The Old School, Brewhouse Hill, Wheathampstead,
Hertfordshire AL4 8AN, UK

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Breeding for better welfare: genetic goals for broiler chickens and their parents

MS Dawkins*† and R Layton‡

† Department of Zoology, University of Oxford, South Parks Road, Oxford OX1 3PS, UK
‡ FAI (Food Animal Initiative), The Field Station, Wytham, Oxford OX2, UK
* Contact for correspondence and requests for reprints: marian.dawkins@zoo.ox.ac.uk

Abstract

Genetics is key to the improvement of welfare in broiler chickens at both juvenile and adult (breeder) stages but progress is hampered currently by the seemingly conflicting demands of welfare, commercial production, food security and calls for increasing intensification to curb climate change. Animal welfare is therefore most likely to be improved on a commercial scale by future breeding programmes that incorporate multiple goals of different stakeholders as far as possible and give higher priority to animal welfare. These include: i) broilers with high welfare traits; ii) broiler breeders that do not need feed restriction; iii) birds that can be grown in an economically profitable way; iv) birds with low disease levels without the need for routine medication; v) chicken meat that is healthy and good for humans to eat; and (vi) broilers and breeders that thrive in systems that are environmentally sustainable. Progress towards achieving these goals is hampered currently by the assumptions that high juvenile growth rate is incompatible with good welfare and that feed restriction in adults is inevitable with fast-growing juveniles. We challenge these assumptions at both genetic and whole-animal level and argue that the conflict between good welfare and productivity can be reduced by making use of all available genetic variation from existing breeds and other sources and selecting birds in the range of environments they will encounter in commercial production.

Keywords: *animal welfare, broiler breeders, broiler chickens, genetics, growth rate, production*

Introduction

With over 53 billion killed annually for their meat across the world (Food and Agriculture Organisation 2010), broiler (meat) chickens raise some of the most serious animal welfare issues in the whole of agriculture. Modern breeds of broilers have been heavily selected for high juvenile growth rate, breast-meat yield and efficiency of feed conversion (Flock *et al* 2005; Bessei 2006; Arnould & Leterrier 2007; Estevez 2007), but this has left them vulnerable to welfare problems such as susceptibility to cardiovascular disease (Mitchell 1997; Julian 1998) and lameness or difficulty in walking (Kestin *et al* 1992; Sanotra *et al* 2001; Bradshaw *et al* 2002; Knowles *et al* 2008).

However, welfare problems are not confined to the young birds that are killed for meat (de Jong & Guémené 2011). The early rapid growth rate that has been so important to intensive production of broilers has also had a concomitant damaging effect on the welfare of the birds that are grown to adulthood and used for producing the next generation ('breeders'). Breeders rapidly become obese (Dunnington & Siegel 1985); the males have reduced fertility (McGary *et al* 2002) and are reluctant or find it difficult to mate (Bilcik & Estevez 2005), while the females have multiple ovulation (Hocking *et al* 1987) and decreased egg output (Robinson *et al* 1991). The breeder birds also have a tendency for high mortality, locomotory problems (Katanbaf *et al* 1989) and high levels of male aggressiveness towards females (Millman *et al* 2000).

These negative symptoms are commonly avoided in practice by restricting the amount of food that the growing breeders ('breeder rearers') receive, often to 25–50% of what the birds would consume if fed *ad libitum* (Savory & Maros 1993; Ducuypere *et al* 2007; Renema *et al* 2007). However, while restricting the amount of food available greatly improves the physical health and reproductive potential of the birds, it also raises welfare problems of its own, since with such a large degree of feed restriction the birds exhibit signs of chronic hunger (de Jong *et al* 2002; Mench 2002; Hocking 2004; D'Eath *et al* 2009). Furthermore, as broiler growth has continued to increase, the degree of feed restriction needed to keep broiler breeders on a healthy growth trajectory has also increased (Renema *et al* 2007). Attempts to mitigate the increasing welfare problems caused by feed restriction have included reducing the quality of the food, for example by adding fibre (eg Savory *et al* 1996; Sandilands *et al* 2005, 2006), have proved controversial (Hocking 2006; D'Eath *et al* 2009; Nielsen *et al* 2011), since if long-term metabolic needs are not met, 'metabolic hunger' may still occur (D'Eath *et al* 2009). The breeder dilemma remains (Decuypere *et al* 2006; Kasanen *et al* 2010): there are welfare issues of health if feed restriction is not imposed and there are welfare issues of hunger if it is not.

The two major welfare problems of broilers — health issues with the juveniles and the need to restrict-feed the breeders — thus both originate from the genetic changes brought about by intense selection for growth rate, efficiency in food production and meat yield. Although environmental factors, such as nutrition and husbandry, have also contributed, 50–60% of the increased growth rate is attributed to genetic selection (Robins & Phillips 2011). This has led many people to conclude that the only real solutions will come from improving the genetics of broilers and breeding them with improved welfare (eg Jones & Hocking 1999; Arnould & Leterrier 2007; Thiruvenkadan *et al* 2011). The question we address in this paper is whether this desirable goal of breeding broiler chickens for better welfare necessarily means reversing the production and efficiency gains that have been achieved over the last 60 years or whether 'efficient' poultry production can only be achieved at a cost to animal welfare.

This question is particularly important in the face of increasing calls for agriculture to be 'sustainably intensive' and more 'efficient' to feed a rising human population with a growing demand for meat, but to do so with lower greenhouse gas emissions and greater efficiency (Steinfeld *et al* 2006; Royal Society 2009; Godfray *et al* 2010). More 'efficient' poultry production, however, will put chicken welfare under even greater pressure, since to be more efficient, chickens will need to grow even faster and to convert less food into more meat in even less space (Lawrence 2008; Dawkins 2012). The desirable breeding goals for broiler chickens now have to balance not just health, welfare and economics (Lawrence *et al* 2004; Sandøe 2010), but take into account other goals that are also important to people such as producing safe, healthy food, reducing greenhouse gas emissions and allowing farmers to make a living in a way they can be proud of (Dawkins & Bonney 2007). Is it possible to achieve all this and still improve animal welfare? Or will the goal of breeding birds for better welfare clash inevitably with these other goals that are likely to have higher priority in many peoples' minds?

The signs are not promising. Many of the most influential recent reviews of the future of livestock production, such as Steinfield (2006), Godfray *et al* (2010) or the UK Government's Foresight Report (2011) barely mention animal welfare at all. Because chicken meat is already highly efficient (chickens can convert 3 kg of food into 2 kg of meat (Julian 2005; Robins & Phillips 2011), chicken production is set to expand even further in the future. With greater chicken production is likely to come even greater pressures on chicken welfare (Lawrence 2008). It is therefore essential to make sure that in setting breeding goals for broiler chickens, animal welfare is given priority but also that welfare is integrated as far as possible with other goals.

Breeding goals for broiler chickens should therefore include: (i) broilers that have high welfare; (ii) broiler breeders with high welfare without the need for feed restriction; (iii) broilers that can be grown in an economically profitable way; (iv) birds with low disease levels without routine use of antibiotics; (v) broilers that yield meat that is healthy and good for humans to eat; and (vi) broilers and breeders that thrive in systems that are environmentally sustainable.

Some of these goals, such as producing food that is healthy for humans, do not conflict with animal welfare. On the contrary, selection for one might actually enhance the other. For example, whereas once poultry meat was considered exceptionally healthy for a human diet, because it was very low in fat, meat from modern broilers now has more fat energy than protein energy (Wang *et al* 2010). Selection to reduce the fat and increase in muscle protein might benefit both chicken welfare and human diet (Wang *et al* 2010).

Other goals, on the other hand, appear to be in direct conflict. Breeding programmes based on economically important production traits have been directly linked to reduced welfare (Rauw *et al* 1998; Jones & Hocking 1999; Sandøe *et al* 1999; Renema *et al* 2007). For example, chickens that are most efficient at converting food into meat (and therefore have a good Food Conversion Ratio or FCR) also have a lower metabolic rate and low oxygen consumption (Steward *et al* 1980), which in turn renders them liable to heart failure and ascites (Decuypere *et al* 2000). In addition, selection for another important production factor — rapid growth rate — has resulted in decreased heart and lung size relative to the rest of the body (Julian 1998; Ducuypere *et al* 2000) and in skeletal defects that affect walking ability (Mercer & Hill 1984; Rauw *et al* 1998; Corr *et al* 2003).

A key question here is whether these adverse effects on bird welfare are an inevitable and unavoidable consequence of selective breeding for high production traits or whether they are simply the result of breeding programmes that, at least until recently, have set their breeding goals too narrowly by concentrating on just one or a few production traits (Rauw *et al* 1998; Simm 1998). In the latter case, broadening the selection criteria would reduce the apparent conflicts and achieve a wider range of goals (Lawrence *et al* 2004).

The aim of this paper is to examine various ways in which these conflicts between different goals might be reduced or eliminated so as to maximise the chances of achieving improved welfare for broiler chickens at both broiler and breeder level. Animal welfare goals are most likely to be achieved if they can be accommodated alongside, rather than in opposition to, other goals that also matter to large numbers of people. However, while there is increasing understanding among geneticists of the correlational structure between different traits, we argue that, paradoxically, this may sometimes hinder rather than help the achievement of multiple breeding goals that include animal welfare because it leads to over-pessimistic views of what can be achieved. We argue that, in addition to these tried and tested current methods, there is also a need for a more empirical approach that can open up new possibilities for discovering what poultry breeding programmes might achieve.

Multi-trait selection for broilers: is growth rate the real problem?

The breeding companies now increasingly incorporate health and welfare goals alongside economic ones into their breeding programmes and use a variety of traits such as leg health and feather cover, as well as meat-yield and feed-conversion efficiency (Katanbaf & Hardiman 2010). However, from a welfare point of view, growth rate is still seen as the problem (Cooper & Wrathhall 2010), leading to an apparent direct conflict between selecting for good welfare and selecting for production. But is this conflict inevitable or might it be possible to genetically select birds that had both high growth rate and high welfare? At first sight, the negative correlations between growth rate and welfare (Julian 2005; Bessei 2006) would seem to suggest that the conflict was inevitable, since strong negative association between traits suggests that selecting for an increase in one will also lead to a decrease in the other. However, while the success of any breeding programme depends on the correlations (genetic and phenotypic covariances) among traits, it can also be influenced by whether or not there are any individuals that show the desired combinations of traits. For example, in a sample of 173 commercial-type broilers, there was an overall negative regression of $r^2 = -0.89$ ($P < 0.01$) between bodyweight at 63 days of age and walking ability as measured on the Bristol Gait Score (Kestin *et al* 1992), and of these 54 (31.2%) had the best walking ability (Score 0). But, of this sub-set, 54 birds, 21 (39%) had bodyweights of 2.0 kg or more (data from FAI Farma [http://www.faifarms.co.uk]). The existence of these individuals shows that, despite the correlations that currently exist between poor walking and high bodyweight, a programme to breed birds that both grow as productively as the commercial market demands and walk well is within the realms of possibility, although it might take some time. We need to look beyond correlations (which describe populations) to individuals that show what is actually possible.

A further reason for not being constrained by existing correlations between traits in particular strains of poultry comes from looking across species subjected to different selection pressures. Many wild bird species have naturally high juvenile growth rates with no ill effects and often with a positive advantage where there is a high risk of predation or short breeding seasons (Remes & Martin 2002). Birds that breed in the arctic, such as the red knot (*Calidris canutus*) and greater snow goose (*Chen caerulescens atlantica*), have adapted to the short summers by having chicks that grow much faster and are independent of their parents earlier than their temperate counterparts (Fortin *et al* 2000; Schekkerman *et al* 2003). Juvenile growth can speed up under the influence of natural selection to yield healthy juveniles and adults (Arendt 1997), so that there is nothing intrinsically wrong with a high juvenile growth rate. What matters is that the juvenile body also evolves so that it can deal with the rapidly increasing weight. The problem may not be the high growth rate itself but the way that growth rate is achieved. In nature, a fast-growing young animal whose skeleton could not support its bodyweight would die. Fast juvenile growth will only be favoured if there are also changes in the skeletal, muscle and other systems of the body so that the fast growth is also healthy growth. Natural selection is almost always *multi-trait* selection — that is, selection is not just for one trait at a time, but fine-tuning of the whole body with changes occurring in many different genes to accommodate the increased growth rate. By contrast, many breeding programmes have concentrated on just a small number of traits, usually to do with growth rate and other production outcomes. Fast growth rate may not in itself be a problem, but it can easily become so if the breeding programme is focused on a small number of traits rather than selecting for a wide variety of health and welfare traits alongside production ones. The solutions are to learn from evolution by natural selection and to develop multi-trait breeding programmes that select for a wider range of goals (Lawrence *et al* 2004) and to make use of the breeding potential of individual animals that, by chance, already have some of the desired combination of traits.

Multi-age selection in broilers: can juvenile and adult growth rates be selected for separately?

Another conflict of breeding goals occurs potentially between selecting for high welfare in the parent birds and commercial productivity of the broilers. Here, the problem is not so much that there has been one breeding goal for meat-producing juveniles and another for egg-producing adults, as that, until recently, very little attention has been paid to the welfare of the adults at all. Broiler breeders have been the by-product of selection for fast juvenile growth rate. The consequent need for feed restriction in the parents could also be mitigated by selecting for slower growth rate in broilers but as we have seen, this conflicts with efficient production. An important approach here is to select birds for different characteristics at different stages of their growth (Barbato 1991; Mignon-Grasteau *et al* 2000, 2001). Breeding programmes that alter the shape of the broiler growth curve could maintain the necessary early growth and protein accretion in the young birds while curbing later growth and fat deposition in the adults. Instead of seeing bodyweight at a given age as the result of a single function 'growth rate', it should be seen as the result of at least two separate growth phases (Grossman & Koops 1988).

Divergent selection of broilers for growth rate at 14 days of age and separately for percentage body fat at 42 days has shown that that early growth in juveniles can indeed be genetically uncoupled from adult obesity, resulting in birds that have early high growth but lack the high percent of body fat typical of obese adults (Kerr *et al* 2001; Sizemore & Barbato 2002). Similarly, differential selection at 8 and 36 weeks resulted in divergent changes in the shape of the whole growth curve (Mignon-Grasteau *et al* 2000, 2001). Recent QTL analysis has now shown that there are different sets of genes controlling growth at different stages of the lifecycle or different sets that are active at different stages (Ankra-Badu *et al* 2010; Gao *et al* 2010), giving a genetic underpinning to multi-age selection. Different selective pressures operate at different stages of the lifecycle of any animal (Roff 2000; Ricklefs 2010) and each species has its own growth trajectory that is achieved by having different genes coming into play at different stages of life (Zera & Harshman 2001). What is now needed are systematic attempts to select broiler chicken birds that have commercially competitive growth rates as juveniles but require less (ideally no) feed restriction as breeders.

Both multi-trait and multi-age selection are thus important ways of resolving apparent conflicts between breeding goals. The idea that breeding for high welfare in broilers and breeders inevitably involves selecting for slower juvenile growth rate and is on a collision course with efficient production, therefore needs to be challenged by breeding programmes with a wider range of strategies than have been adopted up to now. In the next section we outline some possible strategies that might help to achieve these goals.

Starting points

The success of any breeding programme depends critically on the genetics of the founder populations, since this provides the range of genotypes that can be selected. This is a particularly important consideration for any breeding programme involving broiler chickens because of the possibility that many generations of selection for a narrow range of traits may have eliminated the variation necessary for breeding for a broader range. Indeed, the genetic diversity present in modern commercial pure lines has been estimated to be only 50% of that present in ancestral breeds (Muir *et al* 2008), suggesting that looking for genotypes outside the current commercial stock could be important. On the other hand, comparisons of single-nucleotide polymorphisms (SNPs) between junglefowl and domestic lines have not supported the idea of reduced variation among domestic breeds taken as a group. On the contrary, most of the SNPs (Single Nucleotide Polymorphisms) identified in junglefowl also appear to be present in broilers, suggesting that they originated before domestication (Wong *et al* 2004; Wiener & Wilkinson 2011). Artificial selection on broilers has also lead to an increase in the recombination rate (Groenen *et al* 2009), giving a persistent wide range of variation in each generation.

There is, thus, evidence of a great deal of useable variation still existing within modern breeds of chickens (Granevitze *et al* 2007; Hill 2010; Weiner & Wilkinson 2011), but in order to maximise the potential of any multi-trait breeding programme for broilers, it may be valuable to utilise as many different sources of genetic variation as possible, such as:

(i) Using a wide range of breeds from different parts of the world to reintroduce 'missing alleles' that may have been lost in the course of domestication or more recent selection for particular traits. These include the 'Three Yellow' from China and other varieties of chickens native to particular areas (Yang & Jiang 2005) and 'high welfare' breeds such as those used in Label Rouge production (N'Dri *et al* 2007; Lariviere & Leroy 2010).

(ii) Introducing specific genes to commercial breeds, such as a 'dwarf' gene, which is a popular approach among commercial breeders, because it alters the growth rate and leads to a smaller body size (Jones *et al* 2004; Ducuypere *et al* 2006). Dwarf males result from a sex-linked mutation of the growth hormone receptor (Zheng *et al* 2007) and have some advantages in reducing growth rate in male breeders (Puterflam *et al* 2006). Dwarf male broilers have normal fertility but the dwarfism gene affects the reproduction of females (Zheng *et al* 2007). With the introduction of modern genetic techniques that can identify genes more precisely, this kind of approach can become more targeted (Sandøe 2010; Lyell *et al* 2011), but, as with variants produced by more conventional means, the welfare and other implications still need to be monitored in the phenotype.

(iii) Starting with existing commercial breeds and selecting for higher welfare. The advantage of this approach is that the existing valuable commercial traits are preserved. It makes use of the large amount of genetic variation that still remains within commercial strains (International Chicken Polymorphism Consortium 2004; Hill 2010) to give rise to the birds that have desirable combinations of traits, some of which may already exist.

In summary, to achieve the multiple breeding goals that are desired by different stakeholders, we may need to find the required genetic variation from a variety of sources, including rare breeds, and also the considerable variation that still remains within commercial strains.

Achieving the multiple goals: classical breeding and modern genetic technology

The twentieth century saw the rise of the science of genetics and with it came more control over animal breeding through more active decisions over which animals mated with each other ones. Measurements of heritability and the correlations between traits allowed the choice of animals for breeding to be made not just on the phenotypic qualities of the animal itself but of those of its offspring and other relatives (Simm 1998). Although this means that the process of selection can be speeded up and targeted, it carries the disadvantage that in order to measure heritabilities and correlations, poultry are often selected in controlled environments that are different from the ones the offspring will encounter. For example, the parent and grandparent broiler breeders have until recently been selected in disease-free environments different from the commercial farms (de Jong & Guémené 2011). Genes that are expressed in one environment may not be expressed or may be expressed differently in another. For example, measuring FCR in Label Rouge chickens kept in cages (to facilitate the measurement of how much each bird eats and its daily weight gain) does not give a good indication of FCR when the birds are kept on free range outside (N'Dri *et al* 2007). More control and greater accuracy of measurement is thus gained at the expense of greater generality and an understanding of how the birds

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will perform in the environment in which they are actually to be kept (D'Eath *et al* 2010; Rodenberg *et al* 2010).

The reason for this is that 'heritability' is not a fixed quantity for each trait, to be measured once in one environment and then applied to all other situations (Feldman & Lewontin 1975). Heritability and the apparent genetic correlations between different traits depend on: i) the range of genotypes that have been looked at; and ii) the range of environments in which they have been reared, so that heritability measured in one set of environments cannot readily be extrapolated to another. For example, the heritability of learning ability among six strains of mice was found to vary by a factor of 10 (0.4 to 4.0) depending on whether they had been reared in enriched cages or standard laboratory ones (Henderson 1970). For this reason, we should not let apparently low values of heritability or apparently high correlations between traits put us off attempting to breed chickens with the combinations of desirable traits. There is a role for small scale, empirical studies that explore what might be possible. Prior estimates of heritability and trait correlations, based on a narrow range of genotypes kept in a restricted range of environments, may be highly quantitative but also may lead to pessimistic views of the likely success of such a breeding programme. By encompassing a wider range of genotypes (including outliers and unusual individuals within existing breeds) and exploring the effect of a wider range of environments, the future looks brighter, because the genetic constraints may not be as great as they seem.

There are now even greater opportunities for controlling breeding programmes in poultry (Muir *et al* 2008), beginning with the sequencing of the chicken genome in 2004 (International Chicken Polymorphism Consortium 2004). A range of techniques has led to the mapping of genetic pathways that control growth, development and metabolism of chickens (Cogburn *et al* 2003) and can even reveal which genes are active at particular points in development (Cogburn *et al* 2003). Marker-assisted selection using QTLs (Quantitative Trait Loci) enables more efficient identification of birds with desirable traits and so speeds up the process of selection, but this very efficiency brings with it dangers and ethical issues (D'Eath *et al* 2010). The research emphasis so far has been on broiler traits associated with production such as growth rate (Wahlberg *et al* 2009; Nie *et al* 2010), feed conversion (Pakdel *et al* 2005; Gonzales-Recio *et al* 2009), carcase quality (Zheng *et al* 2009) and egg production (Zhang *et al* 2008). While some attention has been paid to traits associated with welfare (Keeling *et al* 2004), there is a danger of once again focusing too narrowly on commercially valuable traits and neglecting the importance of selecting for many traits including welfare (Lawrence *et al* 2004) simply because less is known about them. The side-effects of using modern techniques to apply even more intense selection than is possible with conventional breeding are unknown (D'Eath *et al* 2010). Even if chicken genotypes are selected with sophisticated new techniques, the resulting phenotypes are still going to have to be scrutinised for welfare in the real world. Until we have a much greater knowledge than we do at present of all the main effects and side-effects (pleiotropisms, linkages etc) of the genes that are being manipulated, we will not do away with the need for classical genetics or even traditional methods for selecting animals. On the contrary, achieving the multiple goals for boilers will need assessment of the phenotype in the environment in which it will be reared and at many different stages of its life even more urgently than ever.

Can we have it all? Limits to selection

We have set a number of aspirational goals for a programme to selectively breed for improved broiler welfare alongside commercial traits, goals that, if they were all achieved, would satisfy a large number of stakeholders. But, in reality, is it possible to achieve them all? In the end, will we be forced to make difficult choices — between acceptable standards of welfare and commercial production for example. Cheap, healthy, high welfare, environmentally friendly chicken meat may not be a possibility. The purpose of this paper is to argue that the answers to such questions should not be assumed in advance and need better empirical data than is available at the moment. Widely held assumptions, such as that commercially valuable growth rate is inevitably linked to poor welfare, need to be challenged, possibly by small-scale 'risky' breeding programmes that set out to put such assumptions to the test and to collect empirical data to see whether such traits can be selected for separately. Some of the existing conflicts between goals — such as that between production of broilers and welfare of parent breeders — may not be as implacable as they might seem at first. We will not know until we try. Using a variety of genetic starting points and applying a range of techniques, both old and new, there is now the potential to shift the balance points and achieve far more of all goals than is currently the case. But the potential is not infinite and we may still come up against serious constraints on what can be achieved.

Natural selection constantly encounters constraints. For example, the most colourful males may be the most attractive to females but are also most vulnerable to predators (eg Godin & McDonough 2003). The antelope that visits the waterhole and gets eaten by a predator while it is drinking is an example of such a compromise, Natural selection has not evolved the perfect antelope that does not need to drink, can always escape from predators and lives an infinitely long time. Natural selection, in other words, does not lead to perfection, but to optimal compromises between conflicting goals, constrained and limited both by underlying genetics and by the real world (R Dawkins 1982). These constraints include pleiotropy (genes with both desirable and undesirable effects), historical constraints (such as the blind spot in the vertebrate eye) and the simultaneous evolution of other organisms, such as predators and diseases, engaged in a constant arms race to run faster or to overcome immune resistance.

Artificial selection can overcome some of these constraints that limit the power of natural selection. For example, when a new organ or structure evolves, natural selection has to do the equivalent of changing a propeller plane into a jet airliner one step at a time, while ensuring that each intermediate step is not only airworthy but actually flies better than the previous step (Jacob 1977). Nature cannot 'go back to the drawing board', find some new genetics and have a break while the new design is tested and perfected. Everything has to be done on the fly, based on the mutations that happen to be around at the time and in the full glare of competition from other animals. Artificial selection has the advantage that some of these constraints can be relaxed (Sandøe 2010). It is possible to import new genetics, for example, and to greatly increase the range of mutants that selection has to work on. We can keep animals alive that would die in nature (such as ones that need our help in mating) and there is also a sense that we are beginning to literally go back to the drawing board and 'design' animals for the goals we want. We can hope to produce animals with traits and combinations of traits that could in the end be successful and have high welfare, but which would never have been possible in the wild.

But this very power to overcome some of the constraints that have operated through billions of years of natural selection should not blind us to the constraints that are still present and that may still mean that achieving all the goals we might want to is not possible, certainly in the short term and possibly in the longer term too. At least in the short term, we are limited by current ignorance of all the effects that a given gene, even one with supposedly desirable effects, might have. In the short term, and possibly in the long term too, we may have to make difficult ethical choices and decide our priorities between different goals. If environmental constraints point to greater intensification of methods of keeping livestock (Steinfeld *et al* 2006; Godfray *et al* 2010) and economic pressures demand higher productivity that is incompatible with animal welfare despite a genetic programme for breeding better welfare, then we may not be able to 'have it all'. Our aim in this paper has to be to lay out the options for maximising the chances that we can have as many of our goals as possible and to make sure that with the public concern for food security and global warming, the welfare of broiler chickens is kept firmly on the political agenda, either alongside other goals or, if that proves impossible, as stark choice in front of all of us.

Animal welfare implications

Broiler chicken welfare is most likely to be improved in practice if animal welfare traits such as good walking ability, good feathering and healthy legs and feet are seen as compatible, rather than in conflict, with other goals such as commercial production. Although reduction in juvenile growth rate is often seen as the only way to improve broiler welfare, evidence from a variety of sources shows that high growth rate does not inevitably lead to poor welfare in either broilers or broiler breeders. In order to give animal welfare a higher priority in poultry breeding programme, it is necessary to explore more ways of reducing the conflict between high welfare and commercial needs.

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