

# Genetic progress in the poultry industry

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In this article progress attributable to genetic selection in the poultry industry is discussed in three sections: genetic progress in broilers and broiler breeders, in laying hens, and in disease resistance. Selection methods are evaluated and future objectives are suggested.

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In hierdie artikel word die vooruitgang wat toegeskryf kan word aan genetiese seleksie in die pluimveebedryf, in drie afdelings bespreek: genetiese vooruitgang by braaikuike en teelbraaikuike, by lêhenne en t.o.v. siektebestandheid. Seleksiemetodes word geëvalueer en doelwitte vir die toekoms word voorgestel.

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Since poultry breeding started in earnest over 50 years ago there have been considerable environmental changes in the industry, some beneficial (improved disease control, housing, nutrition, lighting) and some deleterious (increased stocking rates, larger populations), which make it difficult to determine the relative contributions of breeding and management when assessing the improvements that have been made in the poultry industry during this time. This difficulty has been addressed by, among many others, Clayton (1968), Dickerson (1970) and Manson (1972).

Clearly, breeding and management must be improved simultaneously. By increasing nutrient supply to laying hens the apparent plateau in egg numbers among some stocks would disappear; in vaccinating birds against debilitating diseases the laying hen or broiler would be more capable of expressing its genetic potential. Similarly, considering the tremendous improvements in management, housing, disease control, etc. there is now more potential for detecting the best genotypes. Also, due to advances in processing, transportation, and marketing techniques there is an increasing demand for poultry products world-wide, which has intensified the incentive of poultry geneticists to improve their product and have a greater range of genetic stocks available to supply the different and changing demands of poultry producers around the world.

## Broilers

Significant changes have taken place in the broiler industry in the past decade. Whilst rapid growth rate continues to be the most important selection criterion, there has been increasing interest in other genetic aspects, such as improving feed conversion efficiency, reducing fat content, improving egg production in the female line, dwarf broiler mothers, changing the shape of the growth curve, and attempting to overcome the problems of leg weakness.

In the past 11 years one international broiler-breeding company (A.F. Gristwood, personal communication) has increased livemass gain by 65 – 70 g per year, reduced the time taken to reach 1900 g livemass by 1,3 days per year, and reduced cumulative feed conversion ratio to 1900 g livemass by three points each year. Since 1971, coinciding with the introduction of Marek's disease vaccination, genetic progress in egg production to 61 weeks of age has been 18 eggs per hen housed. Not only are these results remarkably good, but it is particularly interesting to note that there has been no hint of a plateau being reached in any of these traits during this time.

Long-term selection response can come both from the

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variation existing within or between the population or populations at the outset, and from new variation generated by mutation or other genetic events subsequent to the start of selection. Hill (1984) presented evidence to suggest that mutations are particularly important after only about 20 generations of selection if, in the base population, there was substantial variation initially. The contribution of mutations is likely to increase further after this and to be very dependent on population size. He recommended maintaining large populations; the sampling of competitor's stock (in effect, increasing total population size); being aware that mutations would occur in an individual, not in a family, so the exclusive use of family selection would cause such individuals not to be recognized, whereas it is critical that the first individual carrying the mutant gene is selected as a parent.

Because broilers are selected individually from large populations it is likely that favourable mutations will not be overlooked, and that gains in growth rate could be expected to continue at the rate of about 70 g per year for many more generations.

The genetic characteristics of economic importance in an integrated broiler enterprise are growth rate and food utilization, which together account for 94% of the annual potential economic savings in the production costs in such an enterprise (Shalev & Pasternak, 1983). Geneticists have selected almost exclusively for the first of these characters (growth rate) and this has had correlated responses in feed efficiency, which improves, and fat content, which decreases, when broilers are compared at the same market livemass (A.F. Gristwood, personal communication).

#### Food utilization

It is only relatively recently that more emphasis has been placed on the improvement of feed conversion efficiency. Fisher (1984) quoted a number of references in which it has been shown that efficiency of food (energy) utilization has changed very little, if at all, with virtually all the selection effort being directed toward increased bodymass. This increased growth rate will, however, have had the effect of reducing the food required for maintenance during the growth period and in this respect utilization of food will have been improved.

Selecting for improved food utilization is expensive and tedious so it would be unwise to subject all birds in the flock to such a selection programme, which necessarily involves caging broilers individually. An initial screening process would be likely in practice, with only the heaviest males at a certain age being evaluated. Measurement of food utilization can take the form of *ad libitum* feeding over a short (2-week) period or of feeding the birds on a restricted amount of food daily (Leenstra, 1984) where appetite is less important in determining bodymass, and efficient growth becomes more important. A restricted feeding method of selection applied from, say, 3 weeks of age, would favour birds that are initially smaller, as less of the daily allocation of food would be needed for maintenance purposes. The result of such a selection programme could well be a change in the growth curve of the broiler — low initial mass, followed by a rapid growth phase just before slaughter. Such a bird would use food more efficiently than a bird that grows faster initially, but where growth slows down later (Pasternak & Shalev, 1983). Manipulation of the growth curve, with the concomitant improvement in food utilization, is an exciting prospect for genetic selection in the future.

Where selection for food utilization is made, it is imperative that a good quality feed of high nutrient density is used. When

food of poor quality is fed in a selection programme, the result is an increased appetite and increased fat deposition (Sorensen, 1980). It would not be unlikely that much of the selection for growth rate and food utilization in broilers during the past decades was made on feeds that were sub-optimal in some or other nutrients, resulting in the high fat content exhibited by some strains.

Food conversion efficiency is genetically correlated with body fat content, consequently, by selecting for improved feed utilization, body fat content is reduced (Pym & Farrell, 1977). Also Leclercq, Blum & Boyer (1980) have shown that feed utilization improves as a consequence of selection against fat deposition.

It is predicted that greater emphasis will be placed on improving food utilization, as the response to selection for growth rate declines, although it is questionable as to whether the latter will occur in the near future. Nevertheless, now that the relative economic importance of food utilization has been realized, tandem selection for this criterion and growth rate may provide greater genetic-economic gains in the future than selection for growth rate alone.

#### Fat deposition

It is a common complaint that the broilers of today contain more fat than those of a decade ago (Fisher, 1984) and a considerable amount of genetic research has been channelled into breeding leaner broilers (Pym & Solvyns, 1979; Leclercq, *et al.*, 1980; Whitehead & Griffin, 1982). This subject was critically reviewed by Fisher (1984), whose conclusion was that 'the modern broiler is fatter than its forebears at a given age simply because it grows faster, but is not fatter at a given weight or stage of maturity'. McCarthy & Siegel (1983) proposed that selection for increased bodymass in chickens has kept the proportion of fat in the body constant up to the age at which selection is made, whereafter there is a rapid increase. Gristwood (personal communication) has shown that under commercial conditions, selection for increased growth rate has improved feed efficiency with a concomitant lowering of fat levels (Table 1).

**Table 1** Comparison between genetic control (1973) and broilers in 1984 for percentage abdominal fat at various livemasses (Gristwood, personal communication)

	Livemass		
	1 kg	2 kg	3 kg
Control male (1973)	1,57	2,37	3,17
Ross male (1984)	1,35	2,05	2,75
Control female (1973)	2,17	3,57	4,97
Ross female (1983)	1,81	3,21	4,61

There is no doubt that genetic variations exist in carcass fat content. Within-strain coefficients of variation among birds of between 30–35% are typical (Becker, Spencer, Mirosh & Verstrate, 1979), and the heritability of fat content in broilers is high (0,48 according to Friars, Lin, Patterson & Irwin, 1983). Selection against fat deposition is therefore a real possibility, as has been shown convincingly by Leclercq, *et al.* (1980) and Leenstra (1984), who used sib selection, and by Whitehead & Griffin (1982) who used very low density lipoprotein (VLDL) concentrations in blood plasma to select broilers directly on their own performance. Because of a

virtually zero genetic correlation between percentage abdominal fat and bodymass (Leenstra, 1984), selection against fat deposition is possible without direct negative effects on growth rate.

The main difficulty in selecting against fat deposition is that of measuring carcass fat content of the live bird. Various techniques have been tried, including the abdominal caliper method (Pym & Thompson, 1980), backskin and skinfold thickness (Becker, *et al.*, 1979), and the VLDL method mentioned above. None of these is entirely satisfactory: the first depends a great deal on the operator; the second and third correlate poorly with total fat content and the fourth method is very sensitive to the nutritional status of the bird at the time of measurement as well as being a correlated character whose relationship with total fat content would not be expected to remain strongly positive for more than a few generations.

Whittemore (1978) cited by Leenstra (1984) has cautioned against selecting directly against fat deposition, as success in this direction might be brought about as a result of a lower appetite, and hence the economic benefit would be nullified.

Perhaps the best approach to decreasing fat content and increasing lean tissue gain simultaneously, would be to select for improved food utilization (as outlined above) and to rely on the correlated response in fat gain, rather than attempting to measure fat gain directly. Pym & Thompson (1980) and Leclercq, *et al.* (1980) indicated that selection for decreased fat content improved food utilization by approximately 40% of that obtained by direct selection for improved food utilization, and in both cases the decrease in fat was similar.

The biological and economic benefits of selecting for food utilization would therefore be greater than selecting against fat growth in broilers.

#### Leg weakness in broilers

It is likely that selection pressure on bodymass gain has led to a reduction in overall fitness over the years, which, to a large extent is inevitable, as broilers are now growing at a rate which exceeds their skeletal growth, which therefore comes under increasing pressure (Mercer, 1984).

In an analysis of a large volume of data on leg weakness in broilers (classified as crooked toe, bow leg, splay leg, twisted leg, tibial dyschondroplasia and knobby keel), Mercer (1984) showed that these abnormalities of the broiler chicken have a genetic component and that their frequency can be altered by selection. However, the incidence of defect traits increased if selection was performed on livemass only, or even if only individual (mass) selection was applied against them.

It was apparent that if selection were to be applied against defect traits, that this would be at the expense of livemass gain, but that the use of index selection, including family information on all traits, offered a compromise with good responses in all traits. Fortunately, positive genetic correlations amongst defect traits enable them to be considered as a whole, so selection can be carried out against a group of defects rather than having to concentrate on each separately. This allows the application of a greater selection pressure and reduces the amount of recording necessary.

#### Female parent stock

Reproductive characteristics are in most cases negatively correlated with the desired broiler traits (van den Eynden, 1978) and as a result specialized sire and dam lines have been developed for broiler production. The major objective in selecting the dam line is to increase egg production and

hatchability without reducing the growth and conformational characteristics contributed by the male. Progress has been made in reproductive characteristics of the female line in the past 15 years, with egg output now averaging between 155 and 160 eggs per hen housed to 60 weeks of age, with an average hatchability of all eggs set of between 80 and 85%.

There have been two particularly interesting developments in the genetic selection of female broiler parent stock that could have a considerable impact on the cost of production of day-old broiler chickens in the future. These are the use of dwarf broiler mothers, and the manipulation of the growth curve of female parents.

The dwarfing gene (*dw*) is sex-linked and is situated close to the rate of feather growth (*k*) allele. The dwarf female, when mated to a normal (*DwDw*) male will produce normal progeny. There are a number of dwarf broiler breeds that have been developed, and on average the egg production of these breeds is virtually the same as that for the conventional broiler female, hatchability is in most instances approximately 4–6% better and adult bodymass is about 30% lower. The major advantages are the lower food cost per chicken hatched (a difference of between 23 and 28%, N.F. Barton, personal communication), and the lower housing cost per bird. Although fertility of dwarf breeders is as good as, or better than that of normal broiler females when housed on the floor, there would be further advantages to be gained in food consumption, management and fertility by housing these birds in cages.

Growth rate and feed conversion efficiency of the progeny from dwarf broiler mothers are not in all cases as good as those from conventional parents, although, where differences do exist, these are slight. Shalev & Pasternack (1983) question the economic value of the dwarf parent in an integrated operation on the grounds that growth rate is the trait with the greatest economic significance, comprising 49% of economic gains versus only 4% for egg production. They also maintain that as egg production in the normal female lines increases, the relative economic value of growth and food utilization will also increase, whilst the advantage of using dwarf females will decrease. Nevertheless, a reduction of 25% in the cost of feed per day-old broiler chicken must be of economic value if no other characteristics suffer as a result.

Mature body size in female broiler parents is a problem. This has resulted from selection for increased growth rate in the broiler without any check being made on adult bodymass. There is evidence, however, that early growth and adult body size are controlled by different sets of genes (Merritt, 1974; Ricard, 1978) making it possible to select for rapid early growth without increasing mature mass. McCarthy (1977) suggested that the genetic correlation between these two factors is weak, which would imply that the potential for affecting the growth curve is good. In producing fast-growing broiler strains with relatively low adult body size problems associated with feed restriction, i.e. cannibalism, coccidiosis, uneven growth, higher mortality, etc. will be lessened, with the result that the economics of day-old broiler chicken production will be improved.

#### Egg production

Clayton (1980) summarized a number of papers concerning genetic progress in laying hens (including Dickerson & Mather, 1976) in which it was claimed that substantial genetic progress has been made in the major components of egg production. Estimates of genetic gain per generation in production to about 72 weeks of age range from 0.8–1.8% for rate of egg production; 2.4–5.9 for hen housed egg number, 0–0.37 g

for average egg mass and 0,3 – 2,1 days for sexual maturity. Although these results are substantial, there is evidence that laying hens in the early part of this century were capable of much higher levels of production than is popularly supposed (Clayton, 1972) and that greater gains could have been realized with more efficient selection techniques.

Two of the most important non-genetic influences suppressing the expression of the genetic potential of laying hens are diseases and nutrition. Gavora (1979), for example, recorded a difference in hen-housed production to 497 days of approximately 50 eggs when comparing vaccinated and non-vaccinated strains which had been selected for egg production. The difference was due to a sharp reduction in mortality following vaccination against Marek's disease. This difference far exceeds the progress made by genetic selection, although there is evidence that selection for increased egg production should enhance resistance to Marek's disease (Gavora & Spencer, 1979).

It is only comparatively recently that the nutritional requirements of laying hens have been presented in a manner which allows for the determination of optimum intakes of amino acids for flocks of laying hens of different bodymass, egg output and characteristic food intake (cf. Fisher, Morris & Jennings, 1970; McDonald & Morris, 1985). To illustrate to what extent the daily supply of amino acids will allow the expression of the genotype of the laying hen, Table 2 was constructed in which six different genotypes were supplied with five daily intakes of lysine. Those birds with the greatest potential egg output would not be identified if 700 mg lysine were supplied each day — maximum genetic progress can be made only if this concept is recognized and used in selection experiments. The principle applies equally to growing animals. By selecting in a sub-optimal environment birds with large appetites will be favoured, which does not improve feed conversion efficiency, nor does it allow the identification of the best individuals in the flock.

Although no progress can be expected in the improvement of net efficiency of utilization of amino acids by laying hens (Morris, 1972) the major thrust among geneticists has been to improve the gross efficiency of nutrient utilization. This has been accomplished by selecting for smaller body size, and

increased egg output which has resulted in lower maintenance costs and greater returns. Commercial egg-producing companies can choose among stocks varying in average egg size and average egg number, in egg colour and shape, in shell quality and in body size. These differences are the result of the application of quantitative genetic theory, which, if continued, will probably result in as much progress as has been achieved recently.

Of far greater interest are the more recent innovative approaches to genetic improvement in laying hens, which are potentially capable of far more significant improvements in egg production than has been realized thus far. These approaches involve manipulation of the environment, increasing the net rate of ovulation, and selecting heavily for an earlier age at sexual maturity.

Under hemeral lighting conditions laying hens are constrained to lay a maximum of one egg per 24-h day (Sharp, 1980). Some laying hens are, however, genetically capable of ovulating more frequently than this, but cannot be identified under normal lighting conditions. Such birds have been identified with the use of intermittent lighting (Abplanalp, 1966); ahemeral light-dark cycles of less than 24 h (Foster, 1972) and under continuous light (Sheldon, Yoo & Podger, 1984).

Foster (1972) reasoned that because the response to selection would decline as the rate of egg production increased, light-dark environments with cycle lengths shorter than 24 h would increase genetic variance in the population thereby once more increasing the rate of genetic progress. However, he concluded later (Foster, 1983) that there was little evidence to support this selection procedure because there was in turn, no evidence to indicate that such selection could produce genotypes capable of laying at a rate of more than one egg every 24 h when they were subjected to a normal 24 h light:dark cycle. Only by maintaining such birds on short ahemeral cycles could their potential be realized, but this necessarily resulted in the production of small eggs and some incidence of internal laying. The level of expression of such genotypes under the restriction of normal light:dark cycles might thus have been achieved equally well by selection in normal lighting.

Sheldon, *et al.* (1984) chose to use continuous lighting in an attempt to 'break the selection plateau'. They have been successful in this approach — the mean interval between successive ovulations in their Australorp selection line is just over 22 h, and in normal light up to 50% of the flock has an individual mean interval of less than 24 h. There has been a reduction of only 1 g in pullet egg mass; age at first egg has been increased by 6%, mean bodymass by 5%, and pullet-year egg production by 18%. These authors stress that this improvement has come about only after 15 – 20 generations of selection and suggest that earlier selection experiments (Cahaner & Abplanalp, 1979; Foster, 1983) were terminated after too few generations of selection to allow the birds to break through the 24-h barrier.

A particularly interesting aspect of the work by Sheldon, *et al.* (1984) is that they discovered that about 30% of the Australorp selection line actually ovulated at or before oviposition (as opposed to a mean delay of 24 – 32 minutes after oviposition). One bird had ovulated 4 h before an oviposition, i.e. the second ovum would have been covered with its full complement of thick albumen and shell membranes whilst the other egg was still occupying the shell gland pouch. The authors have observed this phenomenon in all strains so far studied (including a broiler breeder line) and suggest that this variability for early ovulation clearly represents a possible

**Table 2** Theoretical maximum egg outputs sustained by laying hens of different bodymass and potential output when fed different amounts of lysine daily

Body-mass (kg)	Potential egg output (g/bird/d)	mg lysine/bird/day				
		500	600	700	800	900
1,5	45	39	45 <sup>a</sup>	45 <sup>a</sup>	45 <sup>a</sup>	45 <sup>a</sup>
	55	39	49	55 <sup>a</sup>	55 <sup>a</sup>	55 <sup>a</sup>
	65	39	49	59	65 <sup>a</sup>	65 <sup>a</sup>
2,0	45	35	45 <sup>a</sup>	45 <sup>a</sup>	45 <sup>a</sup>	45 <sup>a</sup>
	55	35	45	55 <sup>a</sup>	55 <sup>a</sup>	55 <sup>a</sup>
	65	35	45	55	65 <sup>a</sup>	65 <sup>a</sup>
2,5	45	32	42	45 <sup>a</sup>	45 <sup>a</sup>	45 <sup>a</sup>
	55	32	42	52	55 <sup>a</sup>	55 <sup>a</sup>
	65	32	42	52	62	65 <sup>a</sup>

Egg outputs calculated by means of the following equation (McDonald & Morris, 1985):

$$E = \frac{\text{Intake of amino acid} - 73 \text{ Bodymass}}{9,99}$$

<sup>a</sup>Genetic potential has been achieved

alternative pathway to overcoming the barrier of one egg per 24-h light:dark cycle. The limit would appear to be a shortening of the interval between successive ovipositions in this manner to around 20 h. Intermittent lighting (Abplanalp, 1966) has the same effect on ovulation rate as continuous lighting.

Whereas there is little chance of improving peak rate of lay in the short term, there are two non-productive periods in the life of the laying pullet that deserve further attention: the period after peak when production declines (persistence), and the period prior to the present age at sexual maturity.

Practically all selective breeding in egg-laying stocks has been conducted on an annual cycle. There are two advantages to this procedure: a genetic advantage due to a reduction in generation interval and the practical convenience of caging, selecting, mating, hatching, etc. at the same time each year (Foster, 1981). The greatest disadvantage of this practice is that selection for the full laying record ('persistence') must be made on a 'part-record', which, depending on the record chosen, might not adequately indicate total egg production, or might at first be genetically correlated with total egg production but, after a number of generations of selection this correlation might fall to zero or even be reversed (Morris, 1963). By selecting on the full record of annual production, greater accuracy and genetic variation and a higher heritability would result in an increased selection response, but generation interval is lengthened considerably, thereby nullifying much, if not all, the advantage gained by recording production over a longer period of time prior to selection.

T.R. Morris (personal communication) is at present selecting vigorously for early sexual maturity in a heavy line capable of laying large eggs. His reasoning is that a great deal of genetic variation exists in age at sexual maturity which could be used to good effect in reducing the cost of rearing pullets to point-of-lay. Age at sexual maturity is a trait with high heritability and is expected to be reduced by 77 days in 10 years — generation interval is reduced with each generation, thereby compensating for the reduced genetic variance and heritability that should result. It is expected that egg size will decline by 12% (6.8 g/egg) and body size by 37% (660 g) during this time which is the rationale for starting with a heavy breeder line. The expected improvement in feed conversion (kg eggs/kg feed from day-old to 72 weeks of age) is 13%, which would otherwise require output to be increased from 280 at present to 338 eggs/bird if sexual maturity were to be kept at the present age.

Growth rate of ovarian follicles might well be a limiting factor in the control of ovulation (T.R. Morris, personal communication) in that each successive follicle might not achieve maximum size ('ripeness') within a 24-h period. Fisher (1980) has argued that yolk protein deposition is a continuous process, and it could be argued further that yolk protein synthesis and deposition is under genetic control. Also, the supply of nutrients to the laying hen would account for much of the variation that has been found to exist between birds. No published work on increasing ovulation rate by selection for rate of yolk protein deposition could be found, but if a method could be devised to measure this variable in laying hens it might prove to be a valuable additional measurement to be used in a selection programme.

### Disease resistance

Because commercial breeding companies are under intense pressure to produce genetic material that will match or surpass the commercial efficiency of that of their competitors, little

progress has been made in the selection of strains resistant to specific diseases, or disease in general. There are two reasons for this: selection for viability is one of the more difficult tasks of the geneticist, because heritability for this trait is low, resulting in slow improvement, whilst the cost of exposing birds to diseases, with resultant morbidity and mortality is high (Goodwin, 1966). Secondly, effective control measures (e.g. coccidiostats, vaccinations, isolation rearing) have made the need for genetic resistance to disease less compelling.

That selection for resistance to disease is possible is without question. For every disease of domestic animals which has been adequately investigated for evidence of genetic resistance, such evidence has been found (Hutt, 1958). Many reviews have dealt with this type of selection experiment in poultry (cf. van Albada, 1964; Fredeen, 1965; Hartmann, 1985).

Some spectacular improvements have been made in disease resistance in this manner. For example, Roberts & Card (1935) improved the survival rate of chickens exposed to a standard oral dose of *Salmonella pullorum* from 28% to 70% in only four generations. The selection experiments of Rosenberg, Alicata & Palafox (1954) caused differences in the survival rate of chickens exposed to caecal coccidiosis (*Eimeria tenella*) of nearly 50%, whilst Klimes (1969) raised the survival rate of chickens exposed to *E. tenella* from 40% in the base population to 78% in the line selected for resistance with the unselected control remaining unchanged. Resistance to the avian leukosis complex was highly successfully accomplished by genetic selection (Waters, 1945, Hutt, 1958; Cole, 1972), as was resistance to Marek's disease (Morris, Ferguson & Jerome, 1970; Friars, Chambers, Kennedy & Smith, 1972).

A number of interesting consequences of these selection experiments have recently fuelled a resurgence of interest in selection for disease resistance. One of these is that correlated responses have been observed to occur following selection experiments, which allows the geneticist the opportunity to select for disease resistance without exposing the birds to the disease. Examples are (1) the association between resistance of chickens to *S. pullorum* and control of the thermoregulatory mechanism (Hutt & Crawford, 1960) — chickens that raised their body temperature most rapidly in the 6 days after hatching were consistently more resistant (82% survival) than those of the 'low temperature' line (37% survival); (2) the association between resistance to Marek's disease and the major histocompatibility complex (MHC) (alleles of the B blood group locus) of the fowl (Briles, Stone & Cole, 1977) — hens carrying the B21 allele have better viability and suffer fewer losses from Marek's disease than their sisters lacking the gene. Susceptibility to Marek's disease appears to be greater if birds carry the B19 allele. The effects of other B-alleles on susceptibility and resistance to Marek's disease were summarized by Briles, Briles, McGibbon & Stone (1980).

In addition to the involvement of B blood group alleles, additional genetic alternatives exist for resistance to Marek's disease (Hartmann, 1985).

Although selection for resistance to disease is effective, if the heritability of the trait were low and genetic control were polygenic, a considerable amount of time would need to be spent in improving the strain. If genetic resistance were dependent only on a single gene locus, such as the B21 allele, resistance could be established in a relatively short time. Nordskog (1983) suggested practical ways of using marker genes as a means of selecting fitness genes in poultry. With our present state of knowledge these genes are confined to the B complex haplotypes.

Another consequence of selecting for disease resistance that is of particular importance to the poultry industry is the correlated response of this trait with general disease resistance, liveability and production characteristics. Hartmann (1985) reviewed a number of papers that identified a genetic factor in disease resistance which is not specific to individual pathogens but is of a more general nature. Such genetic improvement in general disease resistance would be more cost-effective and hence more attractive than selecting for resistance to specific diseases.

Gavora (1979) showed that genetic resistance to Marek's disease is associated with lower bodymass, earlier sexual maturity and a higher rate of egg production. He also presented evidence that this genetic resistance enhances the protective value of Marek's disease vaccine and probably has a beneficial effect on mortality from other causes.

### Conclusion

It is difficult to separate genetic and environmental contributions to the progress observed in production traits in the poultry industry during the past decades. There is no doubt that genetic improvements in the broiler industry have been immense and far exceed the progress made in the egg laying industry, where improvements in disease control, environmental control and nutrition have contributed the bulk of the progress.

From a genetic point of view the future of both sectors of the poultry industry looks promising — there is no hint of a plateau in growth rate in broilers; the importance of use of food has been realized and is being addressed; exciting selection experiments with laying hens, in which the period between successive ovipositions is being reduced below 24 h and in which very early sexual maturity is being sought without sacrificing egg size, have the potential of increasing production and improving food efficiency significantly.

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### References

- ABPLANALP, H., 1966. Selection for egg number in chicken and quail population held under diverse lighting. *13th World's Poultry Congr.*, Kiev, p. 70.
- BECKER, W.A., SPENCER, J.V., MIROSH, L.W. & VERSTRATE, J.A., 1979. Prediction of fat and fat free live weight in broiler chickens using backskin fat, abdominal fat and live bodyweight. *Poult. Sci.* 58, 835.
- BRILES, W.E., BRILES, R.W., MCGIBBON, W.H. & STONE, H.A., 1980. Identification of B alloalleles associated with resistance to Marek's disease. In: Resistance and immunity to Marek's disease. ECSC-EEC Publ. Brussels, p. 395.
- BRILES, W.E., STONE, H.A. & COLE, R.K., 1977. Marek's disease: Effects of B histocompatibility alloalleles in resistant and susceptible chicken lines. *Sci. J.* 195, 193.
- CAHANER, A. & ABPLANALP, H., 1979. Changes in egg production and egg intervals under selection for high egg number under 22 hour day cycles of artificial lighting. *Poult. Sci.* 58, 757.
- CLAYTON, G.A., 1968. Some implications of selection results in poultry. *World's Poultry Sci. J.* 24, 37.
- CLAYTON, G.A., 1972. Effects of selection on reproduction in avian species. *J. Reprod. Fert. Suppl.* 15, 1.
- CLAYTON, G.A., 1980. The role of genetics in improving the efficiency of poultry in the 1980's. *6th Eur. Poultry Conf.*, Hamburg, p. 43.
- COLE, R.K., 1972. The genetics of resistance to Marek's disease. In: Oncogenesis and Herpesvirus. IARC Scientific Publ. No. 2, Lyon, p. 123.
- DICKERSON, G.E., 1970. Efficiency of animal production: moulding the biological components. *J. Anim. Sci.* 30, 849.
- DICKERSON, G.E. & MATHER, F.B., 1976. Evidence concerning genetic improvement in commercial stocks of layers. *Poult. Sci.* 55, 2327.
- FISHER, C., 1980. Protein deposition in poultry. In: Protein deposition in Animals, Eds. Buttery, P.J. & Lindsay D.B. Butterworths, London. p. 251.
- FISHER, C., 1984. Fat deposition in broilers. In: Fats in Animal Nutrition. Ed. Wiseman, J., Butterworths, London. p. 437.
- FISHER, C., MORRIS, T.R. & JENNINGS, R.C., 1973. A model for the description and prediction of the response of laying hens to amino acid intake. *Br. Poultry Sci.* 14, 469.
- FOSTER, W.H., 1972. Production and selection under light-dark cycles of abnormal lengths. In: Egg Formation and Production, Eds. Freeman, B.M. & Lake, P.E., *Br. Poultry Sci. Ltd.*, Edinburgh. p. 161.
- FOSTER, W.H., 1981. The estimation of rate of lay from part-record data. *Br. Poultry Sci.* 22, 399.
- FOSTER, W.H., 1983. The genetics of ovulation efficiency. *Proc. 18th Poultry Sci. Symp.* Br. Poultry Sci. Ltd, (in press).
- FREDEEN, H.T., 1965. Genetic aspects of disease resistance. *Anim. Breed. Abstr.* 33, 17.
- FRIARS, G.W., CHAMBERS, J.R., KENNEDY, A. & SMITH, A.D. 1972. Selection for resistance to Marek's disease in conjunction with other economic traits in chickens. *Avian Dis.* 16, 2.
- FRIARS, G.W., LIN, C.Y., PATTERSON, D.L. & IRWIN, L.N., 1983. Genetic and phenotypic parameters of fat deposition and associated traits in broilers. *Poult. Sci.* 62, 1425.
- GAVORA, J.S., 1979. Genetic techniques for controlling Marek's disease and for improvement of multiple economic traits in high performance egg production chickens. 28th Ann. Nat. Breed. Roundtable, Memphis, Tennessee, U.S.A.
- GAVORA, J.S. & SPENCER, J.L., 1979. Studies on genetic resistance of chickens to Marek's disease — a review. *Comp. Immunol. Microbiol. Infect. Dis.* 2, 359.
- GOODWIN, K. 1966. The environment and problems in selection for disease resistance in the fowl. *Wild. Poultry Sci. J.* 22, 299.
- HARTMANN, W., 1985. The effect of selection and genetic factors on resistance to disease in fowls — a review. *Wild. Poultry Sci. J.* 41, 20.
- HILL, W.G., 1984. Mutations and long term selection. *26th Br. Poultry Breed. Conf.*, Norwich.
- HUTT, F.B., 1958. Genetic resistance to disease in domestic animals. Constable Ltd., London.
- HUTT, F.B. & CRAWFORD, R.D., 1960. On breeding chicks resistant to pullorum disease without exposure thereto. *Can. J. Gen. Cyt.* 21, 357.
- KLIMES, B., 1969. Die genetische Resistenz gegen Geflügelkrankheiten. *Dt. Geflügelzt.* 21, 2065.
- LECLERCQ, B., BLUM, J.C. & BOYER, J.P., 1980. Selecting broilers for low or high abdominal fat: initial observations. *Br. Poultry Sci.* 21, 107.
- LEENSTRA, F.R., 1984. Influence of diet and genotype on carcass quality in poultry, and their consequences for selection. In: Recent Advances in Animal Nutrition — 1984. Butterworths, London. p. 3.
- MCCARTHY, J.C., 1977. Quantitative aspects of the genetics of growth. In: Growth and Poultry Meat Production. Eds. Boorman, K.N. & Wilson, B.J., Br. Poultry Sci. Ltd, Edinburgh.
- MCCARTHY, J.C. & SIEGEL, P.B., 1983. A review of genetical and physiological effects of selection in meat-type poultry. *An. Br. Abst.* 51, 87.
- MCDONALD, M.W. & MORRIS, T.R., 1985. Quantitative review of optimum amino acid intakes for young laying pullets. *Br. Poultry Sci.* 26, 253.
- MANSON, J.M., 1972. Body weight, egg weight and egg production. In: Egg formation and production. Eds. Freeman, B.M. & Lake, P.E., British Poultry Science Ltd., Edinburgh. p. 115.

- MERCER, J.T., 1984. The genetics of leg abnormalities in broiler chickens and their implications in selection programmes. *26th Br. Poult. Breed. Conf.*, Norwich.
- MERRITT, E.S., 1974. Selection for growth rate in broilers with a minimum increase in adult size. *Proc. 1st World Congr. Gen. Livest. Prod. Madrid*. 1, 951.
- MORRIS, J.A., 1963. Continuous selection for egg production using short-term records. *Austr. J. Agric. Res.* 14, 909.
- MORRIS, J.R., FERGUSON, A.E. & JEROME, F.N., 1970. Genetic resistance and susceptibility to Marek's disease. *Can. J. Anim. Sci.* 59, 69.
- MORRIS, T.R., 1972. Prospects for improving the efficiency of nutrient utilization. In: *Egg Formation and Production*. Eds: Freeman, B.M. & Lake, P.E., Bri. Poult. Sci. Ltd, Edinburgh. p. 139.
- NORDSKOG, A.W., 1983. Immunogenetics as an aid to selection for disease resistance in the fowl. *World's Poult. Sci. J.* 39, 199.
- PASTERNAK, H. & SHALEV, B.A., 1983. Genetic-economic evaluation of traits in a broiler enterprise: reduction of food intake due to increased growth rate. *Br. Poult. Sci.* 24, 531.
- PYM, R.A.E. & FARRELL, D.J., 1977. A comparison of the energy and nitrogen metabolism of broilers selected for increased growth rate, food consumption and conversion of food to gain. *Br. Poult. Sci.* 18, 411.
- PYM, R.A.E. & SOLVYNS, A.J., 1979. Selection for food conversion in broilers: Body composition of birds selected for increased body-weight gain, food consumption and food conversion ratio. *Br. Poult. Sci.* 20, 87.
- PYM, R.A.E. & THOMPSON, J.M., 1980. A simple caliper technique for the estimation of abdominal fat in live broilers. *Br. Poult. Sci.* 21, 281.
- RICARD, F.H., 1978. Indice de consommation et état d'engraissement de poulets appartenant a des souches selectionnees sur la forme de la courbe de croissance. *Proc. XVI World's Poult. Congr. Rio de Janeiro*. p. 1786.
- ROBERTS, E. & CARD, L.E., 1935. Inheritance of resistance to bacterial infection in animals: A genetic study of pullorum disease. *Ill. Agric. Exp. Stat. Bull.* p. 419.
- ROSENBERG, M.M., ALICATA, J.E. & PALAFOX, A.L., 1954. Further evidence of hereditary resistance and susceptibility to caecal coccidiosis in chickens. *Poult. Sci.* 33, 972.
- SHALEV, B.A. & PASTERNAK, H., 1983. Genetic-economic evaluation of traits in a broiler enterprise: the relative genetic-economic values. *Br. Poult. Sci.* 24, 521.
- SHARP, P.J., 1980. Female reproduction. In: *Avian endocrinology*. Eds. Epple, A. & Stetson, M., Academic Press, London. p. 435.
- SHELDON, B.L., YOO, B.H. & PODGER, R.N., 1984. Results of selection for short interval between eggs under continuous light. I. Selection responses and correlated responses in production traits. *26th Br. Poult. Breed. Conf.* Norwich.
- SORENSEN, P., 1980. Selection for growth rate in broilers fed on diets with different protein levels. *Proc. 6th Eur. Poult. Conf. Hamburg*. 2, 64.
- VAN ALBADA, M., 1964. Geflügelzüchtung und Krankheitsresistenz. *Arch. Geflügelkd.* 28, 81.
- VAN DEN EYNDEN, G.P.A., 1978. Genetics and the broiler industry in the year 2000. *Proc. XVI World's Poult. Congr. Rio de Janeiro*. p. 64.
- WATERS, N.F., 1945. Breeding for resistance and susceptibility to lymphomatosis. *Poult. Sci.* 24, 259.
- WHITEHEAD, C.C. & GRIFFIN, H.D., 1982. Plasma lipoprotein concentration as an indicator of fatness in broilers: *Br. Poult. Sci.* 23, 299.