

# 1 Industrial Perspective on Problems and Issues Associated with Poultry Breeding

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Consumption of poultry meat and eggs is increasing steadily. It has moved from a combined total of 85 million tonnes in 1992 to 117 million tonnes in 2000 (*Executive Guide to World Poultry Trends*, 2001). Of the current total, 8% is produced from turkeys, ducks or poultry species other than chickens. This chapter focuses on developments in chicken breeding. There are unique concerns for each of the other species, but developments in the breeding of the other species have in general paralleled those in the breeding of chickens.

## Egg-type Chickens

Since the early 20th century, the breeding of egg-type chickens has seen significant changes. The genetic performance of the bird has improved substantially over this time. In order to be able to continue the improvement of the laying hen, further changes will need to be made. In the following discussion, consideration will be given to traits, methods of selection and industry structure.

## Traits

Breeders today must select for, or at least monitor, the age at sexual maturity, rate of

lay before and after moult, livability in the growing and laying house, egg weight, body weight, feed conversion, shell colour, shell strength, albumen height, egg inclusions (blood and meat spots) and temperament, plus traits affecting the productivity of the parent. Since the early 1980s, the increasing proportion of eggs broken out for further processing has added additional traits, including percentage solids and lipids in the egg.

Egg production per hen housed will continue to be the single most important trait under selection. However, the emphasis has been shifting from peak rate of lay to persistency of lay (Preisinger and Flock, 1998). As flocks maintain high rates of lay for longer periods of time, they can be kept to advanced ages without being moulted. While much is now known about the physiology of age-related changes, the elements that trigger these events remain elusive (Ottinger, 1992). A better understanding of these processes is necessary for more effective selection, and may allow the identification of specific genes influencing ageing.

There is increasing use of induced moulting to extend the laying life of the hen in much of the world, despite opposition to this practice by animal welfare activists in some developed countries. It can be expected that breeders will continue to work

for improved post-moult performance for the foreseeable future.

It has been stated that the economic impact of variability in disease resistance is relatively small and that it is not a high priority trait in most breeding schemes (Albers, 1993). However, the emphasis placed on disease resistance varies from one breeding firm to another. An epidemic of a specific disease can increase the importance of that disease in the minds of poultry producers and they may choose not to purchase stocks that are susceptible. For example, this has occurred in the USA (in the 1950s) and in Australia (in the 1990s) for the disease lymphoid leucosis. Relative Marek's disease susceptibility affected buying decisions in the USA in the 1960s. Currently, feather pecking and resultant cannibalism is a problem in chickens housed in alternative systems in Europe and perceived differences among commercially available varieties are affecting sales.

Breeding for resistance to disease is difficult because of low heritabilities and rapid evolution to more virulent forms among disease-causing microorganisms. Heritabilities are generally under 10% for total mortality, but somewhat higher for specific diseases (Gavora, 1990). Some diseases thought to be controlled by vaccination, such as bronchitis and Marek's disease, keep reappearing due to the occurrence of variant viral strains.

Breeding for resistance to specific diseases caused by microorganisms involves exposure of the birds to disease agents in a controlled manner, usually by inoculation of highly pathogenic variants of the organism. This cannot normally be done in the pedigree population under selection, due to the risk of killing excessive numbers of breeders and reducing effective selection for other traits. For this reason, the disease challenge is sometimes done in siblings or progeny of the birds under selection, at an isolated location, and the selection is done on a family basis. The deliberate exposure of birds to pathogenic agents raises questions from an animal welfare standpoint.

There is need for improved methods of identification of genetically resistant birds. Marker-assisted selection, or better yet the identification and labelling of specific

genes for resistance, will enhance progress. One such gene, influencing resistance to salmonella in chickens, has recently been reported (Hu *et al.*, 1997).

An understanding of the genetics of the disease organisms themselves might make possible the use of pathogen-derived genes (Witter, 1998), which, once inserted into the bird's genome, could confer levels of resistance to the disease organisms not currently found in existing populations of poultry. To implement this theoretical strategy, these new constructs would have to be inserted through the use of transgenic technology.

The trait with the most impact on profitability is feed conversion. The conversion of feed into eggs is primarily a function of egg numbers. It is also influenced by egg size and body weight. Breeders improved feed conversion throughout the 20th century, especially in brown egg stock, by selecting for increased egg mass and smaller body size. Since the mid-1980s, commercial poultry geneticists have also been selecting for improvement of that part of feed consumption not explained by egg mass and body weight. This is referred to as residual feed consumption. Incorporation of selection on residual feed consumption will improve feed efficiency at a faster rate than selection on egg mass and body weight alone (Nordskog *et al.*, 1991). To accomplish this, consumption is measured for individual hens. Expected feed consumption for each hen is calculated from the bird's egg mass and body size using a linear model. Residual feed consumption is calculated by subtracting expected intake from the measured intake. Hens with high levels of residual intake are culled.

Feed conversion in the USA and Canada has improved from 2.95 g feed g<sup>-1</sup> egg in 1960 (Agricultural Research Service, 1960) to 2.01 g g<sup>-1</sup> in 2001 (R.L. Chilson, California, 2001, in CMC Strain Performance Reports). Further continued improvement will be aided by a better understanding of the factors influencing feed conversion, including feather cover, activity and feed wastage.

Some aspects of egg quality continue to improve, while others remain unchanged. Little change is occurring in overall egg

weight, as most commercial varieties have already been selected to fit the needs of the markets in which they are sold. However, there is selection for attainment of the desirable egg size at an earlier age. This requires concurrent selection against increased egg size at a later age because of the strong genetic correlation between early and late egg size.

Inclusions (so-called blood and meat spots) have been selected to low levels of occurrence in white egg stock, so that little additional response can be achieved. In brown egg populations, there continues to be genetic variability for inclusions, and effective selection is practised to reduce the incidence of blood and meat spots. In brown egg varieties, effective selection also continues for eggshells with a darker brown colour.

Some selection is practised for albumen height, so that Haugh units will remain at acceptable levels in markets where this measure is incorporated into egg grading standards. Shell strength improvement also continues and should improve for the foreseeable future, allowing the hens to produce a lower number of cracked eggs and eggs to be kept for longer periods of time.

New challenges are arising in relation to the use of eggs for further processing. Buyers of liquid egg are setting standards for the percentage of solids or lipids in the liquid egg product. In the USA, buyers of mixed white and yolk require that the mix contain at least 24.2% solids. If the level of solids is below this, processors must add yolk to increase the level. This reduces profits for the processor since yolk generally receives a higher price than albumen. In Italy, where yolks are in high demand for the production of pasta, buyers have established a standard of 10.5% lipid in the yolk. Both solids and lipids vary from one commercial cross to another (Ahn *et al.*, 1997). Breeders can influence these traits by switching parent lines used to produce their commercial cross. However, it is extremely difficult to select within populations, since measurement of solids and lipids for individual birds is time-consuming and expensive. Quicker, cheaper methods are needed for the measurement of solids and lipids.

Another issue affecting further processed eggs is the strength of the vitelline membrane. Egg whites must whip into foam with a good height. Contamination of the white with yolk will reduce the foam height. If the yolk ruptures during separation of the white, the contaminated product must be removed, reducing the speed of the breaking process and reducing the value of the product. Therefore, breeders must maintain vitelline membrane strength.

As more attention is focused on animal welfare, several traits increase in importance. Foremost among these is bird-to-bird aggression, which can lead to cannibalism and which also impacts feather cover. Craig and Muir (1996) have shown that selection in group cages can be used to reduce aggression. At least one commercial breeder has used this practice for over 30 years. Layers from this firm have relatively low levels of cannibalism when their beaks are left untrimmed (Craig and Lee, 1989).

Another welfare-related issue is the increasing demand for eggs produced by floor-housed birds (free-range, organic, etc.). The EU has issued a directive requiring the elimination of conventional cages by 2012. Cannibalism is an important issue for floor-housed birds. Nesting behaviour is another important issue, as birds must search out the nest. Eggs laid on the floor are more likely to be soiled and require special labour for collection.

The EU currently mandates 550 cm<sup>2</sup> per bird in cages. Guidelines of the US United Egg Producers call for 432 cm<sup>2</sup> per bird for all birds placed by the year 2012. Currently most commercial white egg layers in the world are housed in cages at 310–350 cm<sup>2</sup> per bird. Breeders will need to take the changing cage densities into account in their breeding plans.

Other welfare-related factors that are likely to become of increasing concern to breeders include the killing of unneeded cockerels and maintenance of skeletal integrity as the bird ages. If induced moulting is banned, this will also alter optimal breeding strategies.

Intensive animal agriculture has raised concerns among the general public about the

effect on the environment of high concentrations of livestock. Manure output has become a concern and producers are asked to control not only the total amount of manure spread on the land, but also the amount of moisture in the manure (for fly control) and the phosphorus content. Birds that consume less feed will excrete less, so selection for reduced residual feed consumption should also result in less manure to spread on the land. There are genetic differences between varieties in the amount of moisture in the faeces. Varieties with dry droppings are more prone to the development of urolithiasis (Lent and Wideman, 1993). It is possible to select for drier droppings on an individual bird basis (Preisinger *et al.*, 1994) but care should be taken not to increase the incidence of urolithiasis.

The greatest potential for increased egg consumption is in the tropics, where per capita egg consumption levels are low and are increasing. Much research has already been done on resistance to heat stress but, to date, no bird bred specifically for resistance to heat stress has captured much market share in the tropics in general. As a result of depressed feed consumption and poor-quality feed ingredients in tropical areas, there may be a benefit in having a bird for the tropics with a large appetite (Ansah, 2000). However, feed prices are very high in most of the tropical countries, so the ultimate solution for the production of eggs at economical prices in these areas may be the construction of controlled-environment houses to utilize the efficiencies of the modern layer.

### Methods

Beginning about 1970, the advent of high-speed computers and the development of sophisticated statistical estimates of genetic value have permitted improved rates of within-line improvement. Questions remain concerning the effect of statistical tools such as best linear unbiased prediction (BLUP) that incorporate family information on the rate of exhaustion of genetic variability (Muir, 1997). Accelerated loss of

genetic variation due to the use of BLUP may necessitate early outcrossing of the pure lines that make up these crosses, to reintroduce genetic variability. Alternatively, selection rules could be considered that would allow for more conservation of genetic variance and optimal balance of long-term vs. short-term response.

The use of marker-assisted selection (MAS) is expected to increase the accuracy of breeding value information and to be especially useful for traits that have low heritabilities or are difficult to measure. MAS will also allow the improved utilization of available 'selection space' (Soller and Medjugorac, 1999). This underutilized 'selection space' is provided by the surplus males that are available in chicken breeding stock. Far more males can be produced than are needed since, at the time of selection, full brothers without progeny tests all have identical predictions of breeding values for traits that can only be measured in females. Vallejo *et al.* (1998) found several markers for genes controlling resistance to Marek's disease. Lamont *et al.* (1996) reported on markers for egg production, and Van Kaam *et al.* (1999) reported on markers for feed efficiency.

The use of transgenesis plays a major role in the breeding of plants. Several companies are now striving to develop transgenic strains of chickens that can be used to produce pharmaceuticals or other valuable proteins in eggs, but this tool has yet to be applied to the breeding of commercial poultry stocks. Since the single-celled chicken zygote is difficult to manipulate and then reintroduce into the egg for further development, transgenic poultry are more difficult to produce than are transgenic plants or mammals. With the developing concern about genetically modified organisms (GMOs), commercial breeding firms are now being required by some consumers to state that they are not using GMOs. This has a chilling effect on the interest of breeders in using the transgenic tool. Eventually transgenesis will prove too valuable to ignore and commercial hens will become available that have enhanced performance due to the introduction of DNA that has

been synthesized in the laboratory or that originates from other species.

### Industry structure

Since 1950, breeding firms have become much fewer in number and much larger in size. Three holding companies now control the majority of the breeding work on the commercially available breeding stock for egg-type chickens, though their products are marketed under nine different brand names. The reduction in the number of breeding firms has been due to international competition and to the high cost of maintaining modern breeding, marketing and distribution programmes in comparison with potential income.

The reduced number of breeding firms has raised concerns about reduced competition and an associated reduction in the potential for innovative research and development (Sheldon, 2000). From an insider's perspective, competition is still intense, some of it among companies within the same groups. However, there has been a dramatic reduction in the number of geneticists working for breeding firms and in the total number of chicken populations under selection.

There is also concern about the narrowness of the base of the genetic stock now being marketed. There is danger in this situation due to the potential susceptibility of 'monocultures' to new diseases that could destroy or damage a genetically uniform population, as happened with maize in the southern corn leaf blight epidemic in the USA in 1970 (Duvick, 1978).

There has also been increasing planned and unplanned loss of stock used as resource populations in the public sector (Pisenti *et al.*, 2001). Some of the lost stock was developed over a period of many years, and their loss reduces the scope of future research. From the standpoint of genetic variability for long-term improvement in commercial stock, the important factor is not the preservation of unique research populations or of the degree of heterozygosity

within populations, but the maintenance of allelic diversity across the species (Notter, 1999). The combined losses of research and commercial populations formerly held by now defunct breeders can limit the future genetic potential of the chicken.

### Conclusions

Since the early 1960s, feed conversion in the USA and Canada has improved by almost 1 g, from 2.96 g feed g<sup>-1</sup> egg to 2.01 g g<sup>-1</sup>. It is not possible to know how much of this improvement was genetic and how much was due to management, but it is safe to assume that a major part of the change is due to improved breeding stock.

In 2000, there were 50.4 million tons of eggs produced in the world (*Executive Guide to World Poultry Trends*, 2001). Thus, with full implementation of the changes of the past 40 years (i.e. since the 1960s), there would be a saving of about 50 million tons of feedstuffs per year due to improved feed efficiency. As the population of the world continues to grow, there will be increased demand for feed grains and increased importance of the continued improvement in the efficiency of poultry and other farm animals. For that reason, it is critical that the necessary research be conducted and that breeders have access to all available genetic tools, including marker-assisted selection and transgenesis. In addition, care should be taken that important genetic diversity is not lost.

### Meat-type Chickens

#### Global development of chicken meat production and the role of breeding

Well into the 20th century, most chickens in the world were kept in small non-specialized units. Although many very different breeds already existed, true specialization for egg or meat production hardly existed and most chicken breeds were used for both purposes. In the late

19th and the first half of the 20th century, small specialized production units emerged and these used selection from the available breeds. Some new synthetic breeds were also developed. Some genetic selection was applied for the specific purpose of the local industry.

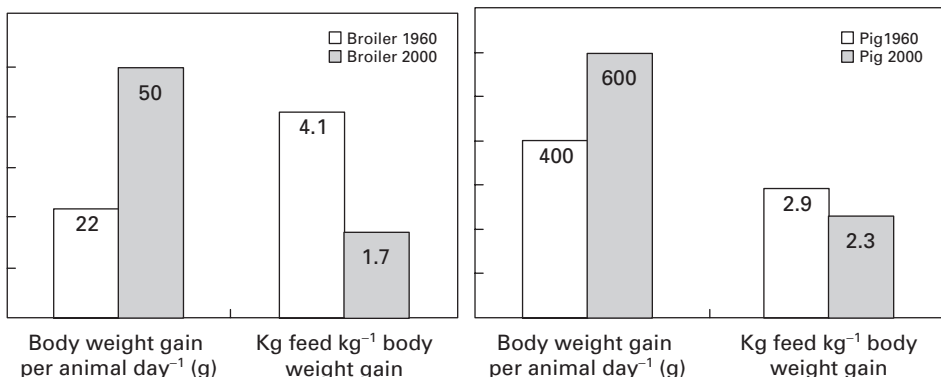
Around the Second World War, larger and more specialized production units for poultry were being developed in North America and Europe. This triggered the development of more advanced genetic improvement programmes. Stimulated by earlier developments in plant breeding, line specialization and crossbreeding were introduced. With the success of the introduction of crossbreds, the number of breeding programmes reduced very quickly to the small number of units that were able to support such large-scale programmes.

In only 50 years, poultry meat production developed from a side activity of numerous small farms into a specialized global business. An industry that was fragmented at first into many small specialized units for breeding, multiplication, hatching, growing and processing soon developed into large integrated poultry meat production companies, often with live production sites contracted out to private farmers. Especially in the Americas, fully integrated companies were spearheading poultry production right from the beginning. In the last quarter of the 20th century poultry production became a truly global industry with international trade effectively enforcing standardization

of production methods and products. Large production companies are even beginning to spread their production facilities around the globe.

World chicken meat production had grown to 56.9 million tonnes in 2000 with 90% of the number slaughtered being young broilers. Output has been growing at an annual rate of 3–5% for many years and this increase is expected to continue. In the last 7 years, poultry's share of total world meat output rose from less than 25% to nearly 29%. Chicken accounts for 86% of total poultry meat output, leaving turkey and duck far behind with 7 and 4%, respectively (*Executive Guide to World Poultry Trends*, 2001).

Poultry breeding has enabled and supported this development of poultry meat production. Breeding companies have been very successful in their efforts to populate the production industry in a logistically efficient manner with increasing numbers of increasingly efficient stock of increasingly high health status. Due to the relatively low cost of breeding programmes for poultry (around 0.5% of live production value), the relative ease of transporting eggs and day-old chicks around the globe, and the fast growth of the industry, the efficiency of chicken meat production has shown a dramatic increase since the 1950s. The joint success of poultry breeding and production is illustrated in Fig. 1.1 by the comparison of the increase of production efficiency in broilers and pigs since 1960. The role of



**Fig. 1.1.** Increase of efficiency of meat production in pigs and poultry over four decades calculated for the entire life of the animal from birth to slaughter.

breeding in this success has been dominant, as has been elegantly shown by Havenstein *et al.* (1994). Some 80% of progress over time has been made possible by improvement of the genetic potential of the birds used.

### Evolution of breeding programmes and breeding technologies

Until the beginning of the 20th century there were no other means of selection and breeding than to identify the best breeder candidates by way of phenotype and to mate these for producing the next generation during the breeding season. A number of technologies in controlled management of reproduction, in control of pedigrees and matings and, lastly, in the accuracy and early availability of estimation of true breeding value of breeding candidates were developed and introduced successively from then onwards. Before the 1940s these technologies were exclusively applied in pure-breeding lines for purebred production stock; from then onwards all breeding programmes for meat poultry consisted of several specialized lines, with distinct breeding goals per line, and production animals (broilers) were crossbreds. Today, final product broilers are a three-way or four-way cross of specific closed pure-breeding lines. There are four generations between the pure-breeding line and the final broiler. The generation and multiplication levels from breeding to meat production are as follows.

1. Pure-breeding line. Owned by the breeding company and subjected to the full-scale selection programme. Three or four lines are used for each broiler product. Each breeding company has a range of broiler products and therefore maintains at least ten pure-breeding lines.
2. Great-grandparent stock. Fully controlled by the breeding company, subjected to limited (usually mass) selection for selected traits. This generation is mainly used to multiply the pure lines to the large numbers (at least tens of thousands) needed to produce the grandparent stock.

3. Grandparent stock. In case of a four-way final cross (ABCD) this generation is the first generation of crossbreeding with A males, B females, C males and D females making up the grandparent flocks. Grandparents are distributed throughout the world in at least hundreds of thousands to local operations, which may be integrated production companies or local distributors of parent stock.

4. Parent stock. This is the second generation of crossbreeding with AB hybrid males being mated to CD hybrid females. Parent stock flocks are largely owned by production companies that produce broilers.

5. Broilers. These are the birds that are grown, slaughtered and processed for large-scale chicken meat production.

Table 1.1 gives a short summary of the various critical breeding and selection technologies and the approximate time of their introduction.

### Evolution of breeding goals

Breeders set breeding goals as a reflection of their expectations of future market demands. With the ongoing changes of production and consumption trends, breeders have responded by adapting breeding goals continuously. Global trends since the early 1950s have been as follows.

**Table 1.1.** Critical technologies for poultry breeding.

Technique	Decade of introduction (approximate)
Mass selection	1900
Trapnesting	1930
Hybridization	1940
Pedigreeing	1940
Artificial insemination	1960
Osborne index	1960
Family feed conversion testing	1970
Selection index	1980
Individual feed conversion testing	1980
BLUP breeding value estimation	1990
DNA markers	2000

1. Broiler growth has consistently been the prime selection trait, because of its ease of selection, high heritability and large impact on total meat production cost.
2. There has been increasing emphasis on yield of white (breast) meat, because this was increasingly favoured by consumers.
3. There was also a growing emphasis on efficiency factors, most notably feed efficiency of broiler growth, as a maturing production industry was increasingly focusing on financial bottom lines for integrated production operations.

An overview of the most important selection traits and the changes in their relative importance over time is presented in Table 1.2.

At first, up to the 1980s, the impact of these trends was not clear-cut, but with the increasing globalization of the industry only the most profitable breeding products now remain. Only four independent groups with significant world market shares in 2001 have survived this selection process, by adapting their programmes in a more timely and adequate fashion than the non-survivors. Differences between companies in timely adjustment of breeding goals have played a more important role in this process than differences in the availability and application of up-to-date breeding and selection technologies. Alongside the large breeding programmes that produce the 'commercial white broiler' for large-scale production of chicken meat, a limited number of small breeding programmes have continued to breed specific products for small niche markets. In particular, the French market has continuously used slower-growing and

coloured breeds for *Label Rouge* and other types of certified chicken meat production. China has a significant part of its chicken meat production on a similar basis. There is a clear tendency for such markets to increase and this growing interest could well be the start of a new trend of a return to larger product diversification.

### Expectations for the future

Future developments in the breeding of meat-type chickens will no doubt be governed by the same factors that have determined developments in the past but with one important difference: the 'chicken itself' is likely to play its own role when it presents the limits of its biological capabilities. It has been speculated that genetic progress at the present rate and for the current main traits will be possible for a limited period of less than two decades (Albers, 1998). Areas of speculation for the future impact of main determinants include: industry developments; consumer demands; breeding technologies; and biological constraints.

### Industry developments

Further consolidation of chicken meat production into large integrated national and supranational units is to be expected. More emphasis will therefore be on efficiency of production and on the increasingly efficient translation of consumer demands by way of intimate partnerships between large production companies and large clients

**Table 1.2.** Trends in relative selection pressure for various traits in broiler breeding programmes.

Selection trait	Relative selection pressure during years		
	1975–1985	1985–1995	1995–2002
Hatching egg production	+++	++	+
Fertility	+	+	+
Broiler growth rate	+++	+++	+++
Broiler feed efficiency	++	+++	+++
Meat yield traits	+	++	+++
Liveability	+	+	++

(retailers and food service companies). Even fewer breeding programmes, probably three, will survive.

#### *Consumer demands*

Price will remain the most important buying incentive for consumers and therefore production cost per unit of product will be of prime importance. However, with increasing living standards, secondary consumer demands will increase. General product quality, food safety, further processing and product diversification will complicate the picture. Meat sales will be less through retailers and increasingly through food service companies and therefore processability issues (e.g. meat and bone quality) will become more important. Increasingly wealthy and critical consumers will also set requirements on the production methods used. This will include demand standards for animal welfare (e.g. bird density in the broiler house, feed restriction of breeder birds), safety of products and use of production technologies including genetic techniques (cf. the current GMO debate). The introduction of organic products is an illustration of this trend and it is to be expected that bulk production of chicken meat will at some stage be significantly influenced by this trend. It is not clear whether all trends mentioned will have the same impact worldwide and it is quite possible that there will be regional differences, e.g. due to marked differences in living standards. This could well affect the balance between cost price demands and secondary consumer demands.

#### *Breeding technologies*

Reproduction technologies, breeding value evaluation technologies and DNA-based technologies are the three critical groups of technologies in breeding in general. The increase of reproductive capacity in chickens offers very little perspective for increase of genetic progress, as selection pressures are already very high. Increase of reproductive capacity (e.g. by cloning) could only help to speed up the process of

multiplication of genetic progress to the production units. However, it is very hard to improve, in a cost-effective way, on the relatively high reproduction rate of chickens and no dramatic developments should therefore be expected in this area.

Theoretically, the ability to reproduce at an earlier age would support the increase of genetic progress by a reduction of the generation interval. The technical problems associated with this, the acceptability of the technologies to be used and the relatively small impact of this make such a new development unlikely.

The only remaining reproduction issue for poultry meat production is the determination of sex of the broiler birds, as the production efficiency of males is significantly higher than of females. With BLUP breeding values now being widely used in meat-type chicken breeding, not too much can be expected from improved mathematical/statistical methodologies for estimation of breeding values. The most important challenges in this area for the foreseeable future are likely to be in the best combination of BLUP procedures with methodology to optimize inbreeding and the inclusion of genomic data in the BLUP-based breeding values.

The most promising new breeding technologies are DNA related: with chicken genomics coming of age, as illustrated by the comprehensive linkage map of the chicken genome (Groenen *et al.*, 2000) and the First Report on Chicken Genes and Chromosomes (Schmid *et al.*, 2000), genomics is now starting to yield for meat-chicken breeding. As the economic value of individual chickens is relatively low, DNA-based genotyping of individual breeding candidates must be done at low cost per bird. Therefore commercial application of genotyping at the DNA level will largely be through direct genotyping for critical genes and not through MAS approaches *per se* that are being designed for larger species. With chicken genomics advancing rapidly a significant impact of this technology on meat-chicken breeding is to be expected, especially for the selection of traits that are not easily dealt with in traditional genetic evaluation

programmes. Such traits will become more important, as indicated in the section on biological constraints, below.

Transgenic technologies are not expected to have a significant effect on commercial meat-chicken breeding in the foreseeable future. Transgenic technologies have not advanced in birds as much as in mammals and it is becoming more and more clear that consumers worldwide are opposing such a development. Breeding companies are not likely to enter into the development process for a transgenic chicken for meat production. As DNA-based selection and breeding technologies are patentable, unlike traditional technologies, the introduction of these novel technologies will also add a new dimension to the competition between breeding companies.

#### *Biological constraints*

Growth rate of modern broilers has roughly quadrupled since commercial breeding commenced in the 20th century. The body composition of the birds has changed dramatically, especially the relative size of the pectoral muscles. Although commercial breeding programmes have been successful in counteracting this basic imbalance by genetic improvement of leg strength and other aspects of general livability such as susceptibility to ascites, there is no doubt that commercial broilers today are showing higher mortality and higher susceptibility to suboptimal management of nutrition and environment than broilers that have been selected less extremely for efficiency and meat yield. This is clear from field evidence on slow-growing breeds such as are used in various regional certified broiler production systems in France, but there is also good experimental evidence for higher activity levels and lower mortality rates in such slower-growing genotypes (Lewis *et al.*, 1997).

More constraints will arise on issues such as leg strength, female and male reproduction capacity, metabolic problems in broilers, digestive system functions of broilers and several aspects of carcass and

meat quality. Research is urgently needed for better understanding of the biological basis of the consequences of the lack of balance in the modern broiler compared with its wild ancestor. Understanding this biological basis should direct researchers and breeders to design selection approaches aimed at preventing this lack of balance from progressing further. Genomics could well play a key role in this, both in unravelling the biological mechanisms and in supporting the breeders in selection programmes.

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