The manipulation of egg size and egg quality

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In this article the contribution which geneticists can make to egg quality i.e. eggmass, shell thickness, and albumen height is examined. Factors which the poultryman can manipulate on the farm such as the choice of a lighting system, dietary modification, and force moulting are discussed in relation to egg quality.
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In hierdie artikel word die bydrae wat genetici kan lewer om die kwaliteit van eiers, bv. eiermassa, dopdikte en albumienvlak te verbeter, ondersoek. Faktore wat die pluimveeboer kan verander op sy plaas, soos die keuse van 'n beligtingsstelsel, dieetaanpassings en gedwonge ververing word bespreek met betrekking tot eierkwaliteit.
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Striking improvements in the efficiency of egg production have been achieved in many countries, with the result that eggs are cheap and the market is saturated. In these circumstances, the emphasis shifts from quantity to quality, though what is meant by quality differs considerably from place to place. Some markets pay more for brown eggs and others want only white eggs. In many countries, eggs are graded by mass, larger eggs being worth more per egg than smaller ones; but the premium on size varies considerably and the size of egg which commands the highest price per gram may be as low as 55 g or as high as 65 g. There are also markets where eggs are sold by number, regardless of their individual masses.

Freshness is the first attribute to which attention is paid as markets get organized, but in some places 'fresh' means 'not rotten' whilst in other cases considerable care is taken to ensure that eggs are not more than a few days old when sold to the customer. The physical properties of the albumen and the yolk membrane deteriorate at a rate determined chiefly by temperature: An egg held for three days at 30°C loses more of its initial albumen quality than an egg held for 10 days at 5°C. The proper handling and storage of eggs after they have left the farm is therefore one of the most important determinants of egg quality, but this article will be confined to considering quality in the newly laid egg. First the geneticist's contribution to egg quality will be examined and then the attention will be turned to factors which the poultryman can manipulate on the farm.

What the poultry breeder can do for egg quality

Most of the traits which go to make up primary egg quality — eggmass, shell thickness, albumen height — have a heritability high enough to allow direct selection in individual hens to be an effective method of genetic selection. The difficulty the breeder faces is that some characters, such as eggmass, are negatively correlated with egg number whilst others, like albumen height and shell thickness, have not had a sufficient effect upon the value of the product to justify much selection pressure.

Commercial poultry breeders mostly carry out their selection using an index which incorporates egg quality measurements, along with egg number. If this index is efficiently constructed, taking into account the heritabilities of the traits, their correlations and their relative market worth, the result is usually a steady improvement in egg number while egg quality gets no better (though it may not be getting worse!).

The real problem about egg size is that, in pullet flocks, there is a period of 7 or 8 months during which the bird gradually works up to the optimal eggmass for the market that it has been bred to supply. A strain of chickens which reaches a mature egg size of 65 g at 60 weeks of age comes into lay with a mean egg size of around 45 g. What is needed is a chicken with a much smaller differential between initial and ultimate egg mass. Wehrli & Nordskog (1963) and Cowen, Bohren & McKean (1964) examined this problem and came to the conclusion that there was no evidence of genetic variation in the slope of the eggmass curve. However, we should resist this conclusion. The fact that eggmass increases with age is clearly determined by genes, rather than the environment, and it must be possible to make some change in the rate of increase if sufficient resources and selection pressure are brought to bear. It is a problem rather like changing the shape of a growth curve — difficult but not impossible. It is time that someone made a determined effort to select upwards for 30-week eggmass and downwards for 40-week eggmass.

Shell thickness can be estimated in the intact egg by specific gravity methods or by observing the deformation of the shell under a standard load. Neither of these measures is particularly good for predicting the thickness of an individual shell but they correlate well enough to allow discrimination of family means based on dozens or hundreds of eggs and so shell thickness can be improved by selection based on indirect measures. The main reason why little progress is made is again that the problem is age-related. All pullets produce satisfactory shells initially but all show a deterioration as the pullet laying year wears on. Selection is generally made part-way through the first laying year and this is too early to give much discrimination of families with incipient poor shell quality. Unfortunately, Nagai & Gowe (1969) and Rodda (1972) have shown that the environmental variance of shell thickness tends to increase with age and so the heritability is low for selections made late in the laying year.

Albumen quality (of the new-laid egg) also deteriorates with the age of the hen but, in this case, differences between genotypes can be easily identified early in lay. Subsequent rates of decline tend to be parallel and so selection for early albumen quality is effective in improving late albumen quality. The difficulty is that, in many markets, the producer is not directly penalized for poor albumen quality (nor paid more for better quality) and so the incentive for breeders to do something about albumen quality is lacking.

In all three characteristics — egg size, shell thickness and albumen height — there are large changes with age, which are far more important than differences between genotype means. There is a lack of fundamental research into the biology of these age-related effects. We know that egg size is determined by yolk size and so the question to be answered is: 'What determines the size at which an ovarian follicle is competent to ovulate and how is it that this set-point changes with age?' The declines in shell and albumen quality have been blamed on faulty nutrition or depletion of body reserves, but almost certainly have nothing to do with nutrient supply to the oviduct. It is more likely that the oviduct is gradually wearing out: Both albumen height and shell thickness can be restored (nearly to the levels of a young pullet) if hens are moulted and given a period out of production long enough to allow regression and regeneration of the oviduct. If we had some understanding of the changes taking place in the oviduct during the pullet year we might be able to make more constructive suggestions about how the breeder should select, or how the poultryman should manage, to obtain better egg quality.

What the poultry farmer can do for egg quality

Egg size is primarily determined by genotype and the age of the flock but the farmer is able to increase eggmass by 3 – 5%. Nutrition has surprisingly small effects on egg size. A high-energy diet containing supplementary fat will increase eggmass by a maximum of 1 g, provided that the protein:energy ratio is maintained. There is a response to dietary amino-acid supply, but the input which optimizes rate of lay will also optimize egg size and there is very little scope for the poultryman to adjust egg size by adjusting protein levels.

The main tool for manipulating egg size is the choice of a lighting system. Two procedures are available: the adjustment of light pattern in the growing stages to advance or delay sexual maturity and the use of non-24-h (ahemeral) cycles for flocks already in lay. Manipulation of sexual maturity does not require light-proof houses but the changes in eggmass which result are irreversible, being correlated with permanent changes in body size. Increases in egg size achieved with ahemeral light-dark cycles, on the other hand, are temporary and can easily be switched off if market prices change; but the system only works in properly light-proofed houses and the increased eggmass obtained is at the expense of egg numbers.

The effects of changing daylengths on age at first egg have been reviewed (Morris, 1962, 1968, 1979, 1981) and are now widely understood. Decreasing daylengths during the developmental period will delay maturity and increasing daylengths advance maturity. These changes will alter the number of very early (small) eggs produced but also affect eggmass at later stages of lay to some extent. Mean eggmass for the whole of the first laying year is increased by about 1 g for each 8 days' delay in age at 50% production and the regression of mean eggmass on mean age at 50% lay (as affected by lighting patterns) is linear (and positive) throughout the range. The regression of rate of lay (to a fixed finishing age) is negative and linear. A direct consequence of these two straight-line effects is that the relationship between egg output (kg/hen year) and age at 50% lay (as influenced by lighting) is curvilinear. Neither early maturity nor late maturity leads to maximum total yield — an intermediate is best. If egg income is closely dependent upon eggmass (as in the UK), maximum profit is obtained from current brown-egg stocks by bringing them into lay so that they reach 50% production at about 23 weeks of age.

The most popular ahemeral cycle in the UK is 28 h (e.g. 16L:12D). Six of these cycles are completed in 7 days, which makes them convenient to operate. In a young flock at peak production, a 28-h cycle will reduce rate of lay by about 6% and increase eggmass by 6% (Morris, 1973). Later in the laying year, responses are smaller because the proportion of birds which have potential ovulation rates in excess of one every 28 h, is smaller. It is not necessary to plunge the house into darkness during the working day when using ahemeral cycles. Alternating bright and dim lighting will entrain the flock quite satisfactorily provided that the ratio is right (Morris & Bhatti, 1978). When changing back from a long cycle to a normal 24-h cycle there are rather special rules about the hours of light and darkness to be employed (Morris, 1978) and it is important to understand these if a moult is to be avoided.

Ahemeral lighting is one of the most potent tools available to the poultryman for increasing shell thickness late in the laying year (Leeson, Summers & Etches, 1979; Yannakopoulos & Morris, 1979). Because a longer cycle extends the interval between ovulations it allows each egg to spend an hour or two longer in the shell gland (Melek, Morris & Jennings, 1973), and this gives a substantial improvement in shell thickness. Increases in eggmass are directly related to increases in cycle length up to 30 h, but maximum increase in shell thickness is obtained with 26-h cycles. There is thus no point in using a 28-h cycle to get thicker shells at the end of the laying year, if increases in egg size at this stage are undesirable. A cycle of 26 h 40 min. is convenient, because nine cycles fit into 10 days and smooth rates of lay will be observed if records are summarized every 10 days.

Feeding additional calcium, and other dietary modifications, have very little beneficial effect upon shell quality. If one compares diets containing 3 and 4% calcium one usually finds a consistent (and statistically significant) difference in mean shell thickness; but the actual difference is only about 1%. This must be compared with a 15% decline in thickness occurring between 30 and 70 weeks of age and an 8% increase in thickness which can be achieved at one time with an ahemeral cycle. Many nutritional experiments have reported significant effects of dietary treatments on shell thickness (usually specific gravity) but none has shown worthwhile reductions in the proportion of cracked eggs or changes in the rate of decline of shell thickness.

If shell quality is judged severely in the market place, so that batches in which 10 or 15% of eggs have been downgraded are unacceptable even after removal of the cracks, the only remedy for the poultryman is to replace his flock earlier or to moult it. The choice between these two procedures will depend upon the local economics of egg production and is influenced much by the relative prices of cull hens and replacement pullets. There are signs that early force moulting may be adopted increasingly in the UK by large-scale producers who are supplying the premium supermarket outlets. In the past it has been associated more with small producers who have a special market for large brown eggs and who do not want pullet eggs.

Force moulting is also the only effective means by which the poultry farmer can maintain high albumen quality in his new-laid eggs. This step is certainly not worth taking until the holding system on the farm and subsequent distribution have been improved so that unnecessary deterioration between production and sale is prevented. Given that the downstream handling of eggs has been improved as far as possible, it is then worth attending to the quality of the albumen at the point of production. Unfortunately, no clever tricks for improving this exist and to meet market requirements one must rely upon limiting the production period for each flock.

The problem of ageing in the oviduct and age-related physical changes in the physiological mechanisms controlling albumen formation and shell secretion do seem to need much more attention than they have received so far. There are exciting fields of inquiry here for any young poultry scientist looking for something worthwhile to investigate. Meanwhile it would be valuable for some state-controlled funds to be invested in two medium-term selection programmes, one designed to alter the slope of the line relating eggmass to age and the other designed to alter the slope of the line relating shell thickness to time in lay.

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