0	69	28	1	2	53	40	3	4	47	30	20	3	47	34	17	2
7	78	21	0	1	86	14	0	0	81	16	0	3	73	22	3	4	60	33	6	2	65	30	4	1
8	81	19	0	0	82	16	1	1	59	36	2	3	75	23	1	1	32	43	14	11	35	24	30	11
9	80	18	1	1	84	16	0	0	72	24	2	2	74	23	2	1	83	15	1	1	72	27	1	0
10	78	21	1	0	82	17	1	0	40	44	13	3	79	20	0	1	54	33	12	1	59	34	6	1
11	68	29	3	0	70	26	4	0	33	39	16	12	54	29	13	4	45	44	11	0	70	26	3	1
12	73	22	4	1	69	28	2	1	44	39	13	4	64	26	0	1	25	37	21	17	32	36	23	9
13	67	29	3	1	77	19	3	1	34	49	1	2	63	30	14	3	15	28	25	32	24	27	39	10
14	70	27	3	0	69	28	2	1	43	34	15	8	62	29	16	3	29	50	14	7	35	37	19	9

Table 11. Type of deterioration and the number and percent of eggs showing deterioration during storage at 40 to 45F. for 14 weeks. Experiment 3.

Type of deterioration	Eggs stored with small end down			Eggs stored with small end up		
	No shaking	2.5 hrs shaking	7.5 hrs shaking	No shaking	2.5 hrs shaking	7.5 hrs shaking
			%			
Albumen off color	0.11	0.92	3.74	0.11	0.26	0.96
White rot	0.04	1.11	1.26	0.0	0.18	1.18
Black rot	0.06	.89	2.70	0.0	0.37	0.74
Mixed rot	0.07	0.74	1.62	0.15	0.22	0.89
Stuck yolk	0.15	0.74	0.85	0.15	0.78	0.22
Meat or blood spots	0.18	0.67	0.37	0.55	0.11	0.26
Cloudy white	0.52	0.89	1.37	0.78	1.85	8.37
Mottled yolk	4.07	16.74	27.44	2.18	8.37	8.23
Green white	0.0	0.04	0.0	0.0	0.0	0.04
Bloody white	0.04	0.0	0.0	0.0	0.0	0.0
Green rot	0.04	0.04	0.0	0.0	0.0	0.0
No. and percent of eggs showing deterioration (by shaking pattern)	141 (5.2%)	615 (22.8%)	1,064 (39.4%)	104 (3.9%)	224 (8.3%)	554 (20.8%)
No. and percent of eggs showing deterioration (by position)	1,820 (22.5% of eggs small end down)			882 (10.9% of eggs small end up)		
No. and percent of eggs showing deterioration	2,702 (16.7% of total)					

Table 12. Results of the analysis of variance (ANOVA) and the calculated percentage of variation for experiment 3.

Factor	Weight loss		Height of albumen		Quality score	
	ANOVA	Percentage of variance	ANOVA	Percentage of variance	ANOVA	Percentage variance
Storage time	**	15.8	**	3.7	**	3.3
Shaking	**	12.7	**	62.5	**	68.5
Position	n.s.	-	**	32.7	**	27.2
Place of egg in tray	**	5.1	1/		1/	
Place of egg in case	**	65.3	1/		1/	
Storage time X shaking level	**	0.3	**	0.5	**	0.5
Storage time X position of egg	n.s.	-	**	0.4	**	0.4
Storage time X place of egg in tray	*	0.1	2/		2/	
Storage time X place of tray in case	**	0.6	2/		2/	
Shaking level X position of egg	n.s.	-	n.s.	-	n.s.	
Factor interaction	n.s.	-	**	0.1	**	0.1
Not accounted for	-	0.1	-	0.1	-	0.1

* P>0.05 ** P>0.01 n.s. - not significant

1/ Effect not determined.

2/ Not applicable.