# NEW ALTERNATIVES FOR IMPROVING EGG SHELL STABILITY THROUGH BREEDING

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## Introduction

Egg shell quality is of considerable economic significance for commercial egg production. Eggs with shell defects lead to a direct reduction in yield and damage the image of eggs with the end user. Possible causes of these quality reductions are age, housing conditions, feeding, egg handling technology and genetic predisposition.

The shell is the outer covering of the egg and performs several important functions and tasks. Each individual egg is unique with its own microstructure which provides a wealth of information about the environment in which it was created.

The shell protects the contents of the egg from mechanical impact to some extent and allows a controlled exchange of fluid and gas through the pores. The egg shell also provides protection against microbial entry from the environment and serves as a scource of calcium for the development of the embryonal skeleton.

Because of its central importance for the egg as a commercial product, breeders and producers are continuously seeking to improve the quality and consistency of the egg shell. In this paper we propose to concentrate on breeding approaches and alternative measuring techniques which have a direct impact on product quality at the producer level and which indicate possibilities for improving shell stability.

## Traditional methods of measuring shell stability

In the breeding of laying hens shell quality is one of the most important traits that is considered for selection purposes. In order to improve shell quality, suitable methods for measuring shell stability have to be devised. The direct determination of the number of eggs with shell defects is of minor importance for the improvement of shell quality through breeding as the incidence of these defects is very low in the first half of the laying period and decisions on selection have to be taken early with a view to a short generation interval.

For this reason breeders rely on indirect measuring techniques for determining shell quality:

- Specific weight
- Shell strength
- Deformation
- Shell thickness
- Shell percentage (%)
- Subjective assessment

The first four methods are the most common procedures for the indirect determination of egg shell quality. The specific weight can be measured by two different procedures, the Archimedes principle or immersion of the eggs in salt solutions. Determination of the specific weight is one of the cheapest and fastest methods of assessing shell quality and has the added advantage of not damaging the egg shells.

A range of different devices have been developed for measuring shell strength. They determine the pressure needed to break the egg shell. This can be done for example with a highly sensitive electronically controlled breaking strength tester. Breaking strength can only be measured once per egg as the first fracture affects each further measurement. In German performance tests shell strength is determined routinely every year. The hardness of the shell is expressed in Newton (N).

Deformation is a measure of the elasticity of the egg shell. In the deformation test the shell is subjected to a constant weight of 1 kg. The distance by which the egg shell deforms is then measured. Deformation is preferable to specific weight as the eggs remain dry and therefore not exposed to any risk of bacterial contamination. The age of the eggs or the storage temperature have little effect on deformation.

Shell thickness is measured with a micrometer screw. The readings are subject to fluctuations due to differences in shell structure (shell thickness) and varying membrane and moisture contents of the shell. The results of shell thickness measurements can therefore only be interpreted if the shell fragments have been prepared correctly and the measuring technique has been accurately described.

## Factors affecting egg shell formation

A number of environmental influences to which the hens are exposed play an important role in the formation of the egg shell. Shell quality declines as the hens get older. This deterioration in egg shell quality is associated with a change in the matrix material, which affects the mechanical properties of the shell.

Another reason for poorer shell quality in older hens is their reduced ability to absorb calcium. The increase in egg weight while shell mass remains constant also causes shell thickness to decline with age. It means that the hens must pack more egg mass into the same amount of shell.

A further important factor affecting shell quality is the management regime. Temperature and atmospheric humidity in particular are crucial for the formation of the shell. Failure to get these two parameters right means that the hen suffers from heat stress, which has an adverse effect on shell thickness. V. HAAREN-KISO et al. (1985) state that optimum climatic conditions are temperatures of 17 to 20 °C and a relative humidity of 60 to 80 %.

The progressive deterioration in shell quality observed as hens grow older, primarily due to poor nutrient absorption, can be overcome by dietary adjustments. Particular attention must be paid to the calcium content of the rations. The calcium content of the diet must be adjusted to the hens' requirements (age of hens, daily feed intake). KIRCHGESSNER (1997) pointed out that hens can compensate for an undersupply by improved utilisation of the calcium in the diet and very rapid mobilisation of calcium deposits, especially in the long bones, only for a short time.

The health status of laying hens also plays an important role in achieving good shell quality (HESTER, 1990). Respiratory tract infections in particular are of major significance.

Despite active immunisation during rearing, regular booster vaccinations during the laying period, especially against infectious bronchitis, are crucial both for internal and external egg quality.

### Possibilities for improving egg shell quality through breeding

Heritability estimates for the traits of shell stability (Table 1) are in the medium range, suggesting that manipulation of these traits through breeding work is possible and promising.

**Table 1: Heritability estimates for the traits of shell quality**

| | Heritability estimate |
|---|---|
| Shell strength | 0.22 to 0.53 |
| Deformation | 0.12 to 0.36 |
| Specific weight | 0.29 to 0.48 |
| Shell thickness | 0.30 to 0.42 |

Source: various publications

When assessing the estimates it is important to bear in mind that heritability is not a fixed property of a trait but is also dependent on the population and the environmental conditions to which the hens are exposed.

Improvement of shell stability through breeding can only be achieved at the expense of some productivity as negative correlations often exist between the traits of shell stability and productivity. Table 2 shows the phenotypic correlations between egg weight and the traits of shell quality.

**Table 2: Phenotypic correlations between egg weight and the traits of shell stability according to the literature**

| Author | Shell strength | Deformation | Specific weight | Shell thickness |
|---|---|---|---|---|
| GRUNDER et al., 1989 | 0.5 to 0.09 | -0.02 to 0.01 | -0.03 to 0.19 | |
| FLOCK and PETERSEN, 1973 | -0.04 | -0.02 | -0.05 | 0.11 |
| WASHBURN, 1982 | | -0.7 to 0.15 | | |
| TAWFIK et al., 1981 | 0.01 | | | |
| V. HAAREN-KISO et al., 1985 | -0.07 to -0.12 | | -0.07 to -0.19 | |

Both positive and negative phenotypic correlations are quoted for the traits shell strength, deformation, specific weight and shell thickness relative to egg weight.

The main difficulties of improving shell quality through breeding programmes are defining appropriate benchmarks for the physical and economic assessment of egg shell quality, the correct time for measuring shell quality and the negative genetic correlations to egg mass.

### Material and methods

As criteria of shell quality, we measured shell breaking strength with an electronic testing device and the number of defective eggs with a crack detector in two pure-bred lines of the White Leghorn breed. The measurements were conducted at 56 to 62 weeks of age. Both lines were kept in the same house and fed the same diet.

**Figure 1: Machine for testing egg shell breaking strength**


The electronic breaking strength tester BMG 1.2 (see Figure 1) was used to measure egg shell strength. The machine allows a partly automated measurement of shell stability. The automatic control of the measuring process eliminates some of the subjective influences introduced by operators. The data are transferred via a PC interface to a mobile data recorder. The machine measures the force needed to crack the egg shell. The shell strength measured in this way is expressed in Newton (N). The test was performed at the blunt end and the pointed end, with the egg in the upright position. The third measurement of breaking strength was performed at the equator region of the egg. To determine shell strength at the blunt end, the pointed end of the egg was fixed with a foam rubber ring on the measuring plate and pressure applied to the blunt pole. To measure the breaking strength for the pointed pole the egg was fixed in the inverted position and the pressure plate applied to the pointed pole. The measurement at the equator was performed by fixing the egg horizontally.

The eggs used in the breaking strength test were from three consecutive laying days. Each egg was marked with the hen number to determine the within-hen repeatability. The measurement on the blunt pole was conducted at 56 weeks, on the pointed pole at 57 weeks and in the equator region at 62 weeks of age.

### Crack detector

Eggs with shell defects were identified by means of a crack detector. The crack detector procedure is a technology used in automated grading machines to remove eggs with defective shells. The egg is tapped by small electronic hammers to detect defects in the shell. Copper-covered coils gently tap the egg shells from various angles. The interior of the coils is fitted with tiny microphones which record the sound produced when the eggs are tapped. This sound is then analysed by computer and eggs with faulty sound patterns are removed. Faulty sound patterns are produced even by the finest hairline cracks that are invisible to the naked eye. Eggs for the crack detector test were collected over an 8-day period at 63 and 64 weeks of age and stamped with the cage number. The cage numbers of the removed eggs were recorded and these eggs were later subjected to a breaking strength test.

### Results of the shell strength measurements

The breaking strength readings for the three measuring positions are recorded for both lines in Table 3.

**Table 3: Results of shell strength test for lines A and B**

| Measuring position | Shell strength (N) | | | |
|---|---|---|---|---|
| | Line A | | Line B | |
| | x | s | x | s |
| Blunt end | 42.7 | 8.1 | 37.1 | 8.4 |
| Pointed end | 41.6 | 8.1 | 35.6 | 8.6 |
| Equator region | 36.7 | 7.3 | 35.4 | 6.8 |

The figures represent the average of the three successive measurements. Readings at the blunt end showed the highest value for both lines. The breaking strength at the pointed end differs only slightly from that at the blunt end. The breaking strength test at the equator for line A of 36.7 Newton on the other hand showed a greater difference from the two previous measurements.

### Results of the crack detector test

The vast majority of the hens laid 6 to 8 eggs in 8 production days on which eggs were collected for the crack detector test. Table 4 shows the frequency distribution of the removed eggs per hen for lines A and B.

**Table 4: Number of removed eggs per hen on a maximum of eight production days for lines A and B**

| Number of Removed eggs | Number of hens | | Proportion | |
|---|---|---|---|---|
| | Line A | Line B | Line A | Line B |
| 0 | 283 | 224 | 72.0 % | 58.0 % |
| 1 | 92 | 114 | 23.4 % | 29.5 % |
| 2 | 14 | 39 | 3.6 % | 10.1 % |
| 3 | 4 | 9 | 1.0 % | 2.3 % |

In both lines only four observation classes with an extremely skewed distribution are available. As was to be expected, the class of hens laying only eggs with intact shells predominates. The proportion of hens with at least one removed egg is larger in line B, commensurate with the lower breaking strength of the eggs. In line A two or more eggs were removed in 4.6 % of the hens. In line B this proportion was 12.4 %.

To check the breaking strength values, the eggs removed by the crack detector were individually tested. Half of the eggs were measured at the blunt end and half at the equator region (Table 5).

In 20 to 23 % of the removed eggs the shell strength was less than 10 Newton and therefore not measurable. Among the measurable eggs the mean shell strength was 17 to 20 Newton depending on line and measuring point. There were no indications of appreciable line differences between the removed eggs.

**Table 5: Shell strength measurement of eggs removed by the crack detector**

| | Measurement at the blunt end | | Measurement at the equator | |
|---|---|---|---|---|
| | Line A | Line B | Line A | Line B |
| Number of eggs | 65 | 110 | 65 | 110 |
| Proportion of non measurable eggs | 20 % | 24.6 % | 23.1 % | 22.8 % |
| Proportion of measurable eggs | 80 % | 75.4 % | 76.9 % | 77.2 % |
| Ø Shell strength (N) | 20.5 | 17.4 | 19.0 | 19.3 |
| Standard deviation | 10.2 | 8.4 | 7.8 | 8.3 |

### Correlations between different measuring positions in determining shell strength

The correlations between shell strength values at different locations for lines A and B are shown in Table 6.

**Table 6: Correlations between shell strengths for three measuring positions in lines A and B**

| | Pointed end | | Equator | |
|---|---|---|---|---|
| | Line A | Line B | Line A | Line B |
| Blunt end | 0.43 | 0.41 | 0.26 | 0.31 |
| Pointed end | | | 0.25 | 0.21 |

The measurements at the blunt and pointed end exhibit the strongest correlation in both lines, with r = 0.43 and r = 0.41, respectively. The correlations between the results at the blunt end and at the equator on the other hand are weak, with r = 0.26 for line A and r = 0.31 for line B. The relationship between the reading at the pointed end and at the equator region of the egg is also weak in both lines.

Table 7 shows the correlation between the three measuring positions of shell strength and the crack detector test for both lines.

**Table 7: Correlations between the three measuring positions of shell strength and the proportion of eggs removed by the crack detector for line A and B**

| | Shell strength | | |
|---|---|---|---|
| | Blunt end | Pointed end | Equator |
| Per cent eggs removed in line A | -0.19 | -0.14 | -0.17 |
| Per cent eggs removed in line B | -0.17 | -0.09 | -0.22 |

A negative correlation exists in both lines between the different measuring positions of shell strength and the crack detector test (number of eggs removed per hen). This means that increasing the breaking strength of the egg shell also improves the grading results.

The weak correlations between the traits can be attributed to the skewed distribution of the grading frequencies. To obtain more accurate results it would be necessary to increase the egg collection period and to test several replicates per hen. This would provide a more extensive sample of data that comes closer to the normal distribution. Another point is the fact that the crack detector procedure scans the entire surface of the egg shell and is not restricted to one measuring position. The question as to how calcium deposits for example affect the result of the crack detector test is also unresolved.

## Conclusion

When measuring the breaking strength of egg shells it is irrelevant whether the weight is applied at the blunt end or the pointed end as the readings at the pointed end are only slightly lower systematically while exhibiting the same variance. The results of measurements at the equator region on the other hand have a distinctly restricted distribution range. The lower the variance, the smaller are the realisable selection differences and the breeding progress that can be achieved.

The relationships between mean shell strength and the proportion of eggs removed per hen in the crack detector test are relatively slight. A major cause of the weak correlation between the two traits is the unfavourable distribution of the proportion of removed eggs per hen on only eight collection days.

One way of improving the determination of egg shell quality might be to analyse the internal results of the crack detector test. Evaluation of these internal data might allow a more accurate assessment of shell quality. If individual physical data are available, a continuous measuring series from very poor to excellent stability can be evaluated. The present analysis only supplied two results (shell intact or defective). These were set against the continuous distribution of shell strength values. A comparison of so-called "threshold data" with continuously distributed data is always fraught with problems.

Further studies will have to decide whether shell strength measurements should be performed on all eggs tested by the crack detector, rather than just the defective eggs that have been removed. Doing so might be a way of determining the difference between the two groups "eggs with shell defect" and "eggs without shell defect". It would also reveal whether the crack detector assigns eggs with poor shell strength results to the category "eggs without shell defect".

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