

The challenge of genetic change in the broiler chicken

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Abstract: Genetic progress in poultry species for meat production has contributed to the consistent growth in world production of poultry meat. The poultry species have a number of advantages over the larger species used for meat production. It is possible to maintain large pedigreed populations and use their high reproductive rates to transfer genetic progress to the production generations in less than five years. These populations continue to maintain high heritabilities despite, in some cases, prolonged selection. The history of selection progress in broiler chickens (*Gallus gallus domesticus*) is reviewed and compared with rates of progress in the duck (*Anas platyrhynchos*) and the turkey (*Meleagris gallopavo*).

The rates of genetic change for production traits such as growth, feed efficiency and yield have changed the physiology of the birds. Changes in selection criteria have been made to improve the robustness of the production stock. This allows them to perform well in a wider range of environments. These have been combined with improved definitions of the optimum environments for the birds to minimise any impact on welfare and health. This paper describes examples of selection in the broiler chicken aimed at improving skeletal quality and resistance to ascites.

A number of the factors influencing future selection criteria are discussed. Breeding programmes have adapted to respond quickly to adverse genetic correlated responses. The need to combine selection for a large number of traits requires that the programmes are very efficient and use the best statistical techniques available for multivariate breeding value estimation.

Introduction: The poultry species have a long history of domestication. However the establishment of breeding programmes allowing the development of the international industry producing poultry meat is relatively recent. The broiler chicken industry has grown consistently over its forty-year history until today 20 billion broilers are produced annually. Poultry meat production represents 29 percent of meat production from farmed animals and this proportion is rising each year. The growth has been based on strong consumer demand for products that are perceived as affordable, safe and healthy. Rapid genetic change and developments in the nutrition and management of the birds have driven improved economic efficiency.

Genetic improvement in growth rate of up to 3 percent per year requires major adjustments to how the birds are managed to benefit from the extra genetic potential. The progress is delivered through a short and efficient multiplication process. However, the industry has experienced periods of increased incidence of defects in skeletal development and heart and lung function (Nir, 1998). In an accompanying paper Classen (2000) has described the management improvements introduced to minimise these defects. Genetic strategies have been developed to improve the robustness of rapidly growing birds. This allows them to be grown in a wider range of environments without defects. Systems have been developed to anticipate adverse genetic correlated responses in the future allowing early genetic or management changes. Central to these are the ability to get efficient feedback from within genetic programmes and from customers giving early warning of any new physiological effects of the genetic progress combined with efficient methods of making genetic progress in multiple traits.

Meat production: The production of chicken meat has increased by an average of 6 percent per year for the last 22 years (USDA, 1999). From 20 million tonnes in 1987 production will double by 1999 and is projected to treble by 2007. Over the years 1993-1998 poultry meat production grew by 42 percent against an overall growth of meat production of 22 percent. Market share has been gained against beef and sheep meat production.

Genetic change: Genetic progress is delivered from pedigreed populations under selection to commercial broiler chickens through three generations of multiplication known as great grandparents, grandparents and parents. Each of these generations takes approximately one year. Thus there is a time lag of approximately 4 years from selection decision to the effect of these decisions at commercial production. The combination of short generation interval and high reproductive rate allows the poultry species to respond more quickly than other species to a change in selection emphasis.

Chickens. The current male broiler chicken grows from 40 grams to 2.6 kilograms in 42 days with a feed conversion ratio (FCR) of 1.66. The live bird yields 1.85 kg (71%) as eviscerated carcass and the total meat yield is 875 g (33.7%) and breast meat yield is 460 g (17.8%). Annual improvement rates are an increase of 60 g of live weight to 42 days (2.4%), a reduction of FCR by 0.02 to 2kg (1.2%) and an increase of breast yield of 0.25% (1.4%). Progress is measured relative to control lines, performance in trials facilities and also field performance. The control lines were established as pure lines in 1972 (equivalent to commercial the broilers of 1976). Live weights at 42 days have more than doubled in the last 23 years (from 1050 g to 2600 g) and are projected to reach 3 kg by the year 2007 at current rates of progress. The time to achieve 2 kg (a common killing weight) has reduced from 63 days in 1976 to 36 days in 1999. This will decline more slowly in future because of high daily growth rates. By 2007 birds will reach 2 kg in 33 days. FCR to fixed ages and weights continues to improve with growth rate but must eventually be limited. Breast meat yields continue to increase as a percentage of live weight at a wide range of killing ages and weights. A 2 kg male in 1976 yielded 250 g of breast meat whereas today it yields 340 g and is projected to yield 380 g by 2007. The economic impact of these improvements can be illustrated by the ratio of the weight of feed required to produce 1 kg of breast meat. This was 20 kg/kg in 1976. Has been reduced to less than 10 kg/kg at present and will approach 7 kg/kg by 2007 if current rates of genetic change are sustained.

Turkeys. Turkeys currently have very similar efficiency of breast meat production although the production systems have some differences. A male turkey grows to 19.6 kg at 21 weeks with an FCR of 2.63. It yields 27.6% of this liveweight as breast meat and total meat is at least 50% of the liveweight. The rate of genetic change in turkeys is of the same order as in chickens. Current rates of genetic progress in liveweight are estimated at 3% per annum in male lines and 1% in female lines, giving an overall rate of progress in cross progeny of 2% (Dr James Bentley, British United Turkeys, personal communication).

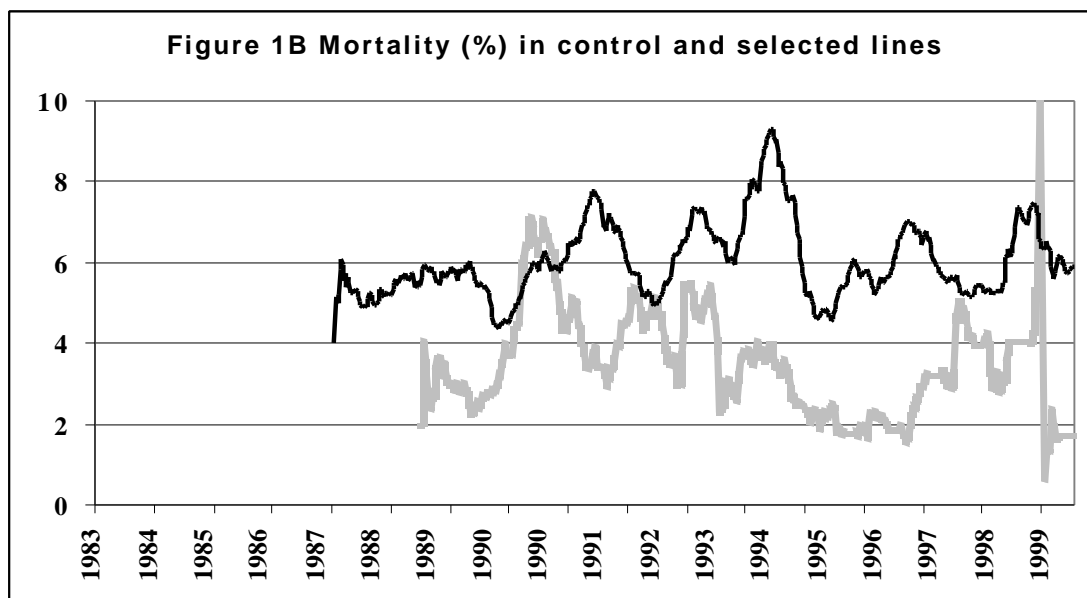
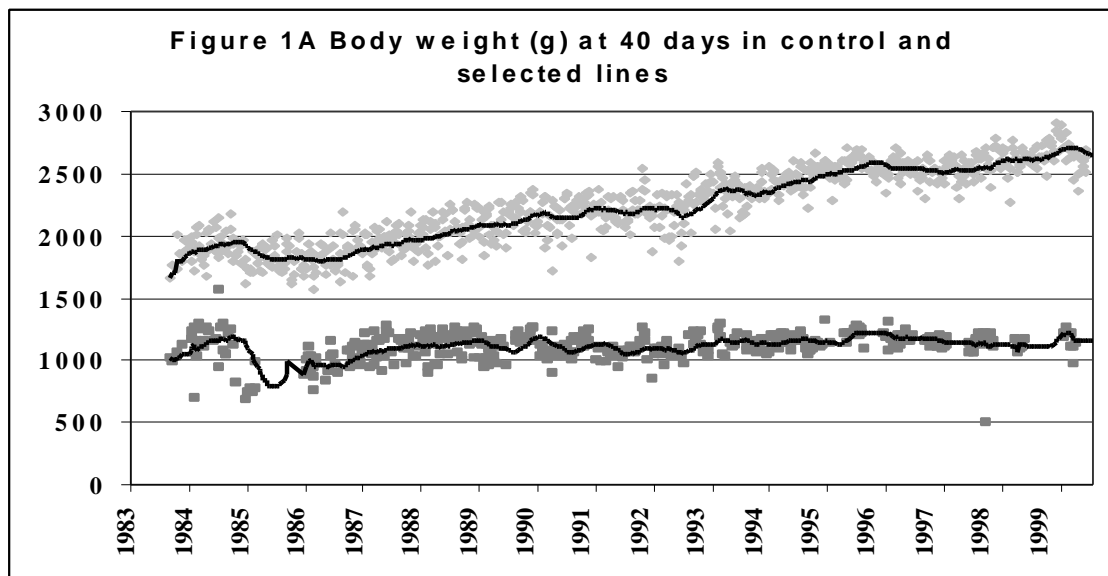
Ducks. Current commercial duck production produces a bird weighing 3.4 kg at 45 days of age with an FCR of 2.2. The current efficiency of breast meat production is 25 kg/kg. Annual genetic improvement rates are estimated as 1% in liveweight to 42 days, 2% in FCR and 1.3% in breast meat yield (Dr David Martin, Cherry Valley Farms, personal communication).

Adverse effects of genetic change: Genetic change of such a magnitude inevitably has an impact on all aspects of the birds' physiology. These have to be accommodated by improvements in many aspects of the management of birds kept for reproduction or growth. For example, the industry has evolved sophisticated and successful methods of managing the growth of breeding stock to optimise liveability, immune function and chick production. These findings have led to significant changes in management practices as reviewed in an accompanying paper (Classen, 2000). The impact of rapid growth on two aspects of physiology – skeletal development and heart and lung function – has come under particular scrutiny and these will be discussed in detail below. More generally it is important to consider whether selection for improved commercial traits must lead to an increase in mortality.

Figures 1A and 1B show the history of one selected line and its control line established in 1972. The liveweight at 40 days has increased from just over 1kg to almost 3kg in the 27 years of selection. The periods illustrated are those for which full computerised records are available. Each point represents one week's production of the line (hundreds of birds) and the line is the 12-week rolling average. A number of other traits have been subject to selection including FCR, conformation, yield and improved heart and lung function and skeletal quality. The control line weight has been stable (slope = +7 g/year, R squared = 0.078, NS). The selected line has increased at a linear rate (slope =61 g/year, R squared = 0.84, P<0.01).

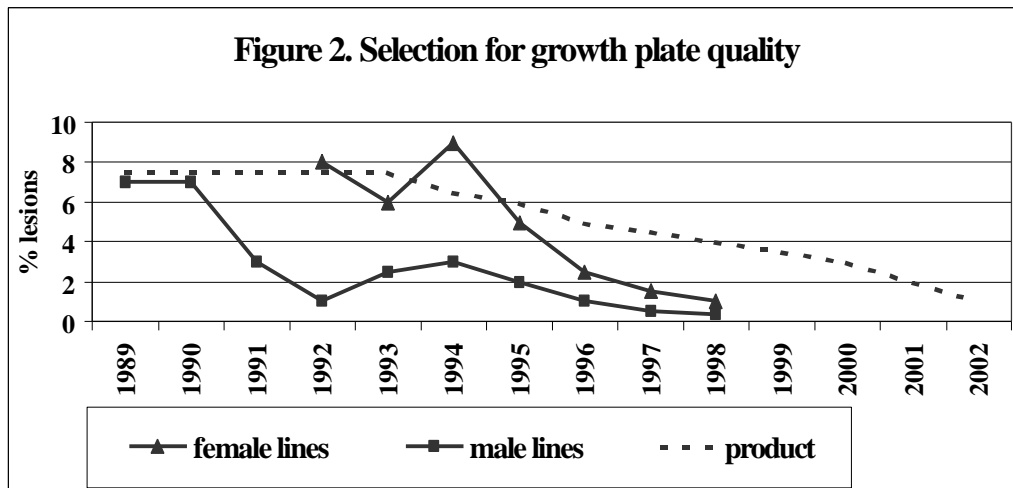
Figure 1B shows the mortality of these two lines (deaths plus culls) when grown in the same environment. It is clear that the lines (12 -week rolling average) are not diverging and that the difference in mean mortality rates (6.0% of selected line versus 3.5% of control line) is not related to growth rate *per se*. Linear regression analysis of mortality over years in the selected line gives an annual increase of 0.05% per year (R squared = 0.005, NS) and in the control

line gives a decrease of 0.15% per year ($R^2 = 0.021$, NS). The environment is designed to maximise growth rate so that we can select more effectively against defects such as ascites or lameness.

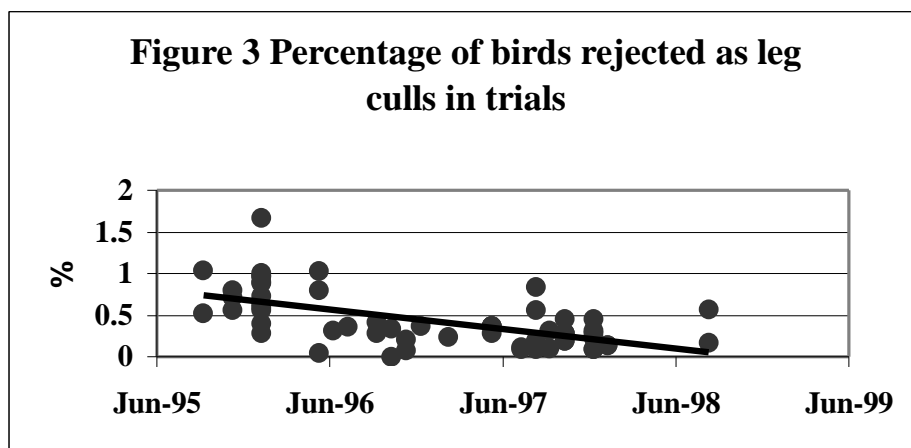


Skeletal development. An increasing incidence of lameness in the 1980's was mainly due to tibial dyschondroplasia. This is a disruption of the growth plate of the tibia and its incidence was affected by many factors in the environment especially mineral nutrition and lighting programmes (Whitehead, 1992; Thorp, 1994). A number of improvements have been made in selection programmes to reduce the incidence of defects in the growth plate.

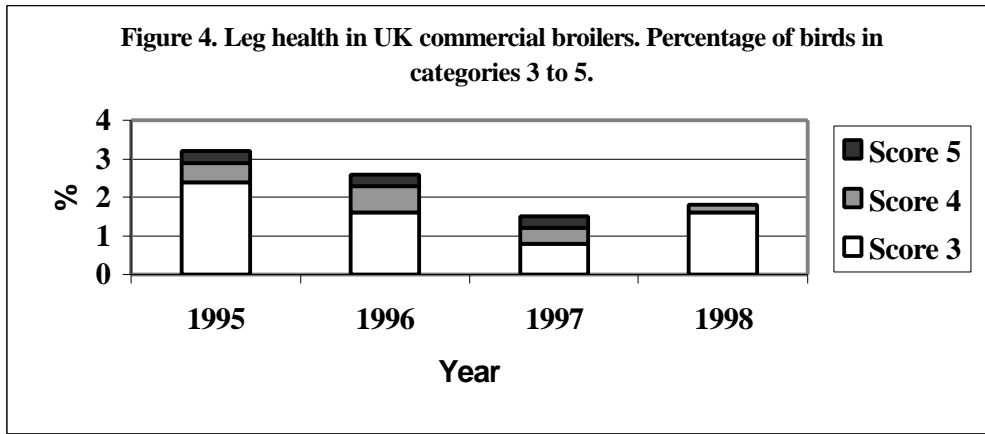
Birds for selection are grown in an environment that allows rapid growth at all ages. Any gross defects of skeletal development are detected by close physical assessment of all selection candidates. Birds culled for lameness are recorded and family incidence of all defects is accumulated to make selection decisions more accurate. The exclusion of all clinical defects from the breeding programme has been extended to seek any evidence of sub-clinical lesions. By using real-time X-ray technology it is possible to examine the quality of the growth plates and assess the uniformity of bone mineralisation behind the growth plate. Thus birds can be detected which have normal gait and gross skeleton but which have small lesions (plugs of cartilage) in the growth plate. The incidence of these lesions is illustrated in Figure 2. Male and female line annual averages are shown in solid lines and the projected impact on product crosses is shown as a dotted line. The incidence has decreased by rejection of individuals with lesions and families with a higher incidence of lesions. Increases during selection coincide with periods of exceptional growth on new broiler farms. The projected improvement in product broilers takes account of the time lag between progress in the pure lines and the final crosses. The progress in skeletal quality has been achieved at the same time as improvements in growth rate, FCR and other commercial traits.



We can also estimate genetic improvement from a programme of trials of pure lines and their crosses under environmental conditions that are stable over this period. Figure 3 illustrates the incidence of leg defects sufficiently serious that the farm staff will cull the affected bird. Performance in the trials facility is better than commercial standards and the level of supervision is also higher. These factors would tend to over-estimate the incidence relative to commercial production. However, it is clear that over the period of expected improvement the incidence of all leg abnormalities has decreased (each trial involves thousands of broilers). The variability of the incidence also appears to be decreasing.

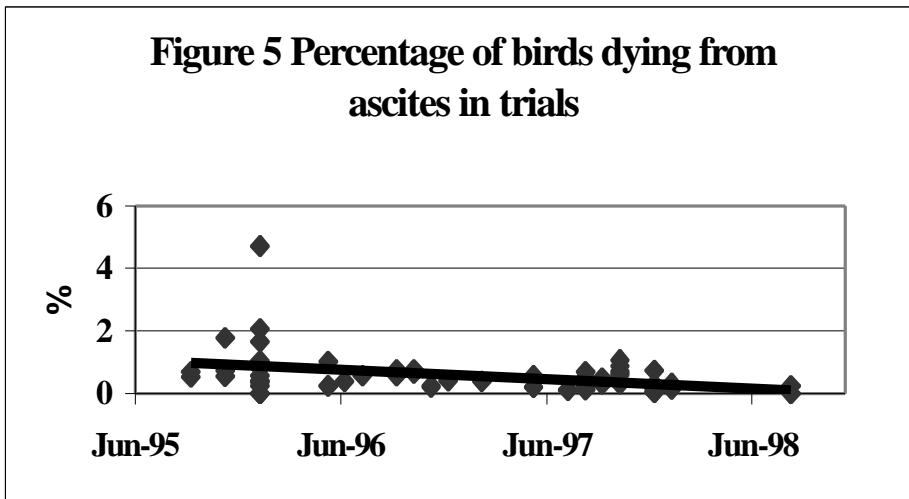


The timetable suggests that we should be seeing significant improvements in current commercial broilers. The United Kingdom's Farm Animal Welfare Council's report on broiler welfare (1992) proposed that the breeding and production companies should co-operate to improve leg health over a five year period. The British Chicken Association has sponsored a survey of leg health in commercial broilers in collaboration with the Farm Animal Welfare Council to monitor the incidence of lameness and 'gait abnormalities' in commercial flocks. The frequencies of birds in the three most affected categories (Score 3: 'abnormal gait' to Score 5: 'lame', Kestin 1992) are shown in Figure 4. The overall incidence of affected birds has reduced by almost 50% and the severity has reduced over the years of the survey.



The success of the selection for improved skeletal quality does not mean that there are no incidents of lameness in broiler chickens. However the birds are more robust i.e. they have good skeletal development in a wider range of production environments. The majority of lameness is now associated either with abnormal mineral nutrition (distorted ratio of available calcium and phosphorous) or infectious agents such as *Staphylococcus aureus* or Reoviruses.

Heart and lung function. It is essential to improve heart and lung function as growth rates increase. Ascites was first observed in birds grown at high altitudes but the incidence began to increase at all altitudes during the 1980's. It is due mainly to pulmonary hypertension, cardiac pathologies or cellular damage caused by reactive molecules (Currie, 1999). A wide range of environmental factors affects the incidence. The most obvious of these are poor ventilation, high dust levels, high diurnal temperature variation, infectious agents, toxins and deviations from optimum nutrition. All of these issues have been addressed in research and have been applied very quickly to production flocks. The genetics of ascites resistance has been an active research area in a number of breeding companies. A range of technologies has been applied including improved family selection, selection in a pre-disposing environment, pulse oxymetry and other measures of heart and lung function. Combining all of the above has seen the incidence of ascites reducing in trials performed under a stable environment which allows the full expression of growth potential (Figure 5).



The levels of ascites in commercial broilers are generally decreasing. It is not possible to distinguish genetic trends in companies where many management actions have been taken to reduce the incidence of ascites.

The intention of the selection is to improve robustness of the genotypes to the variations of the environment. Research also continues to investigate non-genetic factors affecting heart and lung function and to make producers aware of the important environmental variables (Classen, 2000).

Future strategies: The number of possible selection criteria continues to rise. In the original simple mass selection programmes of the 1960's, liveweight and fitness were the most accessible and most important criteria. The formation of large, closed and fully pedigreed populations was an important step towards more sophisticated and balanced selection. A number of new traits such as FCR and yield (assessed by conformation) were introduced in the 1970's. Family index selection for reproductive performance, liveability and freedom from defects was now possible. Further new traits such as feathering, meat quality and disease resistance have been added in the 1980's and 1990's. There are also decisions about breeding strategy that have an important impact on genetic progress. These include improvements in health status such as the establishment of breeding programmes free from poultry pathogens and zoonotic pathogens.

Future selection progress will include closer monitoring of physiological systems to ensure a closely integrated response to multiple traits. The most significant of these include aspects of immune function and reproductive performance. We have established feedback systems that give early warning of performance, welfare, environmental impact or food safety issues from producers in a wide range of environments. These feed back efficiently into a research programme aimed at establishing genetic or management solutions.

It is obvious that by selecting for so many inter-related traits it would be possible to select for everything and make progress in nothing. For this reason we have established an extensive programme to understand the genetic and, where possible, the physiological relationships between the traits of interest. With improving statistical methods it will be possible to deliver balanced genetic progress in a number of traits. This will produce broiler chickens that are more robust at continuously improving levels of performance.

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