Tomorrow's turkeys – breeding to improve turkey health and welfare

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Highlights

- Health and welfare are increasingly important pillars in turkey breeding
- Advances in genomics allow for an increase in accuracy of selection for health and welfare traits
- Corticosterone can reliably be measured in turkey wing feathers **(FCORT)** as an indication of hypothalamic-pituitary-adrenal (HPA) axis activity
- **FCORT** is a heritable trait but further work is needed to understand relationships with robustness and other traits

Introduction

Breeding companies are more proactive in integrating animal health and welfare in their selection strategies for all livestock species *(Flock et al., 2005, Rodenburg and Turner, 2012)*. These selection strategies and decisions are mainly employed at the top of the breeding pyramid benefitting from heterosis or the increase in desired traits in hybrid offspring compared to purebred parents *(Falconer and MacKay, 1996)*. Turkey breeding depends on the selection and maintenance of purebred genetic lines for economically important traits such as growth rate, meat yield, egg production, fertility, and hatchability *(Wood, 2009)*, with more recent interest to also include meat quality traits *(Vanderhout et al., 2018, 2022, Hiscock et al., 2022)* and behaviour traits *(Emamgholi Begli et al., 2019)*. Genetic improvements at the purebred level flow down to the crossbred commercial birds through a series of multiplying generations over approximately four years *(Neeteson et al., 2016)*.

Another important step has been the development and publication of the turkey genome information *(Dalloul et al., 2010, Aslam et al., 2012)* that paved the way for the turkey sector to include genomic-based selection. Genomic-based selection reduces the reliance on phenotypic, pedigree, and progeny information *(Dekkers, 2004)*. It allows for direct selection on traits that are expensive to measure, are only expressed later in life, or can only be collected once the animal is dead (B*aes et al., 2019)*. Genomic selection is used in different livestock sectors and is starting to be more applied to turkey breeding as well *(Abdalla et al., 2019, Emamgholi Begli et al., 2021)*.

These advances in turkey breeding have led to fast-growing birds with heavy breast muscles, but there is increasing attention towards turkey health and welfare from the production sector, the scientific community, and the general public *(Schwean-Lardner et al., 2013, Erasmus, 2018, Bir et al., 2019)*. A balanced breeding goal that accounts for and weighs different objectives is needed to breed robust turkeys. Improving turkey health and welfare through breeding is promising as gains would be cumulative and permanent. However, the difficulty lies in accurate phenotypes that reflect the health and welfare of turkeys and can be collected easily on many birds. Additionally, while selection strategies and decisions are made at the top of the pyramid, it is also important to evaluate the performance of the commercial product to help inform selection strategies, as the environment of commercial birds is often very different from that at the nucleus level. It may be possible to address challenges at the commercial level by changing selection pressures or utilizing novel traits in the pure lines, assuming there is a heritable genetic component to the problem.

The perspective of commercial farmers

When deciding what kind of traits would be important to include in breeding programs, it is imperative to consider the needs or concerns of the sector. *Van Staaveren et al. (2020)* completed a survey of 83 commercial farmers to evaluate what kind of health or welfare issue they considered important. The most frequently selected reasons for culling of turkeys related to leg deformities (68% of farmers) and leg injuries (54% of farmers), but also pecking injuries (38% of farmers) and pendulous crop (25% of farmers) were quite commonly mentioned. While perceived reasons for mortality were often unknown (60% of farmers), when farmers were able to provide a reason it was most often dehydration (43% of farmers) and cannibalism (42% of farmers).

Interestingly, farmers frequently rated the issues as more of a concern for the sector than their individual farm *(Figure 1)*, especially in the case of disease, leg injuries, leg deformities, and breast injuries *(van Staaveren et al., 2020)*. This could relate to the significant impact of these conditions and suggest that tackling these issues through breeding may be beneficial.

Issues of footpad dermatitis and injurious pecking are well-known in turkey production because of their implications for animal health and wellbeing, but also adverse effects on profitability *(Erasmus, 2018)*. Various approaches have been used in turkey production to identify risk factors for footpad dermatitis and injurious pecking injuries *(Sherwin et al., 1999, Moinard et al., 2001, Mayne et al., 2007, Da Costa et al., 2014, Leishman et al., 2021b, 2022a)*. The location of pecking injuries is indicative of the injurious behaviour causing them; pecking injuries to the back/tail area are indicative of feather pecking

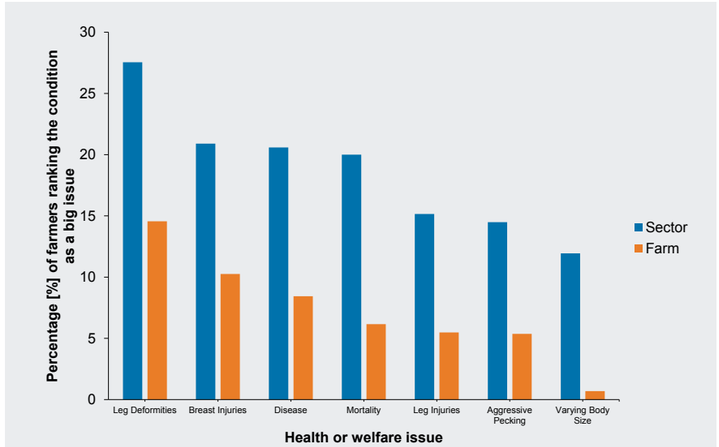

Figure 1: Percentage of farmers indicating the different conditions as a big issue on their farm or for the sector as a whole (adapted from van Staaveren et al., 2020).

while injuries to the head/neck area are indicative of aggressive pecking *(Dalton et al., 2013)*. Turkeys that are victim of feather pecking (i.e., have back/tail injuries) are more likely to have injuries due to aggressive pecking, and also more likely to show signs of footpad dermatitis *(Leishman et al., 2022b)*. The relationships between these different types of injuries require an holistic approach to find solutions. *Leishman et al. (2021b, 2022a)* reported that less than 30% of the variation in prevalence of pecking injuries and footpad dermatitis was explained by investigated on-farm housing and management factors, suggesting that genetics may also play a large role in managing these issues.

Footpad dermatitis is a heritable trait for which genetic parameters have previously been estimated ($h^2 \leq 0.02$: *Quinton et al., 2011*; $h^2 = 0.10–0.15$: *Kapell et al., 2017*). As a trait, footpad dermatitis has already been incorporated in turkey selection strategies *(Neeteson et al., 2016)*. For injurious pecking, the story is more complex. This is due to injurious behaviour depending on the behaviour of individuals and groupmates, and the difficulty in measuring behaviour in large groups of birds *(Dalton et al., 2013, Ellen et al., 2019, van Staaveren and Harlander, 2020)*. However, successful selection for or against feather pecking was achieved in research lines of laying hens *(Kjaer et al., 2001, Rodenburg and Turner, 2012)*, but this has yet to be done on a commercial scale or in turkeys in general *(Dalton et al., 2013)*. These logistic challenges have limited the implementation of behavioural traits for selection. Still, the use of automated sensors combined with developments in genomic approaches is thought to be a promising tool to reduce injurious pecking in poultry *(Ellen et al., 2019)*. For example, several research groups are working on automated systems or machine learning approaches to identify pecking activity, injurious pecking or injuries in turkeys *(Nasirahmadi et al., 2020, Volkmann et al., 2021, Stracke et al., 2022)*, however these require further validation and testing under large-scale conditions.

Other potential novel traits or improved methods?

The idea of robustness, the ability of animals to maintain high production while being resilient to perturbations *(Knap, 2005)*, is also receiving increasing attention *(Star et al., 2008, Leishman, 2021)*. This is extremely complex and can involve reaction norm analysis *(Knap and Su, 2008)* or direct selection for traits related to robustness, for example, selection for leg health *(Neeteson et al., 2016)* or disease resistance *(Jie and Liu, 2011)*. Recent work by *Abdalla et al. (2022)* suggests that reducing susceptibility to pendulous crops in purebred turkeys is possible, as they found a moderate heritability for pendulous crop ($h^2 = 0.17$). As with all novel traits, however, correlations with other traits should be considered before large-scale implementation.

Another consideration has been the genetics of the hypothalamic-pituitary-adrenal (HPA) axis *(Mormède et al., 2011, Mormède and Terenina, 2012)*. The HPA axis plays a major role in the neuroendocrine response to stress as well as energy balance and metabolism through the main end product of corticosterone (CORT) in birds *(Sapolsky et al., 2000, Boonstra, 2004)*. CORT levels have been associated with elements of robustness (e.g., early survival, heat tolerance, disease resistance) in different species *(Gross, 1976, Leenhouwers et al., 2002, Michel et al., 2007)*. Early work showed that there is a genetic component to CORT levels in turkey plasma *(Brown and Nestor, 1973)* and pioneering work by *Bortolotti et al. (2008, 2009)* promoted a more non-invasive way by measuring CORT in feathers (FCORT) that avoids some issues typical with, e.g., blood sampling *(Romero and Fairhurst, 2016)*. Since CORT plays a key role in basal energy balance, the response to perturbations, and has implications for health and wellbeing issues related to robustness, incorporating a trait like FCORT into turkey breeding strategies may be beneficial. While still in initial phases of research, methodological and biological validation have been performed highlighting the importance of understanding which feathers to select due to CORT being deposited during their growth and consistency in using the same feather once this selection is made *(Figure 2, Leishman et al., 2020a, b, 2021a)*.

FCORT was found to be heritable ($h^2 = 0.21$) with negative genetic correlations to other production (e.g., breast meat yield) but positive genetic correlations to liveability traits (e.g., walking score) – though these results should be validated with a larger sample size *(Leishman, 2021)*. Finally, it should be acknowledged that FCORT itself may also not be the most practical or cost-efficient approach, and so other proxy such as fault bars are being explored *(Leishman, 2021)*.

We also observed initial indicators that FCORT was associated with walking score in turkeys *(Leishman, 2021)*. Walking ability in poultry is an important welfare indicator, and of economic relevance because of

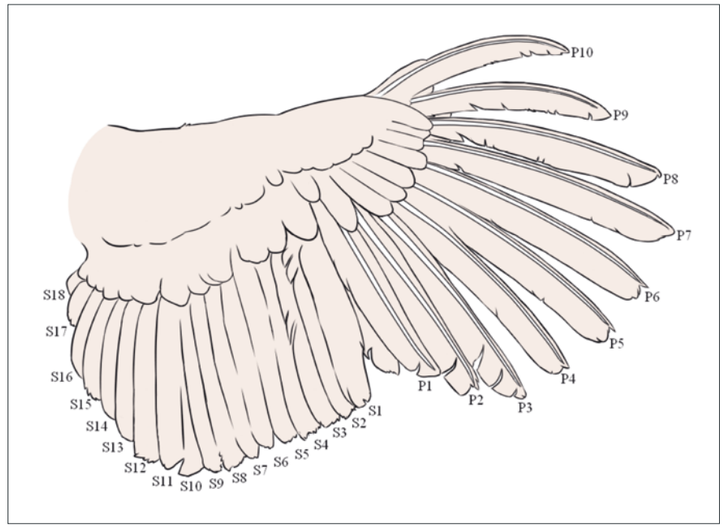

Figure 2: Schematic of turkey wing feathers indicating the primary (P) and secondary (S) flight feathers. (Picture: Garant, University of Guelph).

benefits for feed efficiency, skeletal health, reduced cannibalism, and improved quality at processing (*Oviedo-Rondón, 2007*). Walking score is already included as a trait in selection programs but can only be measured late in life. Improvements in statistical modelling is another avenue through which the turkey breeding sector can make advances in turkey health and welfare. In particular, the application of single-step genomic selection can increase the accuracy of prediction, not only for traditional production traits (e.g., feed conversion ratio, residual feed intake, body weight, breast meat yield), but also for walking score (+16%, *Abdalla et al., 2019*) and novel traits such as pendulous crop incidence (+46%, *Abdalla et al., 2022*) and egg-laying behavioural traits (*Emamgholi Begli et al., 2019*). Genomic information can also be used to assess levels of inbreeding more accurately than using pedigree information alone (*Adams et al., 2021*). Finally, other approaches such as transmission ratio distortion were recently used to identify lethal alleles which opens the possibility of reducing mortality in turkey breeding (*Abdalla et al., 2020*).

Conclusion

Turkey breeding is only just starting to reap the benefits of the advances in genomic selection. With increases in accuracy of breeding values, we can improve the ability to estimate the genetic merit of turkeys. Improvements in traits related to liveability, disease resistance, fertility, health and welfare could considerably advance turkey breeding programs.

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