New breeding goals: adaptability, robustness and biological efficiency

Poultry meat breeding objectives have evolved extensively over the last 50 years. In the 1950s, productivity was the main focus. Currently, a multi-dimensional breeding goal with an increased emphasis on biological efficiency, reproduction, adaptability, welfare and robustness, with focus on sustainability, product quality and health is used.

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This increased dimensionality allows a holistic view of the bird by simultaneously improving antagonistically related traits, for example between growth and skeletal strength or yield and meat quality.

The future outlook for the global poultry meat market indicates:

- ● Poultry will contribute about 50% of the additional meat production and consumption in the next decade.
- ● Poultry will constitute the largest share of additional per capita consumption at the global level.
- ● Developing countries will contribute over 70% of the additional global meat production (OECD-FAO, 2019).

This outlook is offset by environmental sustainability concerns about natural resources availability (land and fresh water) and environmental impact. From a breeding perspective, this means an increased focus on environmental adaptability, robustness and biological efficiency.

The key components of the breeding goal related to environmental sustainability are the genotype and environmental interaction (GxE) and the feed and water biological efficiency. This article focuses on the genetic basis of biological efficiency, the extent of GxE and the contribution of genomics information to genetic improvement in modern broilers and turkeys.

Adaptability and robustness: genetics by environmental interaction

A key component of the success of a global breeder is to deliver genetic potential that performs optimally in a wide range of environmental circumstances. The genetic correlation between the same trait across different environments (GxE) is the key parameter that regulates the robustness or sensitivity of the genetic potential of a specific trait to the environment to which it is exposed.

An effective strategy to handle the GxE in both broilers and turkeys is by selecting on data recorded in contrasting environments which are aimed at representing a wide range (top and bottom quartile) of commercial production environments.

In this set-up, selection candidates are recorded in high biosecure and high input environments (HI) aiming to maximise expression of genetic potential, while their sibs are tested in low input environments (LI) aimed to improve robustness through a challenge on gut health, digestive, and immune function along with liveability, growth, and uniformity.

No prophylactic use of antibiotics is applied in either environment. Fig. 1 shows the ranges of heritability (h2) and genetic correlation (GxE) between environments for live weight (LWT) and liveability (LIV) for a range of chicken and turkey lines within the Aviagen breeding programme.

The h2 of both LWT in broilers (35 days) and turkeys (18 weeks) ranges between 0.2 to 0.5 in both HI and LI environments indicating ample opportunities to improve this trait in each environment.

The GxE for LWT in broilers (0.4-0.7) has a lower range than in turkeys (0.7-0.88). As expected, the h2 of LIV is much lower compared to LWT. Broilers have a wider range of h2 in the LI environment. The GxE range for LIV is similar in both broilers and

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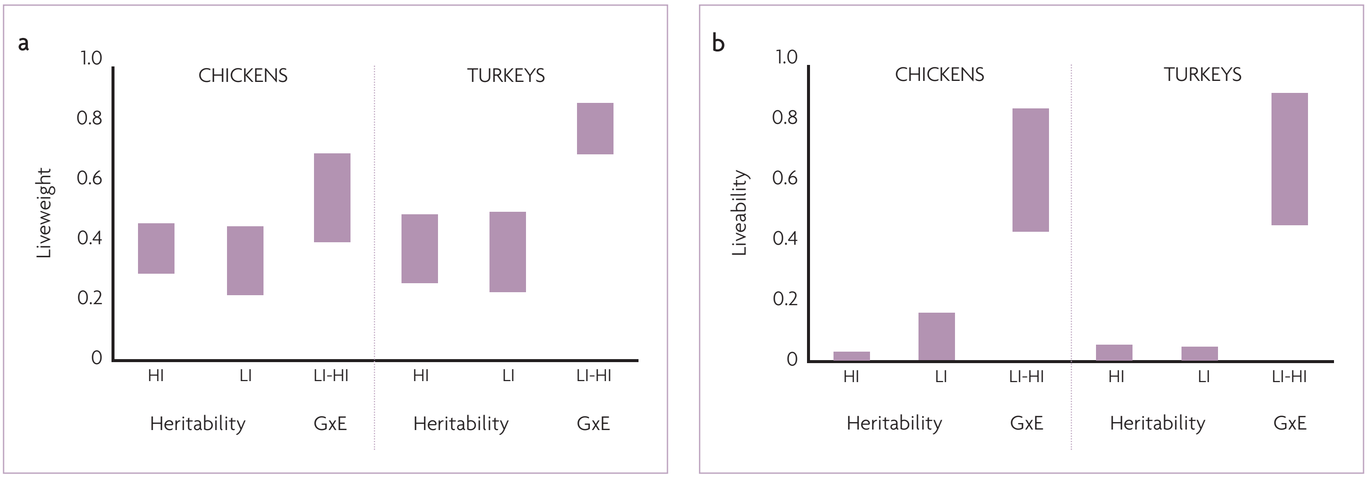
Fig. 1. Heritabilities and genetic correlations for live weight (a) and liveability (b) in high input (HI) and low input (LI) environments in broiler and turkey lines from the Aviagen breeding programme. GxE = Genetics by Environment Interaction.



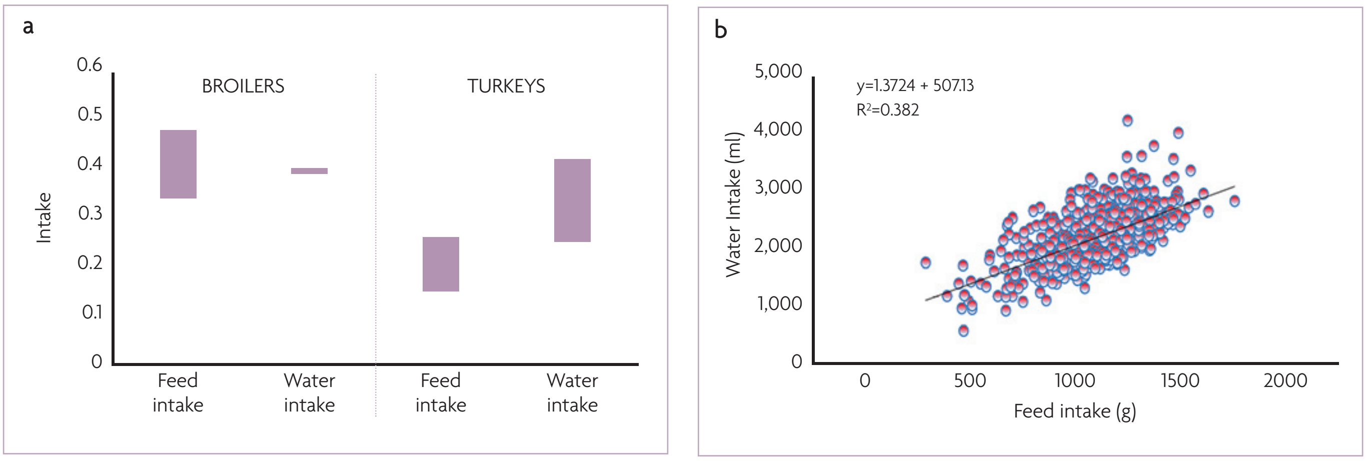


Fig. 2. Heritabilities for feed intake (FI) and water intake (WI) for broiler and turkey lines from the Aviagen breeding programme (a) and relationship between WI and FI in broilers (measured from 14 to 35 days) (b).

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turkeys ranging between 0.45-0.90. Overall, there is a wide range of genetic variation in each environment, but crucially, to improve environmental adaptability and robustness, the same biological trait should be treated as two different genetic traits in the breeding goal to account for GxE.

The improvement of adaptability and environmental robustness arises from identifying genetic lines and families within lines that perform well across environments.

Gene expression can be a useful tool to ascertain the underlying genetic basis of GxE through linking the physiological activity of a bird with markers of immune and cellular functions in a range of somatic tissues. When birds of the same genotype are sampled in the HI and LI environments, differential gene expression can be seen for a range of immune pathways and cellular activity.

In the LI environment a twofold increase in expression of immune genes, such as IL-4 and IL-18, can be seen in tissues such as the bursa of Fabricius, the spleen and the ileum. In birds raised in the LI environment there are also increased expressions of genes associated with physiological stress challenge such as heat shock proteins which provides further information on the biology of the birds in contrasting environments.

Gene expression data can be correlated to specific biological traits or be used to highlight the extent at which specific families can tolerate changes in environmental conditions.

Biological efficiency – feed and water efficiency

With the continuous globalisation of poultry meat production and the concerns of limited natural resources, genetic improvement of biological efficiency will continue to be a central focus in broiler and turkey breeding goals.

The use of electronic feeders and drinkers, named feed and water stations, combined with RFID (Radio Frequency Identification) transponders allowing tracking of individual broilers and turkeys feeding and drinking patterns have enabled the estimation of the genetic basis of both feeding and water efficiency.

Fig. 3. Relationship between kidney nephron diameter (um) and water intake (WI) adjusted for live weight (adj. water intake).

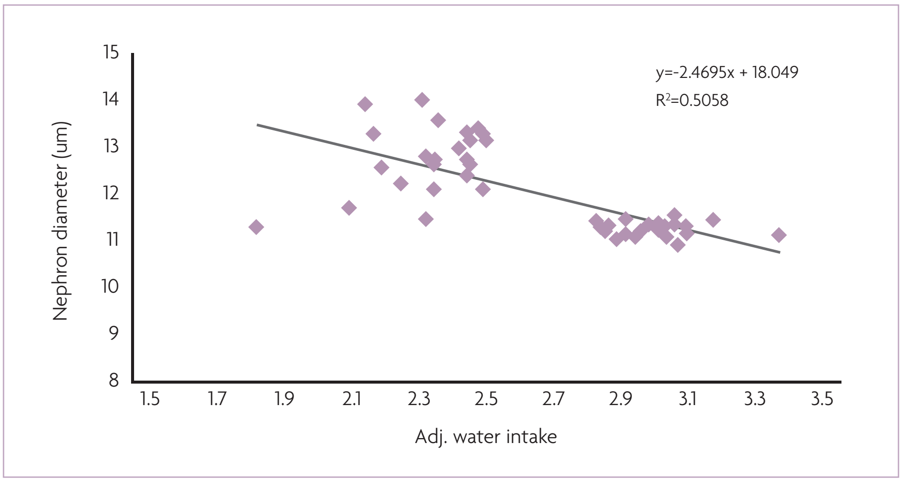

Fig. 2(a) shows the h2 of feed intake (FI) and water intake (WI) for a range of broiler and turkeys lines in the Aviagen breeding programme. The h2 for FI in broilers ranges from 0.34-0.48, while in turkeys from 0.15-0.26.

The lower h2 range in turkeys could be related to the very contrasting testing age ranges, broilers up to 35 days and turkeys up to 18 weeks. For WI the h2 in broilers and turkeys ranges between 0.27-0.47 which is a much narrower range in broilers.

These ranges indicate that there is a wide range of genetic variation available in modern broilers and turkeys for the improvement of biological efficiency.

Fig. 2(b) shows the phenotypic relationship between WI and FI for broilers between 32-42 days of age. It is very interesting to note the wide range of WI observed for a given level of FI.

For example, for FI around 1,000g, there are broilers drinking between 1,000-3,000ml of water. A key component of the selection strategy for overall biological efficiency consists on selecting out birds which consume excessive levels of water at the same level of FI.

Birds with excessive levels of WI are also likely to have poorer gut function and health, make the litter wetter, contribute to a higher incidence of contact dermatitis in the flock and thus have lower welfare, and will also have a more negative impact on the environment.

Understanding physiological differences

In an effort to explain the physiological differences between high and low water consuming birds, we evaluated differences in kidney structure of broilers drinking contrasting amounts of water.

Fig. 3 shows that birds drinking less water had a larger kidney nephron diameter than birds drinking more water.

The relationship indicates that selection for water intake will improve the modern broiler's ability to retain water, which is beneficial for environmental sustainability and also for welfare through improved litter quality and associated foot pad health.

The use of feed and water stations has also allowed us to study the genetic basis of feed and water behaviour. Howie et al. (2010) found that broilers, turkeys and ducks share the same structure of short-term feeding behaviour which is regulated by levels of satiety. This was also observed when comparing broilers, turkeys and ducks to cattle, pigs, dolphins and rats.

In terms of the genetic basis of feeding behaviour in broilers, Howie et al. (2011) found moderate to high h2 for feeding behaviour ranging between 0.24-0.57.

In turkeys, Rusakovica et al. (2017) found a broader range of h2 for water behaviour ranging between 0.09-0.50. Interestingly, both studies found low correlations between feeding and drinking behaviour traits and performance traits.

Given this low correlation, directional selection for biological efficiency is independent from the expression of normal feed and water drinking behaviour. Broilers and turkeys express a wide range of drinking behaviour strategies to achieve a given level of biological efficiency which is a critical component of their adaptability to a wide range of environments and production systems.

The genomics contribution

The use of genomics information for predicting breeding values in broilers and turkeys is part of the routine operation of Aviagen's breeding programmes and has been widely reported.

The availability of 50,000 SNP panels for broilers and turkeys allows important increases in the accuracy of breeding value prediction. Fig. 4 shows that genomics contributes to extra selection accuracy for LWT, FI and feed conversion rate (FCR) ranging from 7-16% in broilers and turkeys. The lower extra accuracy for LWT is expected as every selection candidate has its own phenotype available hence the contribution from genomics is marginal.

Greater contributions to selection accuracy are observed for FI and FCR which arise from increased accuracy in individuals with no phenotypic record.

Current estimates of annual genetic improvement in FCR for chickens and turkeys are 30-45g FI/kg LWT respectively. The increased accuracy achieved through genomics represent an additional reduction of 4g and 7g FI per year.

These significant improvements in biological efficiency will result in increased profitability and sustainability of the poultry industry as a whole.

Conclusions

Multi-environment selection is an effective strategy to improve biological efficiency, environmental adaptability and robustness. Robustness and the ability to adapt to the local environment is a key attribute of the modern broiler and turkey. It also allows the generation of novel phenotypes which will contribute to further elucidate the genetic basis of environmental adaptability.

The combination of feed and water efficiency phenotypes will allow improvement of overall biological efficiency which will have a direct impact on the sustainability of the poultry industry globally. The use of genomics information opens new opportunities to further increase selection accuracy in all traits of the breeding goal.

Collectively, the multi-faceted strategies for genetic improvement discussed in this article support the significant and sustainable further anticipated growth of poultry meat in the future diet of people around the globe. ■

References are available
from the author on request

Fig. 4. Improvements in breeding value prediction accuracy of LWT, FI and FCR from the use of genomics information in broilers and turkeys.