THE EFFECT OF WASHING EGGS ON THEIR HATCHABILITY AND STORAGE QUALITY

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By

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INTRODUCTION

Dirty eggs present a problem to the entire poultry industry. The hatcheryman is hesitant about buying dirty hatching eggs. This arises from the belief that such eggs, especially those which are extremely dirty, will not hatch as well as clean eggs. Dirty eggs going into the incubators also offer a possible source of infection for many kinds of poultry diseases. Likewise, the produce dealer has discriminated against dirty eggs because they do not appeal to the consumer, and because these eggs, if put into storage, result in a high loss due to bacterial contamination and subsequent spoilage. The logical question then is whether or not these dirty eggs should be cleaned or whether they should be sold as a low grade product.

Washing is one means of cleaning these eggs prior to incubation or storage. In the past the poultry industry has advocated that such eggs should not be washed. Such recommendations have usually revolved around the belief that washing destroys or removes the cuticle or "bloom" of the shell, therefore causing excessive loss of moisture, and consequently a corresponding loss in market value as well as a reduction in hatchability. Some authors have taken the view that washing is the most objectionable method of cleaning eggs even when disinfectants are used. They believe that the cuticle is soluble in water and is washed off of the shell and out of the pores, thus providing a passageway for micro-organisms to enter the egg.

There are some indications that such views about washing eggs are not justified, especially if the job is properly done.

It has been shown that there is a difference in the coefficient of expansion between the contents of the egg and the egg shell. Since such a thermotic principle does exist, it appears necessary when washing eggs to take into consideration the temperature of the washing solution, as well as the selection of a cleaning agent which will do a good job.

The objectives of this investigation are:

1. To determine the effect of washing eggs in different solutions and in different ways on their hatchability.
2. To determine the effect of washing eggs on their storage qualities.
3. To determine whether washed eggs lose more or less moisture than unwashed eggs.
4. To provide more information upon which to make recommendations to the poultry industry on the washing of both hatching and storage eggs.

REVIEW OF THE LITERATURE

Since this investigation deals with the removal of dirt from the shell of the egg by washing with different solutions and by different methods, it seems desirable to review the literature on the different parts of the shell of the hen's egg.

The Egg Shell Structure -- The shell of the hen's egg is composed of six essential parts: the shell membranes, matrix, mammilla layer, spongy layer, cuticle or "bloom," and the pores. Within the last century a number of researchers, Rizzo (1899), Clevisch (1913), Almquist and Holst (1931), Sharp (1932), Calvery (1933), Stewart (1935), and Marshall and Cruickshank (1938), have investigated the properties and structure of the hen's egg. Stewart has given a good review of these works with an excellent list of references.

The two shell membranes, the inner and outer, are composed of a network of microscopic fibers. Very early workers such as Landois (1865) and Blasius (1867), quoted from Stewart (1935), have shown this to be true. Later workers, Clevisch (1913) and Smith (1930), have confirmed these early works. Asmundson and Burmester (1936) have shown that these membranes are formed in the isthmus of the oviduct as the egg is passing from the magnum to the uterus. Giersberg (1921), quoted from Conrad and Scott (1938), in a study of the structure of these shell membranes, described their formation as being secretions of material in the form of droplets which later coalesce into fibers. There has been considerable difficulty on the part of researchers in measuring the thickness of these membranes. Hays and Sumbardo (1927) found the inner membrane to be only 0.015 mm. thick with the fibers very closely matted together, while the outer membrane, being much coarser and more loosely matted together, has a thickness of 0.05 mm. Calvery (1933) has demonstrated that the protein composition of the shell membranes is that of a typical keratin. He defined a keratin as "a protein which is resistant to digestion by pepsin and trypsin, which is insoluble in dilute acids and alkalies, in water, and in organic solvents, and which on hydrolysis, yields quantities of histidine, lysine, and arginine so that the molecular ration of these amino acids are respectively approximately as 1:4:12."

Immediately to the outside of these shell membranes is a hard calcareous layer which is the shell proper. This shell is deposited on the egg in the uterus of the oviduct. Although it has not been determined just how the calcite crystals are formed, Burmester, Scott and Card (1939) have demonstrated that shell formation is rapid with more that 50 percent of the calcium carbonate being laid down in the first 13 hours the egg is in the uterus.

The inner part of this hard shell is known as the mammilla layer and is composed of a large number of peculiarly protruding processes which are spherical and distinct from the remainder of the shell. The knobs are exceptionally large spherical calcite crystals and crystals of calcium phosphate. Kelly (1901), quoted from Stewart (1935), by using a polarization microscope, was able to identify these crystals as calcium phosphate. Within the center of each knob of the mammilla layer there is a darkened area which is stained by a protein dye. Nathusius (1868) has shown that these strands of organic material are insoluble in acids but will dissolve when subjected to alkalies and heat.

The second or outer part of the calcareous shell is known as the spongy layer. Landois (1865) believed this layer to be structureless, but Kelly (1901) and others have shown that it is composed of a very fine deposit of irregular calcite crystals, the lower portion of which contains some calcium phosphate crystals. These very small irregular shaped crystals are perpendicular to the surface of the shell. This spongy layer of the shell makes up about two-thirds of the entire shell thickness which ranges between 0.23 to 0.46 mm., Stewart (1935). Although some workers have thought the mammilla and the spongy layers to be only a single layer, they are so much different physically and in crystal structure that they can well be considered distinct and separate.

Within these two mineral layers of the shell there is an interlacing of organic material which appears to serve as a matrix in and around which the inorganic mineral salts are deposited. Since this matrix of organic matter is stained by protein dyes, Almquist (1934) undertook to determine what type of protein it is. He concluded from his tests that is is a collagen.

Immediately on the outside of the mineral portion of the shell is a very thin outer covering called the cuticle or "bloom." This layer has been described by Stewart (1935) as having a deep layer containing nucleated cells and having what appears to be a basement membrane next to the spongy layer. This superficial covering of protein upon drying tends to crack considerably around the pore entrances, thus greatly increasing the effective evaporation surface, Stewart (1936) and Marshall and Cruickshank (1938).

Marshall and Cruickshank (1938) described the thickened areas of protein, which cover the pores of the shell, as "plaques." These "plaques," although continuous with the cuticle and similar to it, are different and stain darker than the cuticle.

The cuticle is probably formed in the uterus but just how it is formed is not known. Richardson (1936), by histological methods, was unable to show that any protein was secreted by the uterus. Beadle et al (1939) found only small amounts of protein in the uterine secretion. They conclude that this small amount probably diffuses through the shell membranes after the egg enters that region. These researchers have shown upon a number of occasions that it is possible for the albumen protein to pass through the shell membranes. Conrad and Scott (1938) have ventured the possibility that such proteins after diffusing out of the white of the egg and through the shell membranes may be rendered insoluble by "surface denaturation." This is a possible explanation of the way the cuticle is formed, since it is known that albumen can be denatured by absorption on a surface.

Plimmer and Rosedale (1925) and Calvery (1933) have shown that the cuticle protein is a keratin. Bryant and Sharp (1934) conclude that the protein covering is not removed by washing, while Munday (1947) states that the "bloom" is soluble in water and that there are individual differences in hens with respect to solubility of the "bloom." It is hard to see how it could be possible for a coating of protein which is insoluble in acid and alkalies and water to be dissolved by the mere washing or wetting of the egg.

Some workers have thought that the disappearance of the flourescence which a new laid egg gives off indicates that the cuticle has been destroyed. Klose and Almquist (1937) have shown that this is not true. Sharp (1932, 1935) suggests a test for the presence of the cuticle by the use of the protein dyes, methylene blue or rosaniline hydrochloride. This test, when used after the flourescence has disappeared, will show that protein is still on the shell of the egg.

Within the heterogeneous network of calcite crystals and organic matter of the shell proper, there are small but definite tubelike passageways. These passageways, or pores, are perpendicular to the shell surface and penetrate all the way through the shell from the surface to the shell membranes. The pores average from 0.038 to 0.054 mm. in diameter.

Rizzo (1899), quoted from Almquist and Holst (1931), showed by a staining procedure that there is a large number of pores in the egg shell. He concluded that there are about 7000 in the normal shell. Almquist and Holst (1931) and Bryant and Sharp (1934) have shown by two different methods that the number of open pores is less than that reported by Rizzo (1899).

<u>The Effect of Porosity (Weight-Loss) on Hatchability</u> -- A number of researchers have shown that weight-loss per unit of shell surface area is a good measure of porosity; Marshall and Cruickshank (1938), Mueller and Scott (1940), and Black and Tyler (1944).

There is some disagreement as to the effect of weight-loss on hatchability. Mueller and Scott (1940) using the weight-loss per square centimeter of surface were unable to find any relationship existing between weight-loss and hatchability. Hays and Sumbardo (1927), in studying the relationship between various physical characters and hatchability, figured the number of pores per square centimeter in the equatorial region of the egg and concluded that the number of pores did not seem to be a factor in hatchability. These workers also checked the relative permeability of the shell and could find no relationship between it and hatchability. Funk (1934) divided eggs into good and poor shell texture and checked the hatchability. This work was somewhat vague as to the criterion of good and poor shell texture, but it is believed that mottling was the main basis for selection. Under the conditions of this experiment it was found that there was no statistical difference between good and poor shell texture in relation to hatchability.

Other workers, Dunn (1923 - 1924), Axelsson (1932), Henderson (1941) and Godfrey (1949), found that there was a relationship existing between the weight-loss of the egg during incubation and hatchability. Dunn, using small numbers of eggs from inbred lines, the shells of which were extremely thin and porous, found the hatchability to be low. He concluded, however, if shell characteristics such as porosity were highly correlated with hatchability, then slight deviations from the normal conditions would be in the nature of morbid or lethal variations. Such extreme conditions of thin and very porous eggs are probably inherited and since few if any of such eggs will hatch, the force of natural selection reduces the population producing such abnormal shells. Axelsson (1932), using weight-loss from the 7th to the 14th day, found a significant difference between groups of eggs which lost weight at different rates and the percentage of hatchability. Godfrey (1949), with 6385 eggs, showed that eggs with a 14-day incubation weight-loss of 11 percent or less hatched better than those eggs with a higher percent weight-loss.

Henderson (1941, 1942) in an interesting approach to the question of weight-loss on hatchability set up apparent porosity scores from 1 to 5 based on candling appearance. He found a high significant negative correlation of -0.17, for 847 degrees of freedom, between these apparent porosity grades and hatchability.

<u>The Effect of Washing Eggs on Their Hatchability</u> -- It has been held for many years that when the egg is washed the cuticle is removed, and therefore the egg does not hatch well because of excessive moisture loss, Lippincott and Card (1934). The belief that bacterial contamination is introduced into the egg when it is washed is another commonly held notion. Perhaps some of these views developed from the work of such early researchers as Jackson (1912). After washing both clean and dirty eggs and comparing them with unwashed controls, he concluded that washing was detrimental. His views were not consistent, however, as he recommended the washing of nest soiled eggs.

Funk (1940) obtained data which indicates that eggs soiled by poultry manure, both washed and unwashed, hatch equally as well as clean eggs. Eggs were washed both with tap water and a one percent solution of sodium hydroxide with no reduction in hatchability. Further investigation by Funk (1942a) shows that cleaning with warm water or one percent sodium hydroxide may even increase hatchability; however, no temperatures were suggested at which to keep the washing solution.

Olsen and McNally (1947) give some indications as to how eggs will react when subjected to various solutions. These researchers presented data to show that eggs immersed in different disinfectant solutions (2 percent sodium hydroxide, 1 percent sodium orthophenylphenate and 1/10 percent quaternary ammonium) would hatch as well as untreated eggs.

Funk and Forward (1949) studied the effect of washing hatching eggs with a 0.38 percent Roccal (10 percent) solution. (Roccal is a quaternary ammonium compound.) Twelve hundred and fifteen soiled hatching eggs washed with this solution and compared to clean eggs indicated no significant differences in the hatchability of the two groups. The washing solution was held at room temperature while washing. Eggs to be washed were cooled prior to washing.

There have been very definite indications in recent years that the temperature of the solution has some influence on the results to be obtained when washing eggs. Solution temperature higher than the temperature of the egg is desirable. There is the possibility that the temperature can be too high. Barott and McNally (1943) in a study of the work done by Funk (1943) pertaining to the thermo-stabilization of eggs reported that embryonic death in eggs heated to 122^{o}F. was complete in about 26 minutes while in eggs heated to 141^{o}F., the lethal time was reduced to approximately 7.5 minutes. This is cited to show that any relatively high temperature to which hatching eggs are subjected must of necessity be quite short in duration.

Pritsker (1941) was one of the first investigators to realize that the temperature of the water may be an important consideration when washing or dipping eggs in a disinfectant solution. Eggs were chilled to 8 to 10°C. and immersed in disinfectant (0.5 percent formalin) solution at 23 to 25°C. Other eggs were chilled the same and washed in water warmed to 23 to 25°C. The contents of the egg have a greater coefficient of expansion than the shell, and thus the immersion of these cold eggs into solutions which were warmer produced an internal pressure within the egg having a tendency to force filth out of the pores rather than suck it in. By altering the temperatures of the eggs and washing solutions, an external pressure was produced which tended to force filth and micro-organisms into the egg. Control eggs with no treatment were also used. While there was not too much difference between the controls and the eggs treated to produce internal pressure, there was a consistently smaller percent of hatch in those eggs treated to produce an external pressure.

Zich (1948) reported that one poultryman who produces embryonated eggs for vaccine propagation has been washing eggs for some time with hot water and detergents with no reduction in the number of live embryos.

<u>The Effect of Porosity (Weight-Loss) on Storage Quality</u> -- Weight-loss is an accurate measure of porosity as shown by Almquist and Holst (1931), Perry (1936), Marshall and Cruickshank (1938), and Mueller and Scott (1940).

Some of the early studies on weight-loss were made by Dunn (1923a, 1923b) in which he showed that individual eggs do vary considerably in the rate at which they lose moisture both over short and moderately long periods of storage.

Marshall and Cruickshank (1938) found that eggs with numerous pores lost seven to thirty-three times more moisture than shells of low porosity. Perry (1936) in his work found apparent porosity and shrinkage to be significantly correlated, and concluded that "loss of weight during storage can be reduced by storing only eggs with shells of slight apparent porosity."

Almquist and Holst (1931) subjected eggs to different temperatures in storage to determine just what effect storing might have on the porosity of the shell. Eggs were kept at room temperature (about 68°F.), at 86°F., and at 102°F. for 25 days. From this study it was found that porosity is not necessarily a fixed character. It may increase with the age of the egg and with high storage temperatures.

The Effect of Washing on Storage Quality and Weight Loss -- The current belief about the storage of dirty eggs is that the keeping quality is materially reduced because washing removes the cuticle from the egg and thus opens the pores to the invasion of micro-organisms. Another belief commonly held is that by washing the cuticle is removed and thus much faster evaporation of moisture from the egg occurs through the open pores. Such beliefs may have their foundation in such work as was done by Bushnell and Maurer (1914). They state that the susceptibility of bacterial invasion is increased by washing eggs before storage and especially so if rubbed with a dirty cloth and put into the cellar before storage. Jenkins et al (1920) confirm these results.

Bryant and Sharp (1934), in a study to determine the effect of washing upon the keeping quality of eggs, concluded that the cuticle is not removed by washing with water, and if it is, moisture is not lost any faster. They obtained some data on eggs from which the cuticle had been taken off which indicated that eggs will actually lose less moisture when the cuticle is removed. Bryant and Sharp concluded from their investigations that there is no foundation for the belief that washing in itself causes eggs to deteriorate, if they are properly handled after washing. They further state that the deterioration of the egg is caused by bacterial infection from dirt which is on the shell rather than the result of increased weight-loss due to washing.

Parsons and Mink (1939) in a review of some methods of cleaning eggs gave some data of interest relative to weight-loss. This experiment was run on a commercial basis. Three lots after being stored for 124 days at 29½ to 30½°F. and 80 to 90 percent relative humidity lost weight as follows: controls 1.67 percent, wet sawdust treatment 1.57 percent and dilute acid treatment 1.60 percent. This adds strength to the belief of Bryant and Sharp (1934) that eggs which have been washed will not lose moisture more rapidly in storage than eggs which have not been washed.

In a study of the keeping quality of eggs, Funk (1938a, 1938b) presented evidence showing that dirty eggs can be effectively cleaned by using a one percent sodium hydroxide solution. Eggs so cleaned kept equally as well in storage as clean eggs which were not washed.

From tests conducted by Mallman and Davidson (1944), it was concluded that washing with water reduces the protective function of the cuticle, but washing with a detergent, sodium lauryl sulfate, materially increases the susceptibility of the egg to invasion by micro-organisms. It should be noted, however, that these researchers did not report any temperatures on their washing solution. It must, therefore, be assumed that they used water at room temperature which may account for their poor results with washing.

That successful washing of storage eggs is dependent upon temperature has been suggested by a number of workers with some results to support their convictions as early as 1938. Haines, quoted by Diehl (1948), suggested the possibility that a washing solution of higher than egg temperature will force micro-organisms out of the pores. Pritsker (1941), although working with hatching eggs, offered the same reason for the increase in temperature of the washing solution. Funk (1942b) reported a progressive decrease in the spoilage of storage eggs from 24 percent to 1.3 percent as the temperature was raised from 40°F. to 120°F. Gunderson and Gunderson (1945) and Gunderson (1946) corroborated this work on the effectiveness of high temperatures and stated that higher temperatures cause a decrease in the number of bacteria in the water. They did not recommend the use of any germicides. It was recommended, however, that a machine be used which will scrub and spray hot water at a temperature of at least 150°F. at the same time. This procedure reduces the possibility of further contamination by dirty water.

Wright, Hall and Stark (1947) and Hall (1949) tested the effect of washing dirty eggs on their keeping quality. Dirty eggs were divided into three lots and washed with plain water at different temperatures. The temperatures used were room temperature, 100°F. to 120°F. and 160°F. In all cases the eggs washed in the cold water (room temperature) showed more spoilage than clean eggs which were unwashed, and in all cases, eggs washed in a solution of 160°F. or warmer kept just as well as clean unwashed eggs. Funk (1948) confirmed these findings by concluding that it is necessary for best results to have the temperature of the washing solution higher than that of the eggs.

Zich (1948) states that eastern producers are rapidly taking to the practice of washing eggs with hot water and detergents. Although no mention was made of eggs going into storage, it was recommended that eggs be washed in a solution of 140 to 160°F. and sprayed with hot water after washing.

Diehl (1948), in a good summary and review of washing eggs for storage, emphasizes that hot water is quite important in the proper washing of eggs to prevent spoilage.

EXPERIMENTAL PROCEDURE

The belief has been held for many years that the washing of eggs will cause a reduction in hatchability as well as a loss in storage quality. These experiments were undertaken to determine the effects of washing upon hatchability, and to see if such washed eggs keep as well as clean unwashed eggs in storage. To carry out this investigation, the following materials and procedures were used.

Hatchability -- All eggs for these experiments were from the Oklahoma Agricultural Experiment Station strains of New Hampshires, Barred Plymouth Rocks, Silver Oklabars, Gold Oklabars and Single Comb Rhode Island Reds. Eggs were set January 28, March 4 and April 8, 1949 for Replications I, II and III respectively. All eggs were held at approximately 50°F. prior to incubation and distribution of these eggs into the lots was at random. Potassium permanganate was used to number the eggs so they could be identified after washing. Because of the relatively few dirty eggs available at the Experiment Station, one-half of the eggs from each treatment were dirtied artificially. These eggs were soiled by dipping them in a compost of poultry manure to which tap water had been added. The temperature of this mixture was about 70°F. After the eggs were soiled, they were placed on egg flats and allowed to dry. It was observed that these eggs were still wet on the small end 12 hours after they were dipped in the compost. This gave ample opportunity for bacteria to enter the egg. These artificially dirtied eggs were held from 2 to 7 days in different replications prior to washing and incubating to determine if the length of time being dirty would affect hatchability.

The solutions, temperatures, and methods used in each replication were as follows:

1. No treatment. Controls.

2. Basket-dipped in a solution of "Suds Mor." * "Suds Mor" is a commercial detergent recommended especially for the washing of eggs. This solution was made by putting 1 tablespoon of "Suds Mor," as recommended by the manufacturer, into each gallon of water heated to 155°F. The eggs were placed in a wire basket and dipped ten times in this solution, sprayed with hot water at 140°F. for 15 seconds, then sprayed with tap water 15 seconds, and allowed to drain dry in the basket.

3. Basket-dipped in a solution of "Breeze." "Breeze" is a detergent which is available at any grocery store. This solution was made by putting 1 tablespoon of "Breeze" into each gallon of water heated to 150°F. The dipping and spraying procedure was the same as that described in treatment 2 with the temperatures of the spray waters being the same.

4. Machine-washed with clean hot water. The eggs for this treatment were washed in a Grange League Federation (G.L.F.) machine. The principle of this machine is that clean water drips on the eggs as they pass through it and the eggs are scrubbed by a series of rough disks. The water is not used the second time which eliminates a possible source of contamination

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* The author wishes to thank the Hilltop Laboratories, 718 Washington Avenue North, Minneapolis 1, Minnesota, for providing the "Suds Mor" which was used in these tests.

to the eggs being washed. Tap water with no chemicals added was heated to 158°F. and used in the machine for this treatment. It was necessary to run the dirty eggs through the machine twice in order to remove most of the dirt; therefore, to make the treatment as uniform as possible, the clean eggs were also run through the machine twice. The second time the eggs went through the machine the ends were reversed thus giving a better chance for the ends of the eggs to be washed. It takes an egg about 20 seconds to pass through this machine.

5. Two percent sodium hydroxide washed by hand. A 2 percent solution of sodium hydroxide was made by dissolving 95 grams of 76 percent pure sodium hydroxide into each gallon of distilled hot water. The temperature fluctuated between 130°F. and 150°F. It was found that at the higher temperature it was quite difficult to keep ones hands in the water while trying to wash the eggs. Each egg was washed by hand with a cotton cloth and stroked 12 to 15 times as uniformly as possible to eliminate any error caused by uneven washing. After these eggs were washed, they were placed in a wire egg basket and sprayed with hot water at 140°F. for 15 seconds, then sprayed with tap water for 15 seconds and left in the basket to drain dry.

After washing, the eggs were weighed on a Toledo egg scale which weighs within an accuracy of 1 gram. All eggs were set at the Oklahoma Experiment Station Hatchery in a Bundy incubator and turned at least 4 times a day. On the 14th day of incubation, all eggs were again weighed on the same scales to determine the weight-loss to that time and transferred to the hatching compartment of the same incubator.

Storage Quality -- The storage phase of this experiment was undertaken to determine some of the effects of washing eggs in different solutions and by different methods upon their keeping quality. Eggs were randomly placed in the different treatments from the production of November 30 and December 1, 1948 at the Oklahoma Experiment Station Poultry Farm. The eggs from the following breeds were used: Single Comb White Leghorns, Single Comb Rhode Island Reds, New Hampshires, Barred Plymouth Rocks, Silver Oklabars, Gold Oklabars and Oklahoma Dominant Whites. Most of the eggs washed were clean eggs. No attempt was made to make any eggs artificially dirty.

These eggs were subjected to the following treatments:

1. No treatment. One hundred eighty eggs were used for controls.

2. Machine-washed with hot water at 160°F. One hundred seventy-eight eggs were run through the G.L.F. machine twice using water which had been heated to 160°F.

3.A. "Suds Mor" solution and machine-washed. The solution for this treatment was made by dissolving 1 tablespoon of "Suds Mor" into each gallon of water heated to 169°F. Eighty-nine eggs were run through the machine twice, placed in a wire egg basket and dipped 10 times in clear hot water at 150°F., and then sprayed for 30 seconds in tap water.

3.B. "Suds Mor" solution and basket-dipped. This solution was prepared the same as that in 3.A. Ninety eggs were placed in a wire basket, dipped 10 times in the "Suds Mor" solution which had a temperature of 150°F. After this, they were dipped 10 times in 150°F. clear water, and immediately sprayed for 30 seconds with tap water.

4. Washed by hand in 2 percent solution of sodium hydroxide. The 2 percent sodium hydroxide solution was made by dissolving 95 grams of 76 percent pure sodium hydroxide in each gallon of distilled water heated to a temperature of 130°F. to 150°F. One hundred and seventy-nine eggs were individually washed with a cotton cloth and given 12 to 15 strokes each. After washing, these eggs were placed in a wire basket and dipped 10 times in clear water heated to 140°F. and then sprayed with tap water for 30 seconds.

Treatments 1 and 2 were washed and weighed December 1, while treatments 3.A., 3.B. and 4 were washed and weighed December 3. The eggs were then placed in 2 wooden egg cases and taken to Swift and Company,* Oklahoma City, for storage. The egg storage room was held at 33°F. to 35°F. for the entire storage period which was from December 3, 1948 to May 30, 1949. No readings on the relative humidity of the storage room were available.

Upon removal from storage these eggs were reweighed to determine weight-loss, candled according to U.S. grades, and then broken out to determine interior quality. Upon breaking out, observations were made for off colored yolks, meat spots, blood spots, pink whites and the height of the albumen. Albumen scores were based on the Van Wagenen - Wilgus grades (1935, 1936). These scores range from 1.0 for the best albumen to 5.0 for eggs with no thick albumen. The eggs were broken out and compared to the Van Wagenen - Wilgus index pictures on equipment described by Thayer (1945).

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* The author wishes to thank Mr. W. A. Stolzer, Swift and Company, Oklahoma City, Oklahoma for his cooperation in providing commercial storage facilities for these eggs.

EXPERIMENTAL RESULTS

Hatchability -- A total of 1424 eggs were set in three replications to determine the effect of washing eggs on their hatchability. The percentages of hatchability for both the total number of eggs set and the number of "fertile" eggs are shown in Tables I, II, and III for Replications I, II, and III respectively. The method of washing apparently had no effect on the hatchability of eggs in the various replications.

Statistical tests further strengthen these findings that there is no advantage in using any one treatment over the others. The data of "fertile" eggs were analyzed by a method used by Norton (1945). The chi-square values for Replications I, II, and III respectively were 0.9407, 3.4815, and 3.9181 which, with 4 d.f. for each, were not significant. Chi-square values were also figured for the hatchability of the total number of eggs set in each treatment. There were no significant differences in the hatchabilities when based upon the total eggs set or the number of "fertile" eggs. There appears, then, to be no advantage in hatchability for eggs subjected to any one of the treatments used in this experiment.

In Table I and II there was a noticeable trend for the clean, washed eggs to hatch better than dirty, washed eggs in all treatments except one, but these differences when tested by chi-square, with 1 d.f. each, were not significant. Since there was only one chi-square value which was significant out of the 30 which were run, it must be assumed that this was a sample which would be expected to be drawn one time in one hundred from the same population which would give a chi-square of 6.635 or higher. Although there was no significant difference between dirty and clean eggs in the way they hatched, there was a noticeable and fairly consistent trend for eggs which have been dirty to hatch a little poorer than the clean eggs within any one treatment.

Table IV gives the results of experimentation to determine the difference, if any, between the hatchability of eggs which had been dirtied 1 to 4 days prior to washing, and those which had been dirtied 5 to 7 days prior to washing. This table indicates that there was no difference in hatchability between dirty eggs held 1 to 4 days and those held 5 to 7 days prior to washing.

Tables V shows the results of naturally dirty eggs and artificially made dirty eggs in relation to hatchability. Based on the total number of eggs set, there was a consistent tendency, with one exception, for the naturally dirty eggs to hatch better than the artificially dirtied eggs. This trend is not as evident when based on the number of "fertile" eggs. The only two significant chi-squares obtained when testing artificially dirtied eggs against naturally dirtied eggs were in favor of the artificially dirtied eggs. Because of the relatively small numbers in each sample, with no replications, and the seemingly conflicting results, little can be said as to the effect of washing on either type of egg.

<u>14-Day Incubation Weight-Loss</u> -- Table VI shows the average percent 14-day incubation weight-loss along with their standard deviations. There appears to be no difference in the amount of 14-day incubation weight-loss in eggs subjected to different treatments.

In data involving percentages, the variance is a function of the mean and as such should not be analyzed by an analysis of variance. For this reason the 14-day incubation weight-loss percentages were converted to angles, (angle = Arc sin $\sqrt{\text{percentage}}$), and the analysis of variance was run on the angles, Baten and Henderson (1941), Snedecor (1946). Incubation weight-loss was run separately on each setting of eggs. The F-tests between error and treatment were as follows: Replication I, F = 6.12**, for 483 and 4 d.f.; Replication II, F = 2.19, for 443 and 4 d.f.; and Replication III, F = 0.85, for 478 and 4 d.f. Replication I was the only setting of eggs which showed a significant difference in weight-loss between the various treatments. In order to see if this difference was constant from treatment to treatment; that is, to see if dirty or clean eggs lost consistently more moisture in each treatment, the interaction was computed, and a significant F value of 3.08*, for 483 and 4 d.f., was obtained. This test of interaction shows that the difference in the 14-day incubation weight-loss between dirty and clean eggs is not the same. Dirty eggs lost more weight in some treatments than the clean, while clean eggs lost more weight than dirty eggs in other treatments. Because of the significant interaction in Replication I and the fact that Replications II and III showed no difference in the way eggs lost weight in different treatments, it indicates that there is no difference in the 14-day incubation weight-loss of eggs which are subjected to the treatments used in this experiment.

Candled Grades on Storage Eggs -- Table VII gives the percentage of the eggs in each treatment which were placed in the

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* Significant
** Highly Significant

various U. S. grades upon candling after they had been in storage for six months. To determine if there was any difference in the proportion which were placed in each grade from the various treatments, all grades of eggs were converted to numorical values so an analysis of variance could be calculated. The values assigned were 1, 2, 3 and 4 for Grades A, B, C and rejects respectively. An F value of 1.099, for 711 and 4 d.f., was obtained which indicates that there was no difference in the candling grade of the different lots of eggs subjected to the various methods of washing.

Storage Weight-Loss -- Table VIII shows the average percent weight-loss and the standard deviation of washed eggs in storage to be less for "Suds Mor", machine washed than any other treatment. The percentage weight-loss was determined by dividing the original weight into the loss and multiplying by 100. These percentages were converted to angles and the analysis of variance was calculated from the angles. In the analysis of variance the F test for error against treatment was 6.49**, for 709 and 4 d.f., which indicates that there was a difference in the weight-loss during storage of eggs receiving different treatments. To isolate this difference, a set of orthogonal comparisons was set up. From these comparisons, t-tests were run in place of the regular orthogonal comparisons because of the unequal number of eggs in each treatment. These t-values are shown in Table IX. It will be noted that a highly significant t-value was obtained between eggs washed in any chemically treated water and those washed in plain water. The mean and the variance go in opposite directions.

** Highly Significant

For eggs washed in chemically treated water, there was a lower mean but a higher variance than for the eggs washed in plain water. A highly significant difference was found between the eggs of machine-washed "Suds Mor" and bucket-dipped "Suds Mor." This difference was in favor of the machine washed egg which showed both a lower mean weight-loss and a smaller variance. These orthogonal comparisons indicate that eggs in storage lose less weight when washed with chemically treated water than when washed with clear water. They also show that eggs washed in "Suds Mor" with a machine lose less moisture than eggs which were dipped in "Suds Mor."

Albumen Score -- After storage, all eggs were broken out and the albumen was scored by using the albumen picture grades of Van Wagenen and Wilgus (1935). Table XI gives the percentage of eggs in the various albumen grades. An F value of 4.52** was obtained which indicates there was a difference in the albumen in the various treatments. The results of t-tests based on orthogonal comparisons are shown in Table X. The difference between controls and treated eggs was found to be in favor of the controls which had a smaller mean albumen score as well as a smaller variance than the treated eggs. This indicates that the unwashed eggs had a firmer, higher albumen after storage than eggs which were subjected to any of the treatments. In the comparison of the clear water treatment against the chemically treated water, eggs washed in the clear water had a smaller mean albumen score, but a higher variance than the eggs washed in chemically treated water. The

** Highly Significant

larger variance in the eggs washed with clear water was thought to be due to the much smaller degrees of freedom for that treatment. Washing with clear water gave a better albumen score on storage eggs than washing with any of the chemicals which were used in this experiment. From these results, clean, unwashed eggs will have a larger amount of firm albumen than eggs which are washed in plain water or chemically treated water. Likewise, eggs washed in plain water will have a higher firmer albumen than eggs washed in any of the chemical waters used.

Some Observations on Internal Quality of Stored Eggs -- A large number of off colored yolks were observed when the eggs were broken out. There were 38.7 percent of all yolks showing some kind of abnormal yolk coloration. Most of these yolks were a brownish to olive color which seemed to be only on the outside of the yolk. Some of these yolks were very dark and some few showed a mottled appearance. It was observed that 7.9 percent of all albumens were pinkish in color. There was no indication that this off coloring of the yolk and albumen was the result of storage or treatments. The mash which these hens were receiving at the time these eggs were laid contained 10 percent cottonseed meal. This feedstuff, according to Thompson (1930), causes a discoloration of the yolk in storage eggs as well as pink whites.

TABLE I

Percentage of Eggs Hatched From Each Treatment in Replication I
(Set January 28, 1949)

Treatment	Temp. Deg. Fahr.	Condition of Eggs	No. of Eggs Set	No. of Fertile Eggs	No. of Chicks	% Hatch of Total Eggs	% Hatch of Fertile Eggs
No Treatment	Controls	Dirty	49	49	30	61.2	61.2
		Clean	49	43	34	69.4	79.1
"Suds Mor", Dipped	158	Dirty	49	47	34	69.4	72.3
		Clean	50	46	39	78.0	84.8
"Breeze", Dipped	140	Dirty	49	47	37	75.5	78.7
		Clean	50	49	41	82.0	83.7
Machine, Water	160	Dirty	49	44	33	67.4	75.0
		Clean	49	47	38	77.6	80.9
2% Sodium Hydroxide	130-150	Dirty	50	47	37	74.0	78.7
		Clean	49	47	40	81.6	85.1
TOTALS			493	466	363	73.6	77.9

TABLE II

Percentage of Eggs Hatched From Each Treatment in Replication II
(Set March 4, 1949)

Treatment	Temp. Deg. Fahr.	Condition of Eggs	No. of Eggs Set	No. of Fertile Eggs	No. of Chicks	% Hatch of Total Eggs	% Hatch of Fertile Eggs
No Treatment	Controls	Dirty	45	34	26	57.7	76.5
		Clean	46	42	33	71.7	78.6
"Suds Mor", Dipped	150	Dirty	45	37	28	62.2	75.7
		Clean	46	36	32	69.6	88.8
"Breeze", Dipped	150	Dirty	46	42	31	67.4	73.8
		Clean	46	34	34	73.9	100.0
Machine, Water	160	Dirty	45	31	24	53.3	77.4
		Clean	46	36	29	63.0	80.6
2% Sodium Hydroxide	131-150	Dirty	42	34	27	64.3	79.4
		Clean	46	42	30	65.0	71.4
TOTALS			453	368	294	64.9	79.9

TABLE III

Percentage of Eggs Hatched From Each Treatment in Replication III
(Set April 8, 1949)

Treatment	Temp. Deg. Fahr.	Condition of Eggs	No. of Eggs Set	No. of Fertile Eggs	No. of Chicks	% Hatch of Total Eggs	% Hatch of Fertile Eggs
No Treatment	Controls	Dirty	47	29	23	48.9	79.3
		Clean	49	37	26	53.1	70.3
"Suds Mor", Dipped	150	Dirty	48	34	23	47.9	67.6
		Clean	50	39	24	48.0	61.5
"Breeze", Dipped	150	Dirty	47	28	22	46.8	78.6
		Clean	50	41	23	46.0	56.1
Machine, Water	150	Dirty	50	39	23	46.0	59.0
		Clean	50	37	24	48.0	64.9
2% Sodium Hydroxide	131-150	Dirty	49	37	24	48.9	64.9
		Clean	48	38	24	50.0	63.2
TOTALS			488	359	236	48.4	65.9

TABLE IV

Relationship of Length of Time Dirty Prior to Washing and Hatchability

Length of Time Dirty	Treatment	No. of Eggs Set	No. Fertile Eggs 14th Day	No. of Chicks	% Hatch Total Eggs	% Hatch of Fertile Eggs
1 to 4 days	Controls	20	15	11	55.0	73.3
	"Suds Mor", Dipped	19	14	12	63.2	85.7
	"Breeze", Dipped	20	18	12	60.0	66.7
	Machine, Water	20	16	11	55.0	68.8
	2% Sodium Hydroxide	17	14	10	58.8	71.4
TOTALS		96	77	56	58.3	72.7
5 to 7 days	Controls	25	19	15	60.0	78.9
	"Suds Mor", Dipped	26	23	16	61.5	69.6
	"Breeze", Dipped	26	24	19	73.1	79.2
	Machine, Water	25	15	13	52.0	86.7
	2% Sodium Hydroxide	25	20	17	68.0	85.0
TOTALS		127	101	80	63.0	79.2

TABLE V

Relationship of Naturally Dirty and Artificially Dirty Eggs and Hatchability

Treatment	No. Eggs Set		No. Fertile Eggs		No. Chicks		% Hatch of Total Eggs Set		% Hatch of Fertile Eggs Set	
	* A	N	A	N	A	N	A	N	A	N
Controls	22	23	16	18	11	15	50.0	65.2	68.8	83.3
"Suds Mor", Dipped	22	23	16	21	12	16	54.6	69.6	75.0	76.2
"Breeze", Dipped	23	23	20	22	15	16	65.2	69.6	75.0	72.7
Machine, Water	23	22	13	18	9	15	39.1	68.2	69.2	83.3
2% Sodium Hydroxide	20	22	16	18	16	11	80.0	50.0	100.0	61.1
TOTALS	110	113	81	97	63	73	57.3	64.6	77.8	75.3

* A - Artificially made dirty
  N - Naturally dirty

TABLE VI

14-Day Incubation Weight-Loss of Eggs Washed in Different Solutions and by Different Methods

Treatment	Condition of Eggs	Replication I			Replication II			Replication III		
		No. of Eggs	Ave. % Wt. Loss	Standard Deviations	No. of Eggs	Ave. % Wt. Loss	Standard Deviations	No. of Eggs	Ave. % Wt. Loss	Standard Deviations
No Treatment	Dirty	49	8.80	.071	45	8.05	.197	47	8.47	.118
	Clean	49	7.94	.114	46	7.66	.131	49	8.19	.047
"Suds Mor", Dipped	Dirty	49	9.37	.104	45	8.75	.164	48	9.02	.120
	Clean	50	8.86	.087	46	8.28	.048	50	8.40	.105
"Breeze", Dipped	Dirty	49	8.35	.089	46	8.55	.139	47	8.64	.132
	Clean	50	8.25	.099	46	8.73	.151	50	8.04	.076
Machine, Water	Dirty	49	7.90	.119	45	7.82	.233	50	8.09	.270
	Clean	49	8.08	.043	46	8.43	.067	50	8.47	.100
2% Sodium Hydroxide	Dirty	50	7.80	.094	42	8.18	.138	49	8.25	.152
	Clean	49	8.34	.063	46	7.98	.100	48	8.38	.151

TABLE VII

Results of Eggs Candled After Six Month's Storage.
The Percentage of Each U. S. Candling Grade
in Different Treatments

Treatments	Temp. of Solution Deg.Fahr.	No. of Eggs Stored	% Candled into Each U.S. Grade			
			A	B	C	Rej.
No Treatment	Controls	180	8.89	73.33	16.67	1.11
Machine, Water	160	178	8.99	71.35	19.10	.56
"Suds Mor", Machine	169	89	6.74	75.28	17.98	----
"Suds Mor", Dipped	150	90	15.56	68.89	14.44	1.11
2% Sodium Hydroxide	130-150	179	10.61	76.54	12.29	.56
TOTALS		716	9.91	73.33	16.06	.70

TABLE VIII

The Percentage Weight-Loss of Eggs Subjected to Different
Washing Methods and Solutions Prior to Storage

Treatments	Number of Eggs	Average Percent Weight-Loss	Standard Deviations
No Treatment	180	3.41	.092
Machine, Water	178	3.81	.128
"Suds Mor", Machine	89	3.02	.079
"Suds Mor", Dipped	90	3.72	.143
2% Sodium Hydroxide	177	3.58	.124

TABLE IX

Orthogonal Comparisons on the Storage Weight-Loss of Eggs and the T-Values

Comparisons Used	T-Value
Control vs. All Treatments	1.22
Clear Water vs. Chemically Treated Water	2.83**
"Suds Mor", vs. 2% Sodium Hydroxide	1.10
"Suds Mor", Machine vs. "Suds Mor", Basket Dipped	3.307**

** Highly Significant

TABLE X

Orthogonal Comparisons on Albumen Scores of Storage Eggs and the T-Values

Comparisons Used	T-Value
Control vs. Treated	2.24*
Clear Water vs. Chemically Treated Water	3.35**
"Suds Mor", vs. 2% Sodium Hydroxide	.415
"Suds Mor", Machine vs. "Suds Mor", Basket Dipped	1.139

* Significant
** Highly Significant

TABLE XI

The Percentage of Eggs in Each Van Wagenen-Wilgus Albumen Score for Eggs Subjected to Different Washing Methods and Solutions Prior to Storage

Treatment	No. of Eggs	Albumen Scores 1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Controls	177	---	3.95	23.16	32.77	30.52	9.60			
Machine, Water	174	---	2.30	30.46	29.31	26.44	9.77	.57	1.15	
"Suds Mor", Machine	89	---	3.37	8.99	29.22	46.07	11.23	1.12		
"Suds Mor", Dipped	89	---	2.25	17.98	35.96	32.57	7.87	2.25		1.12
2% Sodium Hydroxide	178	---	1.69	10.67	36.52	39.33	8.98	2.81		
TOTALS	707		2.69	19.38	32.81	33.94	9.48	1.28	.28	.14

DISCUSSION

The results obtained in the various experiments indicate that hatching eggs and eggs going into storage can be successfully washed.

Hatchability -- The idea which has prevailed for so long that washing tends to destroy the cuticle on the shell of the egg and thus allows excessive evaporation, as well as opening the pores to bacterial infection, appears to have no foundation when the washing is properly done. If too much evaporation were to take place in the hatching eggs, a decrease in hatchability would result; Axelsson (1932), Henderson (1941), and Godfrey (1949).

Eggs subjected to the different treatments used in this experiment hatched equally as well in all three replications. There is no indication that the methods or solutions used in washing had any effect upon the hatchability. From these results, the hatchery flock owner or the hatcheryman can wash soiled eggs by any one of the methods shown in Tables I, II and III with equally good results. The ease of washing by the basket-dip and a detergent should make it one of the most popular methods for washing hatching eggs. Because of the large amount of work necessary to wash eggs individually in sodium hydroxide, and the necessity of wearing rubber gloves while washing, it is doubtful if this method will ever be extensively used.

There appears to be no difference in the percentage hatchability of eggs which have been dirty for several days before washing, compared to eggs which have been dirty only a short time. Therefore, it is possible that the hatcheryman may assume the job of washing the dirty eggs for all of the flock owners just before they go into the incubator. An educational program aimed at producing clean eggs should be carried on, however, to promote the production of clean eggs. Dirty eggs should not bring as good a price at the hatchery for two reasons: (1) The cost of cleaning would be borne by the hatchery; (2) The trend found in this study indicates a smaller percent of hatch may be expected from dirty eggs which have been washed. Although this decrease in hatchability is small and statistically non-significant, there is a rather consistent trend for clean eggs, both washed and unwashed, to hatch better than dirty washed and unwashed eggs. To a hatcheryman a definite trend may not necessarily need to be statistically significant since only a small decrease in hatchability will have a decided effect on net return when considered for the entire hatching season. From the results of this work, it is recommended that clean eggs be produced; however, if eggs to be set do get soiled or dirty, they should be washed.

It is possible that the slight decrease in hatchability noted in most lots of eggs which had been dirtied, compared to the clean eggs, was due to bacterial infection from being made dirty rather than an increase in weight-loss, since weight-loss was not found to be different throughout most of the experiments. The high temperatures of these washing solutions, no doubt, reduced the amount of bacterial infection to a minimum by expanding the contents of the egg and forcing bacteria out of the pores, Pritsker (1941).

Because of the rapidity with which all eggs were washed, it appears that dead germs caused by washing in hot water was not a detrimental factor in these tests. Wright (1948) states that eggs washed with the Grange League Federation Machine increased in internal temperature only 2°F. while being washed.

Storage Quality -- The eggs used in this part of the experiment were for the most part clean eggs. There were no eggs artificially soiled as in the hatchability tests. No difference in the candling grades of the eggs in different treatments could be detected, but since there were some differences in storage weight-loss and albumen scores, between different treatments, candling was not considered to be an accurate enough measure of internal quality. From their candled appearance, washed eggs kept just as well in storage as eggs which were not washed.

The percentage of candled rejects in all treatments was very small and there was no indication that any one treatment tended to cause a larger number of these inedible eggs. The defect common to all rejects was stuck yolks.

There was a difference in the weight-loss of eggs placed in storage. The weight-loss from eggs which were washed with machine and the "Suds Mor" solution showed a decrease in mean weight-loss as well as a decrease in the variance of this loss. The combination of "Suds Mor" and machine appeared to be necessary to get the least amount of moisture-loss in this experiment. Just why this particular treatment should lose less moisture is not clear. It may be that the rough disks which clean the eggs rubbed some of the cuticle off and thus reduced the effective evaporation surface. Marshall and Cruickshank (1938) have thought that the "plaques," cuticular material immediately above and around the pore, and the cuticle proper may be an evaporation surface for the egg. There is no indication that the washing solutions alone will remove the cuticle from the shell, but in combination with the machine it may be removed to such an extent that there is less loss of moisture. By isolating the variance of the weight-loss while in storage, less loss in weight was shown to be caused by chemically treated water as against clear water. When this variance was further isolated, it was found that eggs washed with "Suds Mor" and the machine lost less weight and likewise had less variance than the basket-dipped "Suds Mor" eggs. Although the "Suds Mor", machine-washed eggs lost less moisture, they did not have the better albumen score as might be expected. The slight decrease in weight-loss was not sufficient to reflect a higher, firmer albumen.

Two things are rather clearly indicated as far as albumen scores are concerned. Eggs which were in the control lots, compared to all eggs which received treatment, had a lower albumen index score and also a smaller variance. This lower index score is indicative of a firmer higher albumen. When most of the eggs are clean, as these eggs were before washing, there is nothing gained by washing the egg as far as albumen appearance and score is concerned. If washing is done, it sould be with clear hot water to get the better albumen score.

SUMMARY AND CONCLUSIONS

The effects of washing hatching and storage eggs, both dirty and clean, were studied. From this study of 1424 hatching eggs and 720 storage eggs, the following conclusions may be drawn.

1. There is no indication that the hatchability is lowered by the following methods of cleaning when compared to controls: (a) "Suds Mor", dipped, (b) "Breeze", dipped, (c) Machine and water, (d) 2 percent sodium hydroxide. The temperature of all of the solutions was 150 to 160°F. except the sodium hydroxide which was 130 to 150°F. Although not statistically significant, there is a fairly consistent trend for clean eggs, washed and unwashed, to hatch better than dirty eggs, both washed and unwashed.
2. Hatching eggs, which have been dirty 1 to 4 days prior to washing, hatch no better than eggs which have been dirty 5 to 7 days prior to washing and setting.
3. Washing hatching eggs has no effect on their 14-day incubation weight-loss.
4. There is apparently no advantage in washing clean eggs going into storage. Less weight-loss in storage was found in eggs which had been washed with chemically treated water compared to clear water. Less weight-loss was also observed in machine, "Suds Mor" washed eggs compared to eggs washed by the basket-dip "Suds Mor" method. It might be expected that eggs with less weight-loss would also have better albumen scores, but this was not found to be true. Eggs which were not washed and those washed in plain hot water had better albumen scores after storage than eggs washed in any other way.

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