Aviagen® Group

Decades of Breeding for Welfare and Sustainability

Decades of Breeding for Welfare and Sustainability

Authors

Brendan Duggan

John Ralph

Santiago Avendaño

Anne-Marie Neeteson

Tim Burnside

Alfons Koerhuis

Contents

OVERVIEW OF BREEDING

Aviagen® has the responsibility of managing the world's major broiler and turkey breeding programs. The breeding decisions are important for determining the characteristics of the breeds used by today's farmers. Operating for over 60 years, these programs have a long history of developing and selecting for a diverse range of welfare and sustainability traits.

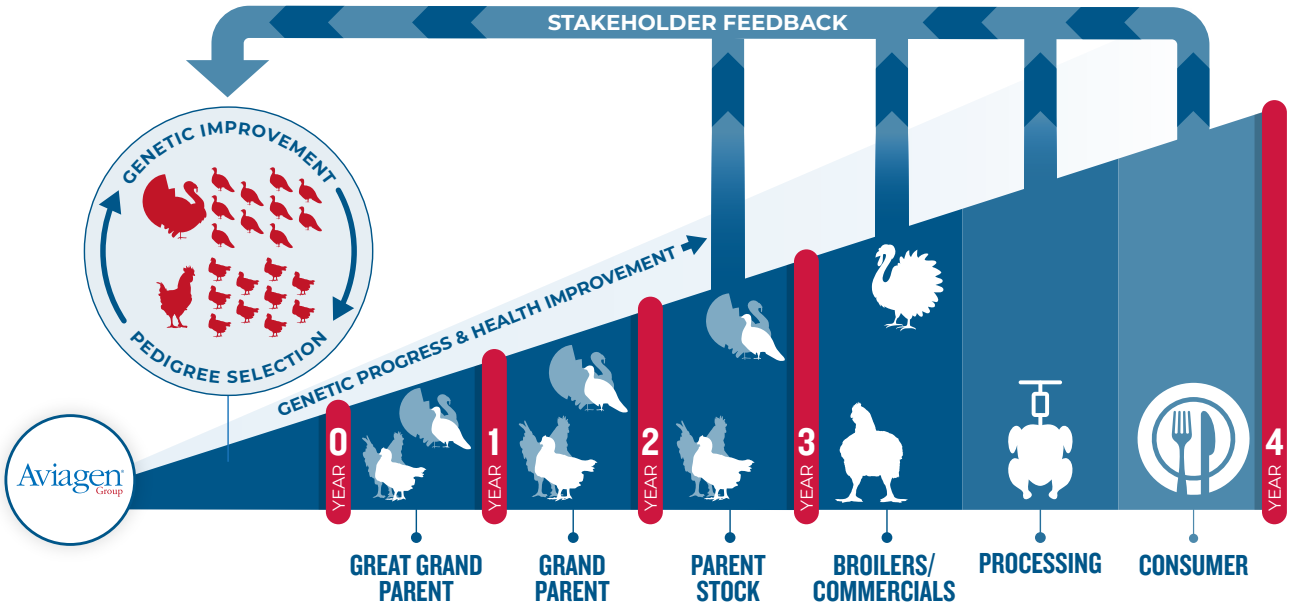
Aviagen operates multiple breeding programs for each species. These programs are the start of the supply chain for poultry producers worldwide. Each program consists of multiple lines of pedigree birds measured under controlled conditions to replicate the growing and reproduction life stages used in poultry production.

The breeding goal is developed by translating requirements from industry and societal stakeholders into measurable traits on individual birds. Pedigree lines are selected for a broad range of traits and offspring are multiplied and crossed over several generations. The balance of selection traits in each line differs depending on the intended use of the final cross.

From pedigree selection through to the final generation grown by farmers takes around 4 years. It is evident that breeding companies therefore need to carefully anticipate the direction of stakeholder requirements in order to satisfy future requirements.

Figure 1 shows the pedigree section of the breeding program, where the selection takes place, and the multiplication generations.

Figure 1
Pedigree program, multiplication pyramid and feedback mechanism of Aviagen breeding programs.



continued...

Whilst consumer preferences are evolving to an increasing awareness of welfare and sustainability of food production, arguably, long-term breeding targets for improving economic efficiency are closely aligned to these goals.

For many years, Aviagen has focussed on minimizing inputs of feed, water, litter and antibiotics and maximizing meat produced through a balance of welfare, weight, yield, and better livability.

This paper will demonstrate the decades long commitment of Aviagen to the genetic improvement of welfare and sustainability of broiler and turkey breeds.

It will also cover the techniques used to ensure robustness and optimal welfare under a wide range of production conditions, as well as new methods to improve the accuracy of our selection and further drive genetic progress for better welfare and sustainability outcomes.

CORE PRINCIPLES OF BREEDING

Within our breeding programs, we record large amounts of data on each bird; for example, bodyweight, feed conversion efficiency (FCR), physical leg assessment and gait score. We combine these carefully recorded measures with the birds' pedigree (a record of how each individual is related to each other individual).

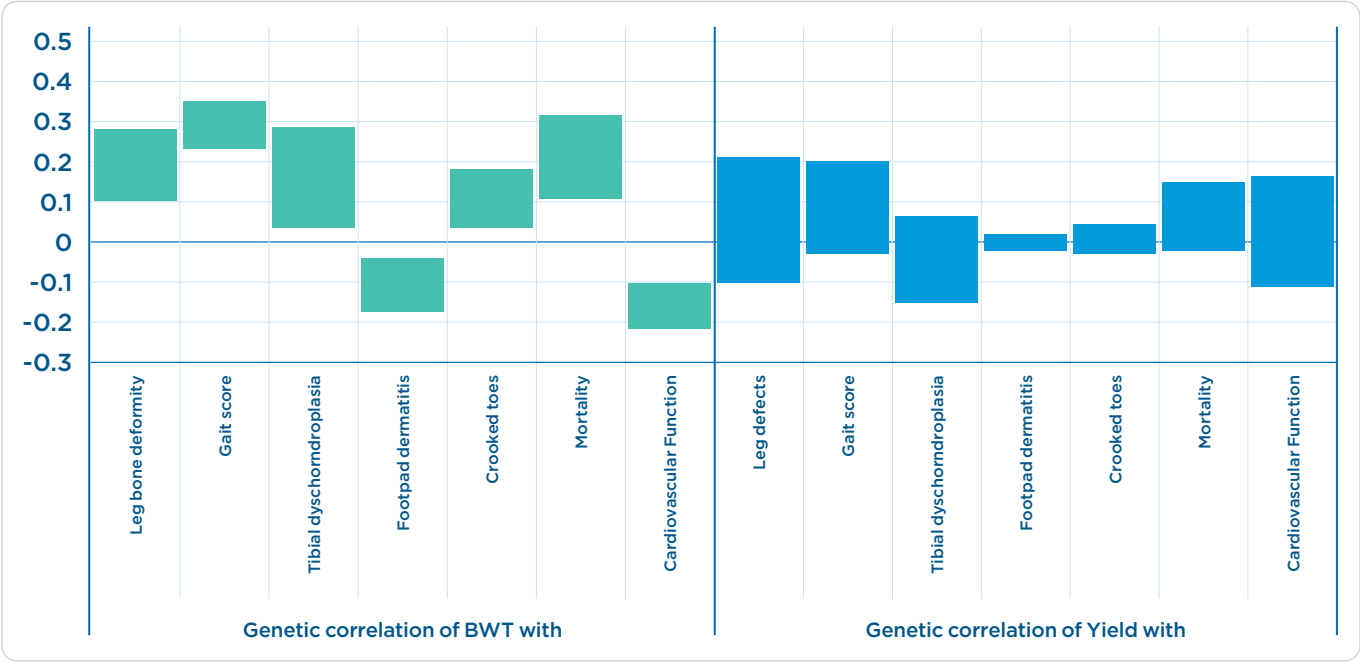
By combining physical measurements with family information, we can create a very clear picture of which birds and which families within our populations have the best genetic potential. These are the families that we breed so that those genes contribute to the next generation and drive the progress of the commercial bird.

In each of our breeding programs, this family information is extensive; for example, our broiler pedigree goes back to 1979. The same principle applies to all other traits. In each of our breeding programs, this family information is extensive.

Aviagen takes a balanced breeding approach to selecting its birds for many different traits at the same time. Many selection traits are correlated with each other (**Figure 2**). Selection of some traits may impact positively or negatively on the development of other traits.

Figure 2

Broiler breeding program ranges of Genetic correlations between Live Bodyweight (BWT) and Breast Yield (Yield%) with Leg Bone Deformities (%), Gait Score, Tibial Dyschondroplasia (%), Footpad Dermatitis (%), Crooked Toes (%), Mortality (%) and Cardiovascular function as measured by blood oxygen saturation (%) (Avendaño et al., 2017).



continued...

A negative relationship – antagonism between traits - is regularly observed between production or environmental impact traits and health, welfare or reproduction traits. This means an improvement in one trait needs to be considered in the context of its effect on other traits.

Such antagonisms are handled, by simultaneously considering multiple traits in the breeding goal and selecting birds which have better than average breeding values than the population average. Amongst the many pedigree candidates there are always a few which are good at both traits in a certain antagonism – these birds are then selected.

Step by step then both traits will improve. This approach of balanced breeding has been used for many years in the broiler and turkey breeding programs at Aviagen.

Sustainable breeding requires a secure breeding program structure and a diverse range of genotypes to cater for current and future industry needs. The broiler and turkey breeding programs share similar, proven structural features for genetic security: high biosecurity facilities with replicated populations spread geographically and at different ages. As an illustration, Aviagen and Aviagen Turkeys each have pedigree operations based in the USA and UK. Within each location, there are various rearing and laying farms housing the pedigree lines.

In the breeding programs, the source of the genetic progress comes from a wide range of pedigree lines (**Figure 3**) with more than 30 in broilers and over 40 in turkeys (Defra, 2010).

Figure 3
Illustration of the genetic diversity in the lines managed by Aviagen's turkey and broiler breeding programs.

A high selection pressure is applied for a broad range of traits. The individual lines, each with clearly defined selection objectives, are then combined to give parents and finally commercial birds. Aviagen´s diverse breed range consists of cross-bred birds, typically made up of four different types of pedigree lines. The diversity of lines gives a large range of opportunities to create novel crosses to satisfy future market needs.

WELFARE AND SUSTAINABILITY TRAITS

Aviagen has a long history of incorporating welfare and sustainability measurements into its breeding program to drive progress (**Figure 4**).

The expansion to include turkey breeding programs has allowed sharing of resources and exchange of new ideas and techniques between the breeding programs.

Figure 4

Milestones in the implementation of selected welfare and sustainability traits into the Aviagen broiler and turkey breeding programs.

Use of hybrids

Pedigree selection

1940–1950

Freedom from defects – legs, skeletal defects and breast blisters

1960–1970

Leg health/strength selection

Selection for gait

Family selection

Family Feed Conversion Rate selection

Full pedigree identification

Livability selection

1970–1980

1980–1990

Oximeter – heart and lung function selection

Selection indices, Individual FCR selection

Lixiscope – joint health selection, Feather coverage

Selection for reproduction using large mating pens

High density brooding to prevent defects

Coccidiostat free selection diets

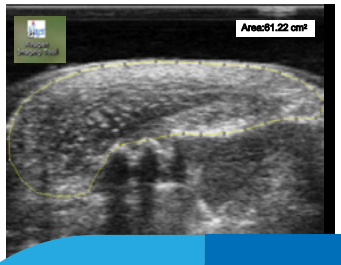
Footpad shape measurement

Selection for improved meat quality

CT scanning

Research on biomarkers of gut function

2000-2010



Ultrasound

Multi-environment selection

Use of DNA

1990–2000

2010-2020

Genomic selection in breeding program

Lifetime FCR

Diet range in pedigree

Footpad dermatitis (FPD) selection

Improved Lixiscope

New processing plant

Water intake measurements

ENVIRONMENTAL SUSTAINABILITY

Environmental sustainability has long been a core focus for Aviagen. Whilst increasing flock outputs through improvements in traits associated with weight, livability, egg and meat yield play a key role in this, the amount of feed a bird requires to develop and grow is key to the global footprint of poultry production. FCR is the single most important trait for reducing the environmental impact of poultry production (Jones, 2008).

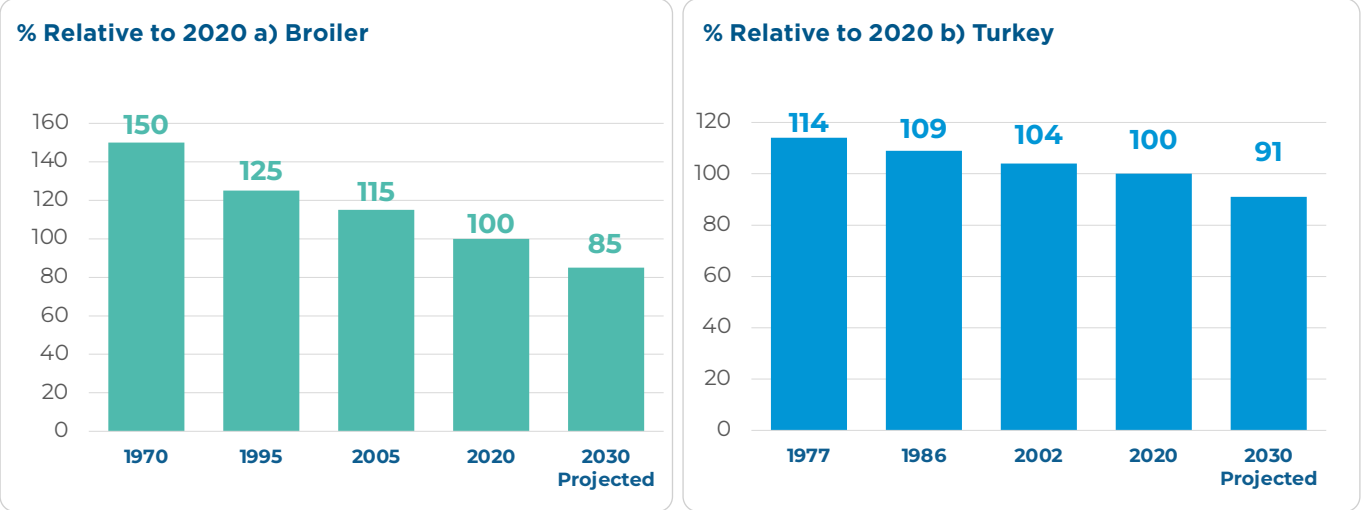
The improvement seen in FCR within both broilers and turkeys has greatly reduced the carbon footprint of poultry meat and also reduced the amount of environmental pollutants associated with poultry production.

Figure 5a shows Aviagen calculations of the relative environmental impact of broiler production over time. Broiler genetics from 1972 had a 50% higher environmental impact than 2020 genetics and future genetics will have 10% lower carbon footprint by 2030 than the bird today, which is in line with the estimations made by Jones (2008).

Turkey genetics resulted in a 20% lower carbon footprint between 1977 and 2020, with an expected 10% improvement by 2030 because of improvements made in the breeding program (**Figure 5b**). These improvements of about 1% per year are primarily driven by genetic improvement of FCR.

Figure 5

Impact of genetic improvement on emissions (Global Warming Potential) from a) broiler production and b) turkey production (Burnside & Ralph, 2023), relative to 2020. FCR is the major contributor to reduction in Global Warming Potential.



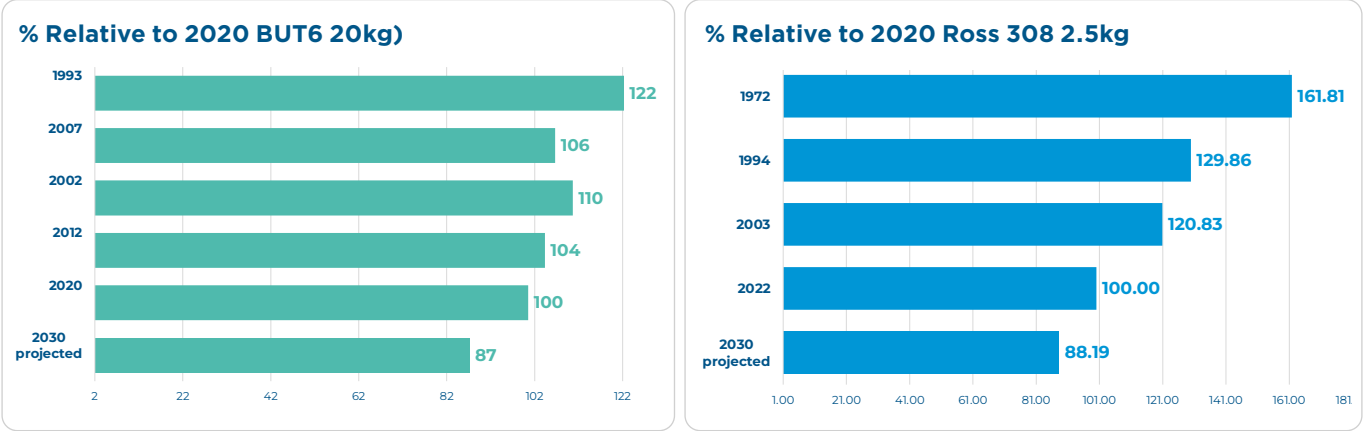
continued...

For decades, intensive selection for improved FCR has resulted in a highly feed efficient animal that is far more sustainable than many alternative meat sources.

This can be seen in the evolution of the performance objectives published for the BUT6 and Ross® 308 (**Figure 6**).

Figure 6

Aviagen published performance objectives of the a) BUT6 and b) Ross 308 showing FCR performance to a fixed weight, relative to the FCR in 2020 (turkeys) and 2022 (chickens) and including a future projection to 2030. FCR = Feed Conversion Rate.



Historically FCR was assessed by measuring feed consumption and weight of birds in individual pens. Since 2004 in broilers and 2006 in turkeys, Aviagen has pioneered the use of feed stations, which record individual bird feed intake using transponder identification within a group environment (**Figure 7**).

Figure 7

Feeding stations for broilers (left) and turkeys (right).

This allows the selection of birds with genes associated with improved feed efficiency while the birds are free to express natural behavior. The feed station technology has been highly successful and example of its importance can be seen in the 50% increase in testing capacity in the turkey breeding programs since 2018.

continued...

The feeding stations have also allowed the study of feeding behavior, which has shown that broilers and turkeys share the same structure of short-term feeding behavior, which is regulated by levels of satiety. This was also observed when comparing broilers, turkeys and ducks to cattle, pigs, dolphins and rats (Howie *et al.*, 2010, Tolkamp *et al.*, 2011). The correlations between feeding and drinking behavior traits with performance traits is low. There is a wide range of feed and drinking behavior strategies in the broiler and turkey populations, which is important for their adaptability to a wide range of environments and production systems. Individual bird FCR alongside livability, robustness and weight have jointly contributed to the significant improvements seen in flock FCR.

Since 2014 in broiler and 2017 in turkeys, Aviagen has been applying genomic selection in its breeding programs. Genomic selection increases selection accuracy which results in greater rates of progress across traits. This has been particularly beneficial for FCR where it is not possible to measure the FCR of every individual and the selection accuracy of unmeasured birds is markedly improved thereby enhancing progress in the environmental sustainability of poultry production.

ROBUSTNESS

A key component of good welfare is the ability of birds to thrive in a variety of production environments. Aviagen's pedigree facilities replicate typical farming environment, management and nutrition conditions and these have been continually refined over the years to keep them relevant to commercial practice.

As an example, in 2013, Aviagen Turkeys introduced a higher density brooding regime to reflect industry practice, which altered the expression of traits such as leg defects.

As pedigree birds contribute to future generations, the pedigree facilities are maintained to the highest biosecurity standards. This means that pedigree birds do not meet the spectrum of natural health challenges found in commercial poultry production.

To measure the potential of birds when grown under natural health challenges, Aviagen uses a parallel farming system where siblings of pedigree birds are grown and assessed in lower hygiene conditions.

Pedigree selections are then based on performance measurements from both locations (multi-environment selection), ensuring that only the families that perform well in both types of environments pass their genes on to the next generation.

This process started in broilers in 2000 and turkeys in 2010. Over time, this process of 'multi-environment selection' has had a dramatic effect on the robustness to various management, immune and gut challenges.

This multi-environment strategy has made current generations of birds better able to adapt to the wider range of management circumstances they may encounter in the field. This testing of siblings has led to more robust animal populations with higher livability and better uniformity and continues today.

LEG HEALTH

Leg Health has been a key feature Aviagen's breeding programs since the 1970's.

This began with the removal of birds with any clinical leg defects (broilers) and walking assessment and defect selection in turkeys (see **Figures 8** and **9**).

Figure 8
Leg and foot health (left), and gait (right) assessment in broiler selection candidates.

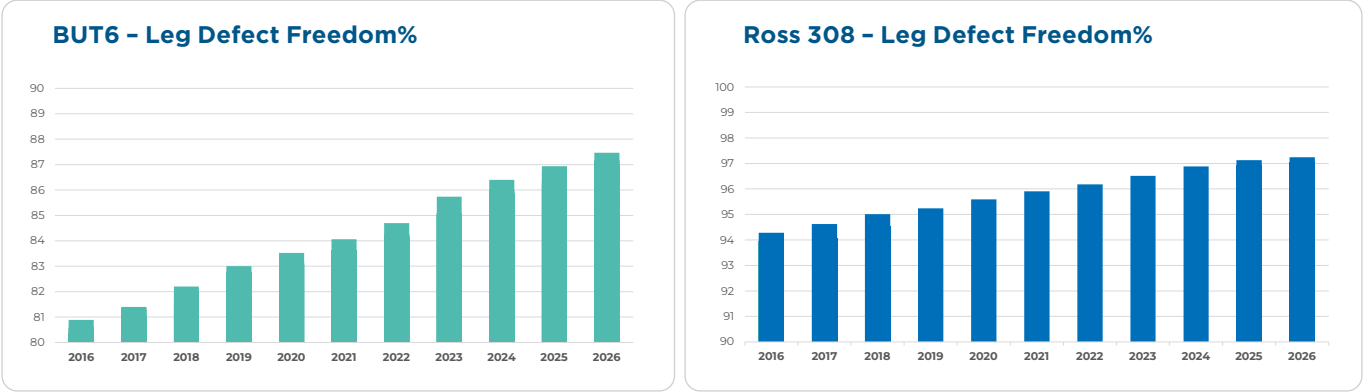
Figure 9
Images of gait scoring in turkeys. Left: healthy legs compared to: Middle valgus and: Right: varus deformities.

continued...

Along with leg defects each bird is also screened for footpad dermatitis (FPD), hock lesions and toe defects. Any birds displaying any type of leg defects are not considered for selection (to contribute to the next generation). This policy continues to this day in both broiler and turkey programs and has been a driving factor in reducing the genes associated with leg defects within our populations (**Figure 10**) as demonstrated by Kapell *et al.*, 2012 (broilers) and Kapell *et al.*, 2017 (turkeys). The addition of family-based selection has also made it possible to exclude defect-free individuals from high-defect families.

Figure 10

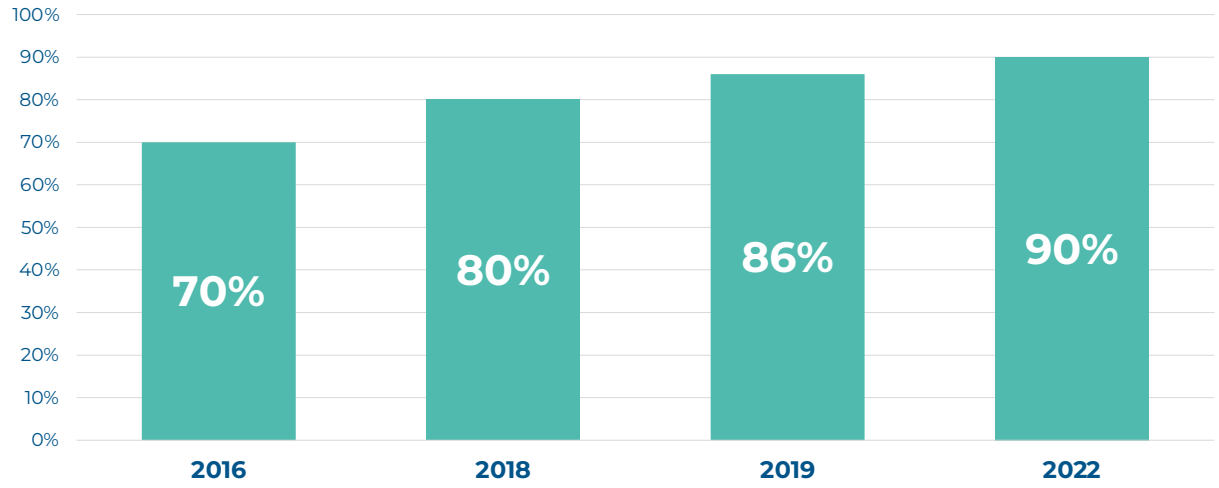
BUT6 (a) and Ross 308 (b) genetic trend for selected leg health traits. X axis: customer year. Y-axis: Leg Defect % Free. For BUT 6 and Ross 308 the genetic trend depicts the improvement in % leg defect free including information from clinical and subclinical leg health assessment and gait evaluations. EBV = Estimated Breeding Value.



The turkey breeding program has a long history of selection for gait. Also in the chicken breeding program improvements in gait score are clear (**Figure 11**). Ross 308 broilers showed a steady gait improvement from 2016 to 2022.

Figure 11

% Birds with acceptable gait scores of Ross 308 broilers (Bristol scores 0-3). Fixed weights at 2.3kg, RSPCA method (RSPCA breed protocol, 2017). Aviagen trials farm. During 2020 and 2021 no measurements could be made due to Covid-19 related travel restrictions.

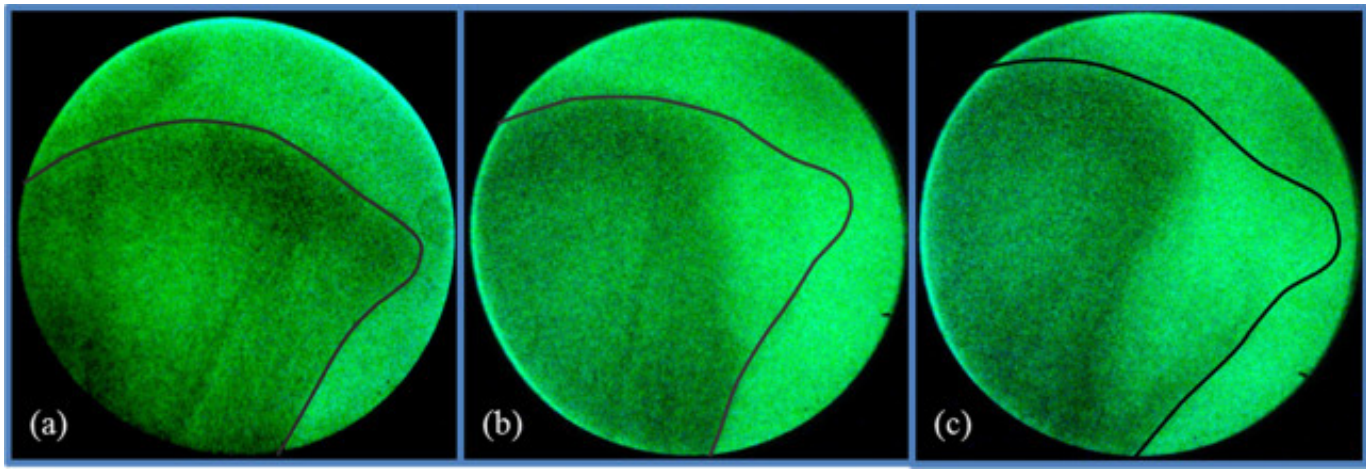


continued...

The scope of leg health assessment has been expanded over the years to include technology such as the pioneering use of a hand-held x-ray device (Lixiscope) for the detection of clinical and sub-clinical tibial dyschondroplasia (TD) (**Figure 12**). This work began initially in broilers in 1989; new generation Lixiscopes in 2007-8 improved the level of detection and also made it possibly to apply this technology to turkeys where, alongside gait and defect assessment, it continues to be used today.

Figure 12

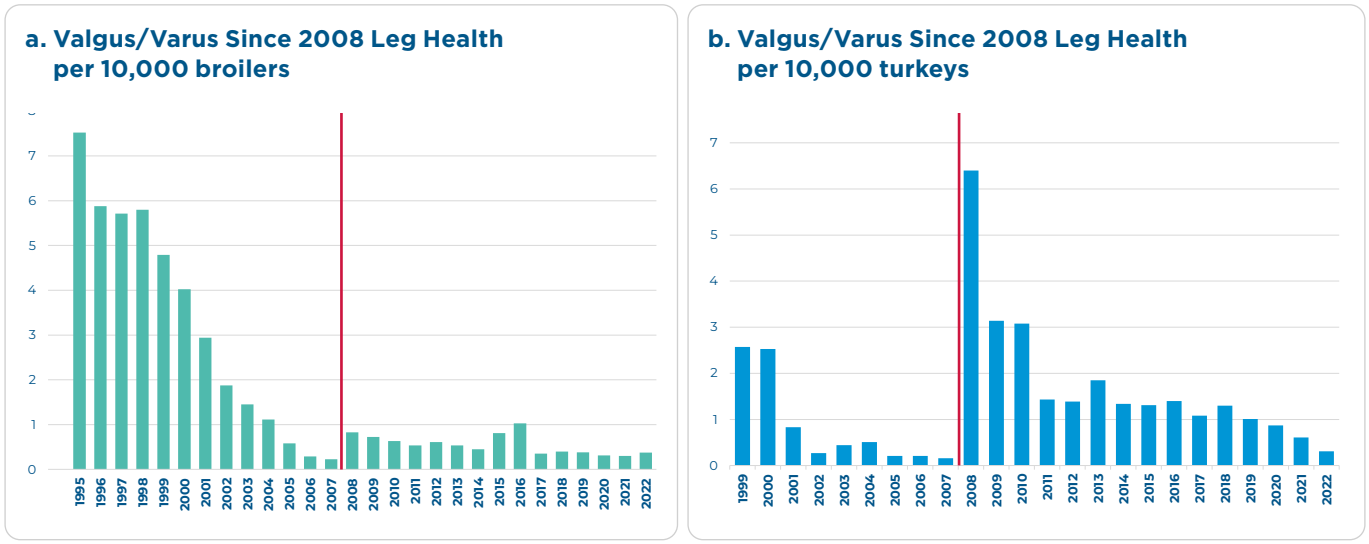
Lixiscope x-ray images showing Tibial Dyschondroplasia assessment in turkeys: (a) no lesions, (b) moderate lesions, and (c) severe lesions (Kapell et al., 2017).



Together, inclusion of a range of leg health traits in the breeding goal has improved leg health in the field as well, as the trend from Agriculture and Agir-Food Canada from the Government of Canada shows (**Figure 13**).

Figure 13

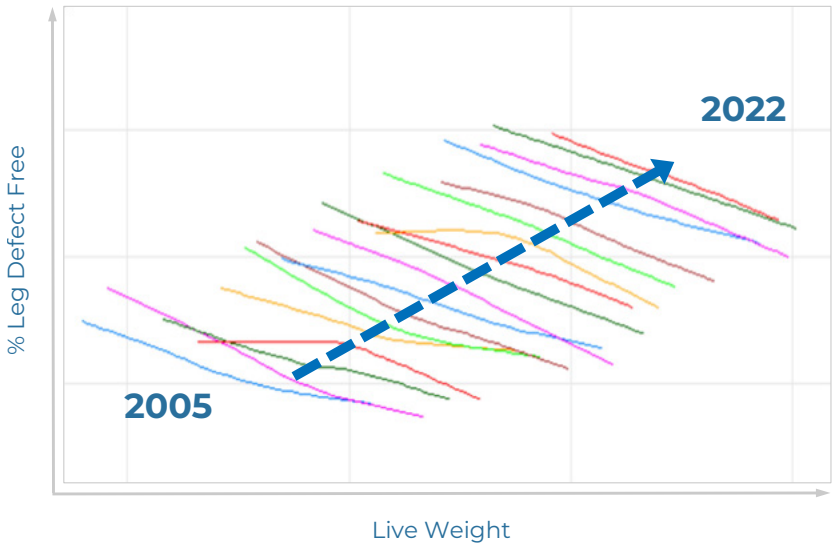
Leg health (until 2007 valgus/varus) related condemnation rates in broilers and turkeys per 10,000. a) Chickens 1995-2022; b) Turkeys 1999-2022). (Agriculture and Agri-Food Canada (AAFC), 2023) The vertical red lines mark the change from valgus/varus to leg health in 2008.



continued...

Improvement in leg health has been achieved alongside liveweight gains. This is an example of the decades' long application of balanced breeding where adversely correlated traits can be improved simultaneously (**Figure 14**).

Figure 14
Long-term relationships between Live Weight and Leg Strength (%). Each coloured line represents the relationship between breeding values for leg strength within a year. The broken arrow represents the joint direction of the average breeding value (Neeteson-van Nieuwenhoven et al., 2023).



Developments in medical imaging technologies present new opportunities within poultry breeding. Today, in both broiler and turkey breeding programs, computed tomography (CT) is used to measure a range of traits (**Figure 15**). As well as recording accurate measurements of breast and leg yield, algorithms have been developed to automatically detect sub-clinical incidence of TD within the birds. CT imaging also allows the recording of a variety of novel skeletal and morphological features that could make it possible to determine the ideal architecture for good gait and balance.

Figure 15
CT scanning of broilers (left) and turkeys (right).

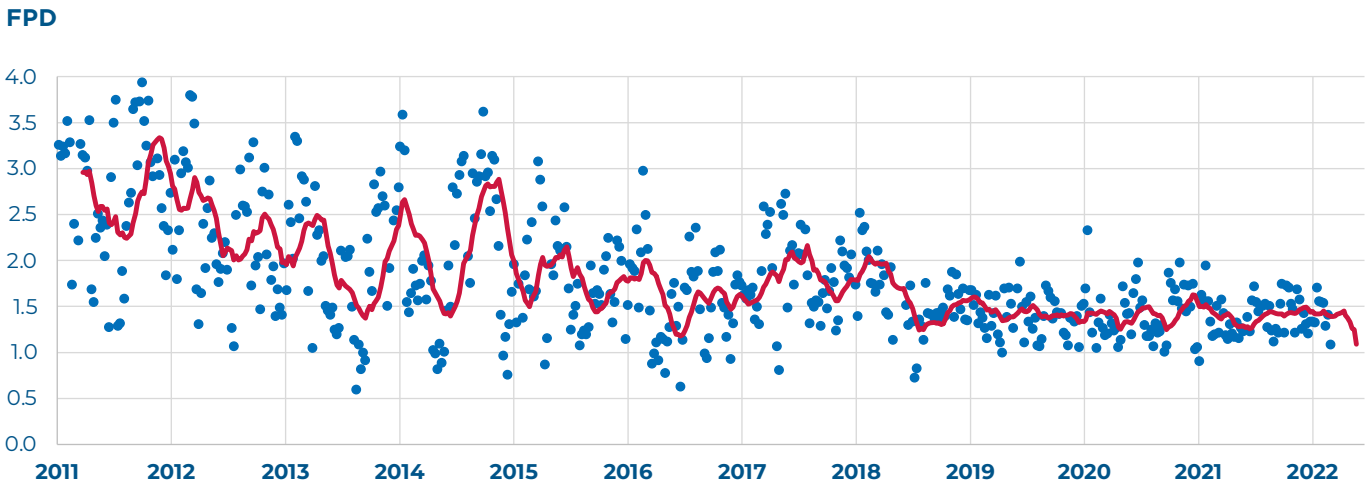
continued...

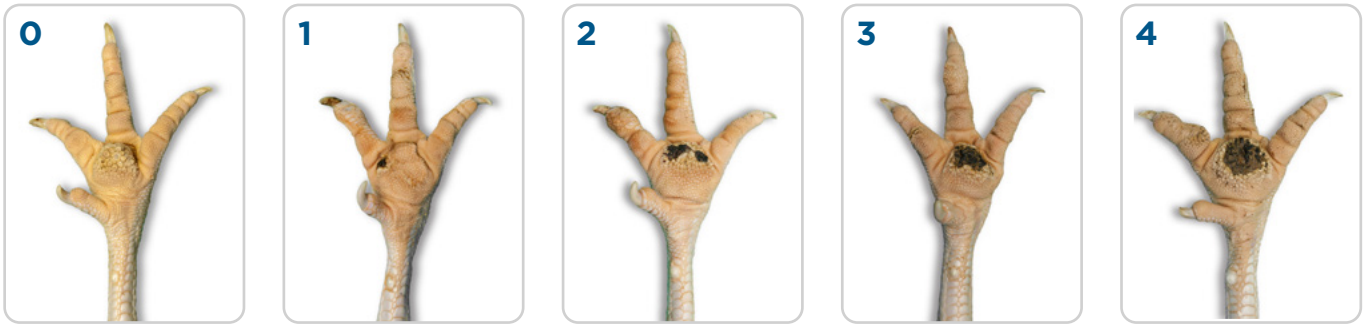
FPD is a common welfare indicator. Genetic selection to improve FPD began in 2008 in broilers and turkeys, by scoring footpads on every pedigree individual and selecting individuals showing a low genetic predisposition to develop FPD. FPD scoring takes place in the pedigree environment and on siblings in the lower hygiene environment, to ensure robustness under field conditions. Wet litter is a key contributor to the incidence of FPD (Mayne *et al.*, 2007). From 2011, starting with turkeys, Aviagen implemented individual water intake measurements using technology similar to its feed stations to identify birds with excessive water consumption which have been shown to contribute significantly to litter moisture. The combination of targeted exclusion of individuals creating wet litter as well as those with a lower tendency to develop FPD is an effective genetic means of improving footpad health of the future population.

Figure 16 shows the trend of FPD improvement in the pedigree program for turkeys. The measurement of FPD was improved in 2018 by adding footpad shape which is very highly correlated to FPD but with around twice the heritability allowing greater levels of progress to be achieved.

Figure 16

Trend graph showing FPD in BUT6 Pedigree birds in the pedigree environment. Scoring: 0=clear, no FPD, 1 = less than 25% of the pad; 2= less than 50% of the pad; 3 = greater than 50% of the pad; 4 = pad and toepads affected. FPD = footpad dermatitis.





Clear, no FPD

Less than 25% of the pad

Less than 50% of the pad

Greater than 50% of the pad

Pad and toepads affected

HEART AND LUNG FITNESS

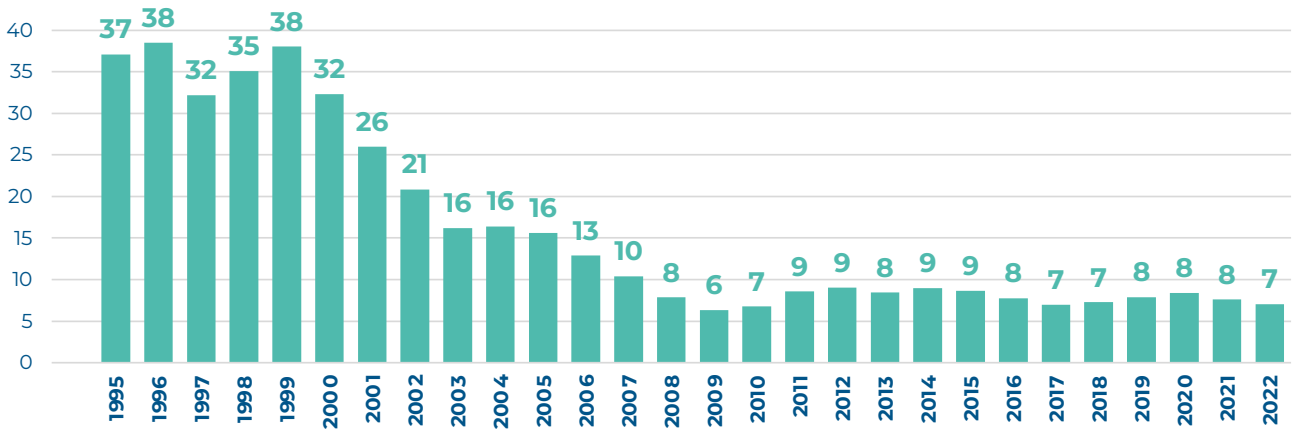
Since 1991, the cardiovascular health of pedigree broilers is evaluated using pulse oximetry to measure the level of oxygen saturation in the blood for each broiler.

This is an important indicator of the susceptibility of a broiler to developing ascites and sudden death syndrome.

Measurements from each bird are linked to their family relatedness information to remove the families that are more susceptible to these issues and thus improve the health and welfare of whole populations. **Figure 17** shows the decline in levels of ascites over the last 3 decades.

Figure 17

Ascites (from 2008 abdominal oedema) related condemnation rates in broilers per 10,000. 1995-2022;. Source: Agriculture and Agri-Food Canada (AAFC), 2023), in: Neeteson-van Nieuwenhoven et al., 2023.



LIVABILITY

Livability is an important trait for all producers for both welfare and sustainability of poultry production. The Aviagen breeding programs target improvements in livability through a number of traits.

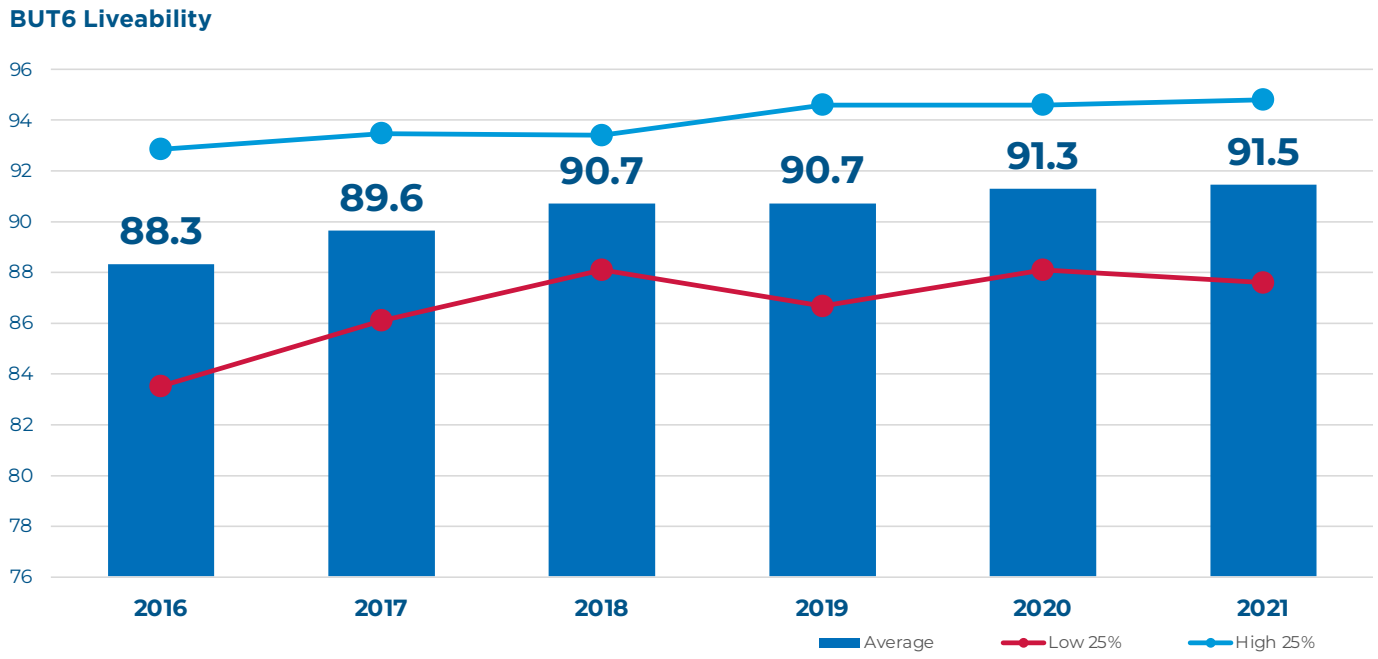
Livability is recorded at all stages of the production cycle as in pedigree and sibling environments. Livability is also indirectly improved through selection for traits like leg health, carcass defects and cardiovascular function.

We record each incidence of livability and link each case through the pedigree to identify any families that may be predisposed to higher livability .

By including this as a trait within our balanced selections, our populations continue to see improved livability each year (**Figure 18**). In broilers, the annual livability improvement through genetic selection in our programs is around 0.05 to 0.10 per year.

Figure 18

Field livability of BUT6 commercial males from a European turkey producer. Chart shows average livability and the average of the highest and lowest 25% of flocks for each year. Results from approximately 170 flocks each year



CONCLUSION

Animal welfare and sustainability have been a cornerstone of Aviagen's selection processes in broilers and turkeys for decades. Improvements in the genetic potential of pedigree lines will continue to benefit current and future generations of commercial birds in production environments globally.

Through steady and carefully balanced selection for better welfare outcomes alongside productivity and reduced resource use, Aviagen have developed breeding programs that produce highly efficient birds which perform well in a variety of environments and maintain excellent standards of health and welfare.

Aviagen is continually looking to enhance rates of improvements in exiting traits and develop novel traits to address industry and stakeholder needs. Research and development is focussed on optimizing the breeding programs and implementing selection tools with the greatest selection accuracy.

Maintaining a broad gene pool and keeping the diversity within and between pedigree populations is also a priority upon which depends the current and future range of poultry breeds. A high-level research and development team comprising personnel with many decades of bird care and handling and solid scientific foundations is at the core of Aviagen´s long-term strategy.

Aviagen is highly committed to deliver continuous progress on balanced breeding, enhancing welfare, robustness and efficiency of its birds.

In line with Aviagen's long-term tradition, breeding goals will continue to be refined after careful consideration of market requirements and the feedback coming from customers and society in the wider sense. This will ensure that future needs of any market segment can be met in a responsible and holistic way.

For most traits, the variation observed that is due to genetic variation is a small proportion of the overall variation observed. Management factors often have a large bearing on the welfare and production outcomes for a flock.

Therefore, Aviagen provides producers with an extensive range of up-to-date management advice to ensure all birds receive the best management, nutrition and veterinary care that will enhance welfare further and optimise performance.

REFERENCES

Agriculture and Agri-Food Canada. Chicken and turkey condemnations. Poultry Condemnation Report by Species for Federally Inspected Plants. Government of Canada. Gouvernement du Canada. **Available online** (accessed 20 January 2023).

Avendaño, S., Neeteson, A.M. and Fancher, B. (2017). Broiler breeding for sustainability and welfare–are there trade-offs?. In Proceedings Poultry Beyond 2023, 6th International Broiler Nutritionists' Conference, Queenstown, New Zealand (16-20 October) 17pp.

Aviagen. (1972). Ross 308 Broiler Performance Objectives. Publisher: Aviagen, Newbridge, United Kingdom.

Aviagen. (1994). Ross 308 Broiler Performance Objectives. Publisher: Aviagen, Newbridge, United Kingdom.

Aviagen. (2003). Ross 308 Broiler Performance Objectives. Publisher: Aviagen, Newbridge, United Kingdom.

Aviagen. (2022). Ross 308 Broiler Performance Objectives. Publisher: Aviagen, Newbridge, United Kingdom. **Available online** (accessed 14 July 2023).

Aviagen Turkeys. B.U.T. 6. (2012). Commercial Performance Objectives. Publisher: Aviagen Turkeys, Tattenhall Cheshire, United Kingdom.

Aviagen Turkeys. B.U.T. 6. (2020). Commercial Performance Objectives. Publisher: Aviagen Turkeys, Tattenhall Cheshire, United Kingdom. **Available online** (accessed 14 July 2023).

British United Turkeys (B.U.T.). (1993). Big6 Commercial Performance Objectives. Publisher: British United Turkeys, Warren Hall, Broughton, Cheshire, United Kingdom.

British United Turkeys (B.U.T.). (2002). Big6 Commercial Performance Objectives. Publisher: British United Turkeys, Warren Hall, Broughton, Cheshire, United Kingdom.

Burnside, T.A., and Ralph, J.H. (2017). Updates on Welfare and Sustainability for the European Turkey Industry. 15th Turkey Science and Production Conference, Chester, United Kingdom Turkeytimes. 44-51. **Available online**

DEFRA. (2010). Poultry in the United Kingdom. The Genetic Resources of the National Flocks. **Available online**

Howie, J.A., Tolkamp, B.J., Bley, T. and Kyriazakis I. (2010) Short-term feeding behaviour has a similar structure in broilers, turkeys and ducks. Brit. Poult. Sci. 51(6):714-724. doi: doi.org/10.1080/00071668.2010.528749.

Jones (2008). A study of the scope for the application of research in animal genomics and breeding to reduce nitrogen and methane emissions from livestock-based food chains. Appendix2. DEFRA Project AC0204

Kapell, D. N., Hill, W. G., Neeteson, A. M., McAdam, J., Koerhuis, A. N., & Avendaño, S. (2012). Twenty-five years of selection for improved leg health in purebred broiler lines and underlying genetic parameters. Poultry science, 91(12): 3032–3043. doi.org/10.3382/ps.2012-02578

Kapell, D., Hocking, P.M., Glover, P.K., Kremer, V.D., & Avendaño, S. (2017). Genetic basis of leg health and its relationship with body weight in purebred turkey lines. Poultry Science, 96, 1553 - 1562. doi.org/10.3382/ps/pew479 .

Mayne, R.K., Else, R.W., Hocking, P.M. (2007). High litter moisture alone is sufficient to cause footpad dermatitis in growing turkeys. Br Poult Sci. 48(5):538-45.

Neeteson-van Nieuwenhoven, A.-M., Avendaño, S., Ralph, J. & Burnside, T. (2023). Improving welfare and sustainability of poultry meat production. In: Proceedings International Poultry Meat Congress. European Association for Animal Production. Ed: Ceylan, N. Antalya, Turkey. 9pp.

Royal Society for the Protection of Cruelty against Animals (RSPCA). (2017). RSPCA broiler breed welfare assessment protocol. **Available online** (accessed 26 July 2023).

Tolkamp, B..J., Allcroft, D.J., Barrio, J.P., Bley, T.A., Howie, J.A., Jacobsen, T.B., Morgan, C.A., Schweitzer, D.P., Wilkinson, S., Yeates, M.P. and Kyriazakis, I. (2011). The temporal structure of feeding behavior. Am J Physiol Regul Integr Comp Physiol. 301(5)2: 378-93. doi: doi:10.1152/ajpregu.00661.2010.

17.0