PHYSIOLOGY AND REPRODUCTION

Estimation of Shell Surface Area from Measurements of Length, Breadth, and Weight of Hen Eggs

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(Received for publication April 24, 1984)

ABSTRACT An algorithm for estimating shell surface area from measurements of length (L), breadth (B), and fresh egg weight (W) was compared with four algorithms based only on fresh egg weight. Eggs were obtained from 17 laying strains at 34, 46, 50, 58, and 66 weeks of age. A total of 1346 eggs was used.

Estimates of surface area derived from the following algorithms $.9109L^{.289}B^{.3164}W^{.4882}$, $3.9782W^{.7056}$, and $4.67W^{.6667}$ were quite similar for a wide range of eggs from different strains of laying hens at various ages. The extra effort needed to measure length and breadth for estimation of surface area was considered not worthwhile.

(*Key words:* egg shell strength, surface area, measurement)

1984 Poultry Science 63:2471–2474

INTRODUCTION

Shell weight per unit surface area is a useful indication of shell strength of eggs (Voisey and Hunt, 1974; Hamilton, 1978). Direct estimation of surface area (SA) usually involves a complicated mathematical derivation based on the profile of the egg. Such methods are quite accurate but require numerous measurements of the shell (Carter, 1968a, 1974; Carter and Jones, 1970). Hence, methods of indirectly estimating surface area from a minimum of simple measurements are of interest.

Carter (1975) compared several algorithms for estimating surface area from combinations of length, breadth, and weight of eggs. He observed that an algorithm based on weight alone yielded results similar to one based on length and width. Neither estimate differed greatly from that obtained from an algorithm involving all three measurements. Carter drew attention to the merit of the method based on only length and breadth measurements, because it avoids the obvious difficulty associated with variation in weight loss if the egg is not newly laid. However, egg weight data are often gathered in studies involving laying performance or shell quality, whereas acquisition of length and breadth data would probably require additional effort.

Other algorithms for estimating surface area from egg weight have been reported (Mueller and Scott, 1940; Paganelli *et al.*, 1974) in addition to those of Carter (1968b, 1975). The present study compares the algorithm based on a combination of length, breadth, and weight of eggs proposed by Carter (1975) with others based only on egg weight to determine whether the extra effort of measuring length and breadth is worthwhile. Because it was not possible to estimate directly surface area of eggs used in this study, it will be assumed that Carter's algorithm based on length, breadth, and weight provides a sufficiently accurate estimate against which others can be compared. However, it should be pointed out that this assumption appears not to have been tested in the initial studies (Carter, 1974, 1975) nor subsequently.

MATERIALS AND METHODS

All eggs used in this study were obtained from the 22nd South Australian Random Sample Layer Test, 1980 to 1981. Sixteen eggs were sampled at random from each of the 17 strains in the test at 34, 46, 50, 58, and 66 weeks of age. Eggs were stored at 13 C and 85% relative humidity for less than 24 hr prior to measurement.

Length (L) and breadth (B) were measured with dial-reading callipers to .1 mm. Egg weight (W) was measured to .1 g. Surface area (square centimeters) was calculated according to each of the following equations:

TABLE 1. *Means ± standard deviations (SD), minima[1] and maxima[1] for weight (g), length (mm), and breadth (mm) of eggs from laying hens of different strains and ages*

Treatment	Sample size	Weight				Length				Breadth			
		Mean	SD	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.
		(g)				(mm)							
Strain[2]													
2	80	62.5	4.8	51.8	74.7	58.5	2.2	53.9	66.5	43.7	1.2	41.0	46.6
6	78	58.6	4.3	50.0	67.4	58.4	2.1	58.1	64.7	42.4	1.0	40.1	45.0
7	80	61.1	4.9	47.9	73.4	58.1	2.2	53.1	63.3	43.4	1.2	40.3	46.6
8	80	60.4	4.4	50.9	73.8	58.7	1.9	54.3	62.1	42.8	1.2	40.0	46.3
17	78	61.5	5.7	45.7	76.7	59.2	2.4	52.3	64.4	43.1	1.4	39.4	46.6
Age[3]													
34	266	55.9	3.9	45.5	68.4	56.3	2.1	50.6	62.6	42.1	1.1	39.4	45.6
46	272	60.4	4.6	47.8	75.2	58.4	1.9	53.4	64.7	42.9	1.2	39.4	46.6
50	270	61.2	4.4	50.7	73.1	58.7	2.0	53.8	63.6	43.1	1.2	40.1	46.5
58	270	62.3	4.6	46.5	74.9	59.2	2.1	52.2	64.9	43.3	1.2	40.5	47.0
66	268	62.6	4.5	52.0	76.7	59.5	2.1	52.6	66.5	43.5	1.2	40.9	46.6

[1] Minima for weight, length, and breadth (and likewise for maxima) do not necessarily occur in the same egg.

[2] Pooled across all ages. Strains 2, 6, and 7 were White Leghorn × Australorp crosses, Strain 8 was a White Leghorn × White Leghorn hybrid and Strain 17 was a New Hampshire × Australorp cross.

[3] Pooled across all strains (total 17).

$$SA1 = .9109\ L^{.289}\ B^{.3164}\ W^{.4882}$$
(Carter, 1975)

$$SA2 = 3.9782\ W^{.7056}$$
(Carter, 1975)

$$SA3 = 4.67\ W^{.6667}$$
(Mueller and Scott, 1940)

$$SA4 = 4.597\ W^{.6667}$$
(Carter, 1968b)

$$SA5 = 4.835\ W^{.662}$$
(Paganelli *et al.*, 1974)

RESULTS AND DISCUSSION

Length, breadth, and weight of eggs varied relatively widely within and between strains and age groups. The extent of the variation is indicated in Table 1, which includes data (pooled over all ages) from five representative strains. Results from the other strains are similar to those presented in Table 1.

Differences in length, breadth, and weight of eggs might be expected to generate even larger differences in estimates of surface area (Table 2). This was not the case, however. Coefficients of variation (standard deviation expressed as a percentage of the mean) for surface area estimates were smaller (5 to 6%) than those for weight (7 to 9%). Length (3 to 4%) and breadth (2 to 3%) were less variable.

Two of the algorithms (SA2 and SA3), based only on egg weight, and the algorithm SA1, based on length, breadth, and weight, gave similar mean values for surface area estimates regardless of strain or age group (Table 2). The closeness of the mean values for SA1, SA2, and SA3, together with very high correlations between SA1 and SA2 and between SA1 and SA3 (Table 2), indicates that surface area estimates for individual eggs were similar even at the extremes of the ranges of length, breadth and weight observed in this study. However, differences in the mean values for SA4 and SA5 coupled with very high correlations with SA1 indicate consistent biases in the estimates from SA4 and SA5. Both of these conclusions were verified by inspection of the data from individual eggs. In the case of Strain 17, which displayed wider variation in length, breadth, and weight than any other strain shown in Table 1, the largest values for the differences between SA1 and SA2 and between SA1 and SA3 were 1.6 and 1.3 cm^2, respectively. These occurred in the same egg, which was 61.3 mm long, 41.0 mm broad, and 53.8 g in weight. The means ± standard deviations of the differences, (SA1−SA2) and (SA1−SA3), were .08 ± .33 and .11 ± .37 cm^2, respectively. Although both mean differences

TABLE 2. *Estimates of surface area of eggs from laying hens of different strains and ages using five different algorithms*

Treatment	Surface area (SA) algorithm					Correlation coefficient
	SA1	SA2	SA3	SA4	SA5	
	(cm^2)					
Strain[1]						
2	73.4 ± 3.9[2]	73.5 ± 4.0	73.5 ± 3.8	72.3 ± 3.7	74.6 ± 3.8	.995[3]
6	70.4 ± 3.6	70.3 ± 3.6	70.4 ± 3.4	69.3 ± 3.4	71.5 ± 3.5	.998
7	72.3 ± 4.0	72.4 ± 4.1	72.4 ± 3.8	71.2 ± 3.8	73.5 ± 3.9	.996
8	71.8 ± 3.5	71.8 ± 3.6	71.9 ± 3.5	70.3 ± 3.4	73.0 ± 3.5	.992
17	72.8 ± 4.7	72.7 ± 4.8	72.7 ± 4.5	71.5 ± 4.4	73.8 ± 4.5	.998
Age[4]						
34	68.0 ± 3.3	68.0 ± 3.4	68.2 ± 3.2	67.2 ± 3.1	69.3 ± 3.2	.994
46	71.7 ± 3.7	71.8 ± 3.8	71.8 ± 3.6	70.7 ± 3.6	73.0 ± 3.7	.994
50	72.5 ± 3.6	72.5 ± 3.7	72.4 ± 3.5	71.3 ± 3.4	73.6 ± 3.5	.996
58	73.4 ± 3.8	73.4 ± 3.8	73.3 ± 3.6	72.2 ± 3.5	74.5 ± 3.6	.996
66	73.7 ± 3.7	73.7 ± 3.7	73.6 ± 3.5	72.4 ± 3.5	74.8 ± 3.6	.995

[1] Pooled across all ages.
[2] Mean ± standard deviation. The sample size is given in Table 1.
[3] Minimum value obtained from the simple correlations between SA1 (based on length, breadth, and weight of eggs) and each of the algorithms based only on egg weight.
[4] Pooled across all strains (total 17).

are statistically different ($P<.05$) from zero according to t tests on paired observations these can be regarded as trivial for practical purposes.

The evidence obtained from a wide range of eggs laid by hens of different strains at various ages indicates that estimation of surface area from egg weight alone compares favorably with estimation from a combination of length, breadth, and egg weight. The use of either of the algorithms SA2 and SA3 proposed by Carter (1975) and Mueller and Scott (1940), respectively, minimizes both the costs of measurement and computation involved in estimation of surface area without undue loss of accuracy.

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