VOL. 6 AUGUST, 1931 NO. 3

HILGARDIA

A Journal of Agricultural Science

PUBLISHED BY THE

California Agricultural Experiment Station

CONTENTS

UNIVERSITY OF CALIFORNIA PRINTING OFFICE
BERKELEY, CALIFORNIA

The titles of the Technical Papers of the California Agricultural Experiment Station, Nos. 1 to 20, which HILGARDIA replaces, and copies of which may be had on application to the Publication Secretary, Agricultural Experiment Station, Berkeley, are as follows:

4. Effect of Sodium Chlorid and Calcium Chlorid upon the Growth and Composition of Young Orange Trees, by H. S. Reed and A. R. C. Haas. April, 1923.
5. Citrus Blast and Black Pit, by H. S. Fawcett, W. T. Horne, and A. F. Camp. May, 1923.
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17. Nutrient and Toxic Effects of Certain Ions on Citrus and Walnut Trees with Especial Reference to the Concentration and Ph of the Medium, by H. S. Reed and A. R. C. Haas. October, 1924.
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20. A Study of the Conductive Tissues in Shoots of the Bartlett Pear and the Relationship of Food Movement to Dominance of the Apical Buds, by Frank E. Gardner. April, 1925.

MEASUREMENT OF DETERIORATION IN THE STORED HEN'S EGG[1]

W. F. HOLST[2] AND H. J. ALMQUIST[3]

INTRODUCTION

If the meaning of the term 'freshness,' as applied to an egg, be restricted to indicate the degree to which the egg has retained its original internal and external quality during storage, then it follows that age, as a criterion of egg freshness, is excluded from consideration. This, within limits, is entirely justifiable, since variations exist not only in respect to the intrinsic keeping powers and initial quality of the individual egg, but also in the storage conditions to which the eggs may have been subjected. By the proper selection of eggs and a suitable control of their storage conditions, time as a factor governing the freshness of eggs may, for practical purposes, be to a certain extent eliminated. The other extreme can also be attained: eggs may be caused to deteriorate at a rapid rate. Unfortunately it is not usually feasible or profitable to modify commercial storage methods so as to achieve the optimum conditions. As a consequence certain undesirable processes may occur.

Several of the changes in the stored hen's egg are sufficiently marked to be noticeable to anyone concerned with the keeping of eggs at or near their original fresh condition. These changes are shrinkage, liquefaction of the thick white, and passage of water into the yolk.

Loss of water from the egg can occur without noticeable change in other respects. Furthermore, loss of water can be prevented, yet thick white liquefaction may proceed at a rapid rate. The loss of water or of carbon dioxide from the egg may be caused to take place, each in the absence of the other, by properly controlling conditions; hence it is possible to test the above statements experimentally. This

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was done by storing 30 eggs in a desiccator over calcium chloride in an atmosphere maintained at 5 per cent carbon dioxide. In this lot of eggs water was removed at a rapid rate by the calcium chloride, while the carbon dioxide concentration was kept constant. A similar lot of eggs was stored in a desiccator over 5 per cent sodium hydroxide solution. Under these latter conditions a high humidity was maintained while carbon dioxide was rapidly removed from the storage atmosphere and, in turn, from the eggs. After 26 days all eggs of the first lot had air spaces ¼ to ½ inch in depth, showing extensive shrinkage, yet the interior quality was excellent. Thick white constituted on the average 52 per cent of the total white. In the second lot very little shrinkage was apparent on candling; nevertheless the eggs were as a whole badly liquefied. The whites averaged only 30 per cent as thick white.

It was found experimentally that the eggs on which figure 4 is based showed rates of shrinkage not at all comparable to the keeping qualities as found in the yolk and in the thick white. A comparison of these lots of eggs is given in table 1. This is further evidence in favor of the view that loss of water is a relatively minor type of deterioration and is not, in itself, responsible for other changes which may take place in stored eggs.

TABLE 1

COMPARISON OF KEEPING QUALITIES WITH RATES OF SHRINKAGE OF EGGS STORED AT 86° FAHRENHEIT.*

Hen	General keeping qualities	Average per cent weight lost per egg per day
A	Excellent	0.678
B	Fair	0.627
C	Poor	0.542

* These are the same eggs as those shown in figure 4.

Holst and Almquist (1931) showed that the loss of water from egg white is uniformly distributed throughout thick and thin white, since the concentration of solid matter in one remains equal to that in the other with varying age of the egg, although increasing regularly with the disappearance of water. These changes in the whites are thus proportionate. *Hence, if shrinkage is the only change, the percentage of total white in the form of thick white will remain constant for any one egg.*

For the above reasons, shrinkage, the only one of the various storage changes which may be reliably detected by candling, is of little value as an index to egg quality, inasmuch as it often fails to parallel other departures of the egg from a fresh condition and becomes significant only in extreme stages.

It is well known that 'watery whites' are associated with weakened and easily broken yolk membranes, yet the extent to which these changes may be correlated with each other has, up to this time, not been demonstrated. The mechanism of thick white liquefaction is at the present time not well understood. However, certain relations between this liquefaction and yolk depreciation have been studied in order to establish a basis of comparison for methods which measure these types of deterioration.

The actual passage of water from the white into yolk may be shown by analysis. The average moisture content of the yolks of fresh eggs examined during some of this work was 48.02 per cent, as compared with a value of 54.33 per cent secured from the yolks of eggs stored for 10 days at 86°F. At the same time the average yolk weights increased from 15.62 to 17.58 grams.

The various changes in egg yolks are all attributable to osmotic forces operating so as to cause a passage of water from the white to the yolk. The water content of fresh yolk is in the neighborhood of 48 per cent, while that of fresh white normally is between 85 and 90 per cent. This difference in concentration of water creates a tendency for water to pass into and dilute the contents of the yolk membrane. One of the first to note this effect was Greenlee (1911). In the fresh egg, where the difference in water content is at the maximum, the osmotic forces are greatest but may largely be controlled by at least one other factor.

The water which thus diffuses into the yolk produces two effects, both of which are undesirable. To make room for the incoming water, the yolk membrane is compelled to stretch and is thereby weakened. Only in very rare cases, however, will this effect result in the breaking of the yolk while inside the shell. A second and perhaps more serious effect is the marked increase in fluidity of the yolk substance.

The fresh yolk, when the egg is broken onto a flat surface, will stand up well, but a yolk which has absorbed much water will slump down rapidly because of its increased fluidity. This slumping down causes the yolk to assume a flat shape much different from that of a sphere which, of all bodies, requires the least surface for a given volume. A greater membrane area is thus suddenly required; this, in conjunction with the previously mentioned weakening of the membrane, often sets up a stress which the membrane cannot resist and the yolk breaks.

A further effect aiding those mentioned is due to the disappearance of all but small amounts of thick white as such in these serious stages of deterioration. The mechanical support offered to the yolk by firm thick white is lost as the thick white disappears.

METHODS OF MEASURING DETERIORATION

There remain then two trends which may be followed with assurance, i. e., the changes in the yolk and the changes in the thick white.

A method of measuring the first of these has been described by Sharp and Powell (1930). A factor which they call the yolk index, representing the quotient of the yolk height and yolk width as measured when the yolk is placed on a flat surface, apparently decreases with the progressive deterioration of the egg. It also decreases more rapidly with increasingly unfavorable storage conditions such as high temperature, etc. The lowering of the yolk index is probably directly associated with the passage of water into the yolk.

This procedure is confined to the yolk and furnishes no clew as to the initial condition of the egg in respect to the amount of thick white. To quote Sharp and Powell, "Some fresh eggs, however, may have a low interior quality, especially a watery condition of the white, so the standards of comparison must be modified to exclude such eggs."

This watery condition of the white in fresh eggs is of as much interest to the investigator as is the gradual liquefaction of eggs during storage. Our researches, though as yet of a preliminary nature as far as these properties, which are difficult to trace are concerned, lead to the suggestion that in the fresh egg the percentage of the total white which is in the form of thick white is directly related to the keeping qualities of an egg. Where other factors may be considered equal, the higher percentage of thick white indicates superior keeping qualities.

A group of 150 fresh eggs gave 62 as the average percentage of the total white existing in the form of thick white, while the individual values ranged from 45 to 90 per cent. Thus even fresh eggs vary greatly in this respect and, on the average, may have whites already 40 per cent liquefied.

If the same yolk is allowed to stand on a flat surface, the yolk index decreases continuously with time so that measurements must be made after an arbitrary time interval. Sharp and Powell secured good agreement by working in this fashion. This feature, however, detracts seriously from the applicability of such a test to experimental work.

Furthermore, the yolk must be carefully separated from the white and dried with a towel while held in the hand. The assumption that this excessive handling has no effect on the yolk is questionable. Our experience has shown that yolks far removed from a condition of freshness can be so handled only with great risk of breaking them. It is much easier to remove the yolk cleanly from the surrounding white and measure the white itself.

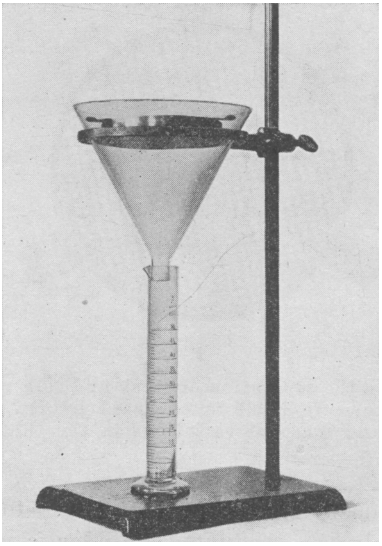

Fig. 1. Assembled apparatus used for the separation of thick and thin white and their volumetric measurement.

A second method of following storage depreciation, one which also furnishes an idea of fresh quality, consists of measuring the amount of white present in the firm jelly-like condition known as thick white. This procedure has been used in this laboratory for some time.

The apparatus required is shown in figure 1. It consists of three simple parts: a funnel, a graduated cylinder, and a specially constructed sieve. The only important specifications are those of the sieve (fig. 2), which has a diameter of 4 inches, a ½-inch raised rim, and a mesh of 9 per inch. The three tabs on the rim are for supporting the sieve inside of the funnel.

For the purpose of making measurements of thick white the egg is first broken into a standard-sized Petri dish. The yolk is removed, care being taken to separate the yolk and leave in the dish any adhering white. The white is then poured into the sieve mounted in the funnel which in turn delivers into the graduated cylinder. Thick white in good condition does not penetrate the sieve. In practice the sieve was gently rocked by hand in order to insure that thin white, which has the same density as thick white, was not held away from the openings by thick white. In a few seconds all thin white runs through.

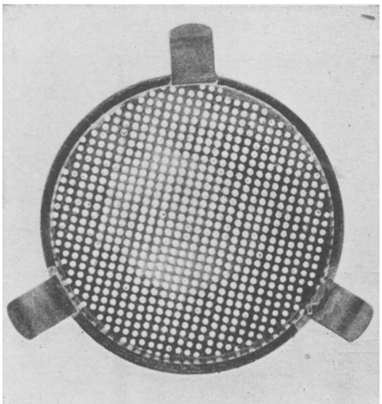

Fig. 2. Sieve used in the separation of thick and thin white in the apparatus shown in figure 1. The sieve itself is one used by Dr. S. L. Parker in her studies on individual and seasonal variations in the thick egg white (unpublished data).

When the penetration by thin white has slowed to a drop every few seconds the volume in the graduated cylinder is read to ½ cc. The sieve is then tilted and the thick white also allowed to run into the cylinder. The difference between first and final volumes represents the volume of thick white. This, expressed as percentage of total volume, gives the figures used at this laboratory to express the interior quality of eggs. Since, as previously mentioned, the densities and the concentration of solid matter are the same in both types of white from any one egg, the volume percentage of thick white is the same as the weight percentage. It is, furthermore, independent of shrinkage.

One source of error is the white unavoidably left behind in the petri dishes because of incomplete drainage. This error is small and assumes constancy for all eggs when dishes of the same size are used. A second source of error is due to the white required to wet the sieve and the portions of the funnel and cylinder with which the white comes in contact, but this error may be balanced out by running the egg whites through as rapidly as proper measurements can be taken, keeping the apparatus wet. Thus the error due to this effect will apply only to the first and possibly the second measurements.

A fair degree of reproducibility may be obtained by this method in evaluating the condition of eggs which may be expected to be closely similar and in getting the same results by repeated trials with the same egg. In table 2 are summarized the results from measurements on series of eggs from the same birds. These eggs were all about one day in age.

TABLE 2

THE DISTRIBUTION OF THICK WHITE IN FRESH EGGS

Hen No.	Volume in cubic centimeters		Per cent thick white	Hen No.	Volume in cubic centimeters		Per cent thick white
	Thick white	Total white			Thick white	Total white	
C-52	21.0	36.0	58	C-21	15.5	25.5	61
	18.0	31.0	58		15.0	27.0	56
	19.0	33.0	58		15.5	25.5	61
					15.5	26.0	60
D-965	22.5	36.5	62				
	27.0	42.0	64	A-60	19.5	31.5	62
	23.0	36.0	64		18.0	29.5	61
	20.5	33.0	62		17.0	27.0	63
					17.5	28.0	62
1370	18.0	22.0	82				
	14.0	18.0	78	B-77	16.0	27.0	59
	15.0	20.0	75		14.0	24.0	58
	17.5	21.5	81		16.0	26.5	61
B-125	24.0	37.0	65	D-842	12.0	25.5	47
	21.0	33.5	63		12.0	25.0	48
	22.5	35.0	64		13.0	27.0	48
	24.0	39.5	62		11.5	23.5	49

It is worthy of note that the percentage column of table 2 shows in each series the least variation as compared to the other two, showing that the thick white percentage tends to be independent of variations in total amount of white and in egg size. Obviously both the eggs and the method must be very uniform to achieve these results.

EXPERIMENTAL METHOD

Since it is well known that thick white disappearance and passage of water into the yolk are found to occur together, it became of interest to secure some conception, first, of the rate of these processes, and second, as to whether they are simultaneous or not.

To investigate these questions the method last described above was used to detect changes in the thick white. Following the simplest manner of detecting the passage of water to the yolk, the yolks were carefully removed from the egg, freed from adhering white, dried briefly by rolling on soft absorbent paper, and weighed. Yolks from eggs which had been stored for some time often broke, even with the most careful treatment, making it necessary to discard all data from the eggs which supplied these yolks.

The storage was carried out at two temperatures, 64° F and 86° F. The humidity was kept constant and the carbon dioxide was removed by a 15 per cent solution of sodium hydroxide kept in the storage space. These temperatures are, of course, much higher than commercial storage temperatures, but have the advantage of shortening the experimental period by accelerating processes which occur at much slower rates under conditions more favorable to the keeping of the egg.

At the lower temperature data were taken at approximate 5-day intervals over a total period of 25 days, while at the higher temperature data were taken at 2-day intervals over a 10-day period.

On the assumption that a single bird generally would produce an egg of uniform characteristics, the work was broken up into a series of studies of the eggs from individual birds. This was expected to reduce as far as possible, the influence of variables such as egg size, shell texture and porosity, initial percentage of thick white, yolk weight, and other probable, but as yet unknown, sources of deviation. Results which are much clearer cut may be obtained by working in this way; those which have been obtained are a justification of the assumption. They were distributed among the various storage periods in a uniform manner, so that any one set of measurements usually would give data on eggs from all the different times of storage.

None of the eggs were protected in any way such as by oil dipping.

The data secured have been condensed and presented in graphic form in figures 3 and 4. Each point on these curves represents the average condition of at least four eggs at the designated time. For all but a few of these points the number of eggs is five or more.

Not all of the data have been shown, since to do so would result only in a repetition of certain type cases. Enough has been included to represent the extreme and mean cases and the trends common to all.

DISCUSSION

Figures 3*A*, at 64°F, and 4*A*, at 86°F, demonstrate that where thick white liquefaction does not occur, the osmotic processes by which water enters the yolk are inhibited, as shown by the fact that the average yolk weight does not increase. Figures 3*B*, 3*C*, 4*B*, and 4*C* show that when these phases of deterioration do take place they proceed simultaneously and to a corresponding degree.

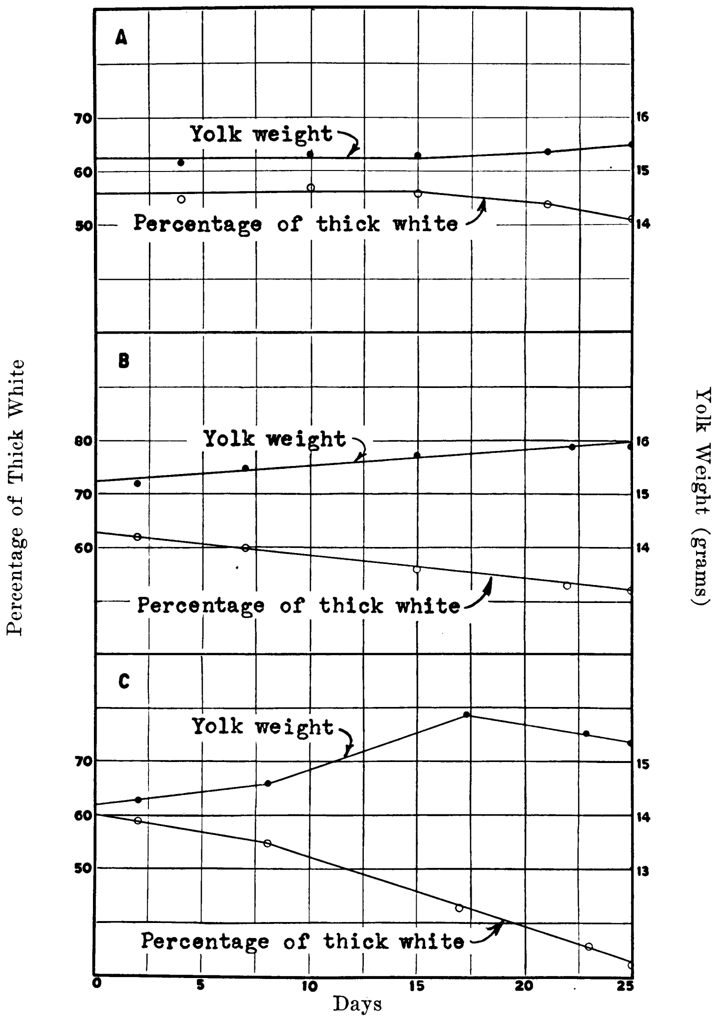

Fig. 3. The changes found in eggs stored at 64° F. Each graph represents data obtained from a series of eggs produced by the same hen. Circles represent percentage of thick white and the filled circles represent yolk weights. Each point shows the average condition of about 5 eggs at the designated time.

The apparent drop in yolk weight in the older eggs as shown in figure 3*C* is probably to be explained by the unusually high shell porosity of the eggs used in obtaining this graph. Under conditions of high porosity the entire egg system, yolk included, may be expected to lose weight after some time in storage.

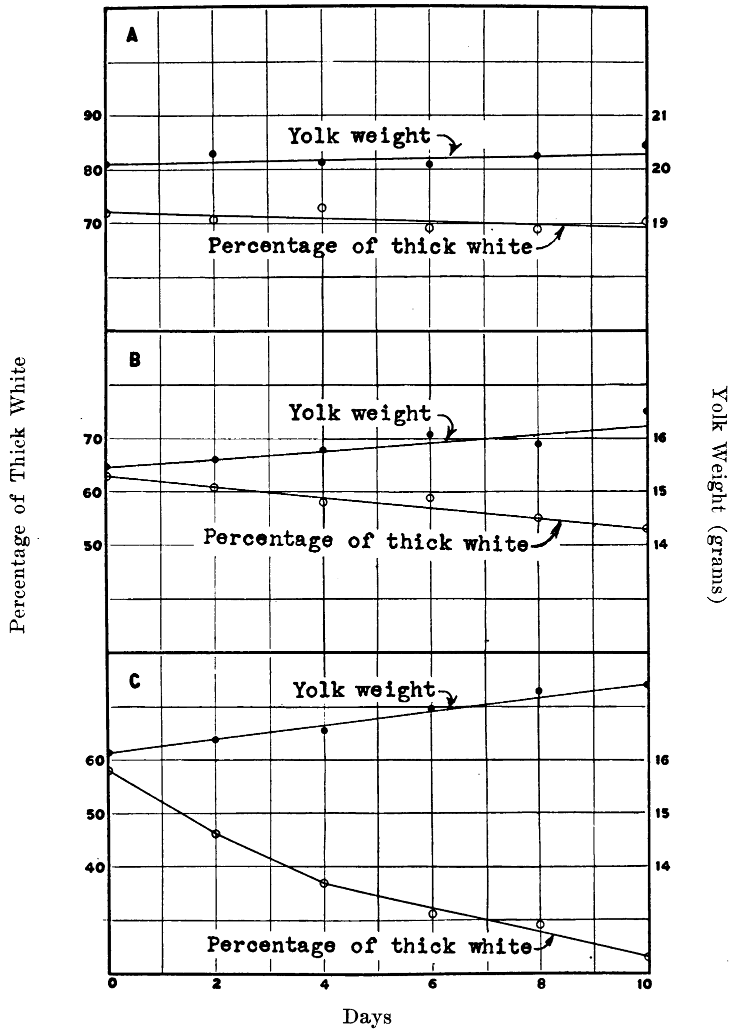

Fig. 4. The changes found in eggs stored at 86° F. As in figure 3, each graph represents the data obtained from a series of eggs produced by the same hen. Circles represent percentage of thick white and the filled circles represent yolk weights. Each point shows the average condition of about 5 eggs at the designated time.

Figures 3*A* and 4*A* are especially interesting in that, although these particular eggs were subjected to the same unfavorable conditions as the others and suffered shrinkage to comparable degrees, they have, nevertheless, demonstrated a high intrinsic keeping power.

The marked differences in the various egg series cannot be explained on the basis of variations in the feeding, housing, etc., of the hens from which the eggs were taken, since these factors were very uniform in these cases. The presented evidence points strongly toward the conclusion that the intrinsic keeping quality of an egg is to be added to the list of characteristics already known to be markedly influenced by the individuality of the hen.

It is apparent from the curves shown that the jelly-like structure of thick white begins to break down as the tendency of water to diffuse into the yolk becomes operative, therefore, *loss of quality in the yolk is accompanied by a corresponding loss in the white.* This is true for every case studied during this work.

The first explanation of these facts which occurs is that the water in thick white, due to the peculiar properties of this jelly-like substance, is held in such a manner that it cannot diffuse into the yolk as long as the thick white is well preserved. This, however, cannot be the true condition since it has been shown (Holst and Almquist, 1931), that the concentration of water in thick white remains exactly equal to that in the associated thin white regardless of losses to the yolk and to the atmosphere. Hence the activity of water in thick white is at all times equal to that of the water in the accompanying thin white, which in turn is nearly equal to that of pure water. The control of the tendencies which may bring about the diffusion of water to the yolk must lie within the yolk itself and may be connected with the increases in alkalinity known to occur in stored eggs.

A logical conclusion concerning the methods discussed is that the two expressions of storage deterioration in eggs, i. e., yolk index and thick white percentage, are correlated, but only as they follow changes which are contemporary. The superiority of the latter measurement lies in the following advantages:

(*a*) Better evidence regarding the initial fresh condition of eggs in respect to an important component, the thick white.
(*b*) Greater simplicity and speed in operation.
(*c*) Less danger of losing the measurements through breakage of the yolk.
(*d*) No necessity of making measurements in a specified time after the egg is opened.
(*e*) Independence of the measurement from shrinkage.

SUMMARY

Shrinkage has little significance as an index to egg quality.

Thick white percentage as an expression of egg quality possesses several points of superiority over the yolk index.

Liquefaction changes in thick white and yolk in stored eggs occur simultaneously or not at all.

The intrinsic keeping quality of an egg is markedly a function of the individuality of the hen.

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