Genetic Parameters of Feed Efficiency Traits in the Turkey (*Meleagris gallopavo*)

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Introduction

The ability of an animal to utilize feed is of interest as it has a large influence on the cost of production in livestock industries. Feed represents two thirds of the total costs in a poultry production system and consequently it would be valuable to identify animals that eat less but perform at the same level as their contemporaries. Improving profitability by reducing the amount of feed without a correlated decrease in performance levels is therefore a primary motivator to improving the feed efficiency of turkeys. Feed efficiency, or feed conversion, has therefore been a dominant trait in the selection indexes of primary poultry breeders for a significant amount of time.

There are a number of ways to asses feed efficiency, such as a feed conversion ratio (FCR) or residual feed intake (RFI). FCR represents the relationship between the amount of feed consumed and weight gain. Genetic selection programs as well as management have improved FCR in the turkey by approximately 20% since 1966 (Havenstein et al. (2007)). In the development of a selection index the correlations between feed efficiency and other economically important production traits should be considered. These relationships impact overall progress in a selection program as genetic correlations determine whether progress in one trait is beneficial to or slows progress in another.

 RFI attempts to isolate a measure of biological efficiency from the energy required for growth and production. RFI is estimated as the difference between actual feed intake and a predicted feed intake based on body weight and growth (van der Werf (2004)). RFI has a moderate heritability value in poultry making genetic selection possible to improve the trait (van Bebber et al. (1994)), however, specific parameters for the turkey are not as widespread. Thus, there is interest to investigate RFI and FCR in the turkey to determine the heritabilities and genetic correlations with production traits for incorporation into selection indexes.

Material and methods

Turkey population. Toms from a male primary breeder turkey line (n = 16 412) with data collected over a 10 year period and pedigree information (28 464 relatives of the birds with records) were utilized. Rearing until 14 weeks of age was under a standard commercial production environment and feeding regime. At 14 weeks of age, the toms were placed in individual cages to acclimatise. Feed intake, body weight and weight gain were measured over a 4-week period from 15 – 19 weeks of age. During this period toms had *ad libitum* access to feed.

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Data analysis. FCR was calculated as the ratio of feed consumed to weight gain and this measurement was adjusted using a regression approach to remove the effect of body weight. To calculate RFI, expected feed intake was calculated as a multiple regression in which observed feed intake was the dependent variable. Two regressions were tested with weight gain and either 15-week weight or metabolic mid-weight as the dependent variables. Metabolic mid-weight was calculated as the average weight over the test period to the power of 0.75. The R-squared value was higher when the regression was on 15-week weight and weight gain and accordingly regression coefficients from this model were used to estimate RFI as:

$RFI=FI_i+(\mu+b_1BWStart_i+b_2WG_i)$

where FI_i represented feed intake over the test period, μ represented the average feed intake, and b_1 and b_2 represent the partial regression coefficients on 15-week body weight (*BWStart*) and weight gain (*WG*), respectively. Phenotypic averages and standard deviations for the measured traits are shown in Table 1. Data exceeding 3 standard deviations from the mean were removed as outliers for each trait and the remaining 15 831 records with included observations for all traits were used for the genetic analysis.

Table 1: Phenotypic means and standard deviations of residual feed intake (RFI), feed conversion ratio (FCR), cumulative feed intake (FI), body weight at 15 weeks (BWStart) and weight gain (WG) during a 4 week feeding trial

Traits	Units	Mean	Standard Deviation
RFI	kg	0	2.21
FCR		2.95	0.39
FI	kg	18.56	3.50
BWStart	kg	13.58	1.46
WG	kg	6.35	1.60

Heritabilities, phenotypic, and genetic correlations were estimated using ASREML (Gilmour et al. (2002)). The model for all traits was: *Trait = Hatch + Animal + e* where *Trait* represents RFI, FCR, FI, BWStart, or WG, *Hatch* was a fixed contemporary group effect adjusting for the common environment influencing a group of birds hatched on the same date and managed in the same contemporary group, *animal* represents the random additive genetic effect, and *e* is the residual random effect. The random effects were assumed to be normally distributed with a mean of zero. The variance of the random effects was $A\sigma^2_a$ and $I\sigma^2_e$ for the animal and residual effects, respectively, where A represents the additive genetic relationship matrix. Estimates of heritabilities were calculated based on a single trait model and phenotypic correlations and genetic correlations were estimated pair wise in bivariate models.

Results and discussion

The results are shown in Table 2. The heritabilities of RFI, FCR, FI, and WG were similar to estimates in broiler chickens (van Bebber et al. (1994); Gaya et al. (2006); Melo et al. (2006)). The heritability of 15-week body weight also agreed with realized heritability

estimates for 16-week body weight in a turkey line selected for this trait (Nestor et al. (2000); Nestor et al. (2008)). The heritability of FCR was higher than that estimated on broilers (van Benner et al. (1994); Melo et al. (2006)). This was most likely due to the adjustments made in the present study for body weight compared to the basic ratio of feed intake to weight gain in the literature. A turkey's feed intake and weight gain are not linear throughout the growing phase and accounting for body weight may remove a portion of this confounding effect.

Table 2: Heritabilies, phenotypic and genetic correlations between residual feed intake (RFI), feed conversion ratio (FCR), cumulative feed intake (FI), body weight at 15 weeks (BWStart) and weight gain (WG) during a 4 week feeding trial[α]

Traits	RFI	FCR	FI	BWStart	WG
RFI	0.22±0.02	0.91±0.00	0.47±0.01	0.09±0.01	-0.23±0.07
FCR	0.80±0.02	0.24±0.02	0.55±0.01	- 0.04±0.01	-0.01±0.01
FI	0.53±0.05	0.28±0.06	0.21±0.02	0.41±0.01	0.55±0.01
BWStart	0.17±0.06	- 0.07±0.06	0.67±0.04	0.35±0.02	0.17±0.01
WG	-0.23±0.07	-0.24±0.07	0.28±0.06	0.41±0.06	0.15±0.02

[α]Heritabilities (s.e.) on the diagonal, phenotypic and genetic correlations above and below the diagonal, respectively.

The proportion of variation in actual feed intake explained by the regression on 15-week weight and weight gain was 60% ($R^2 = 0.60$). This indicates that RFI may account for up to 40% of the variation in turkey feed intake. The standard deviation of RFI was 2.21 kg and the trait had a moderate heritability value of 0.22, similar to both FI (0.21) and FCR (0.24). The variation in the trait as well as the level of genetic regulation indicates that selection pressure can be placed on RFI to improve the trait in a turkey population.

Ideally, RFI is a measure of feed efficiency independent of production. Body weight and weight gain were used in the current analysis to adjust for production levels and the linear regression resulted in a phenotypic independence of RFI from its body weight component trait. There were, however, moderate genetic correlations between WG and BWStart with RFI. RFI can only be genetically independent of production traits when the genetic regression is equal to the phenotypic regression, which does not appear to be occurring in the turkey population (van der Werf (2004)). As a result, selection on RFI may have an impact on the genetic progress of weight gain and body weight. Additionally, not considered here were the production traits related to body composition such as breast meat yield. These additional traits should also be considered prior to implementation in a breeding program as important genetic relationships with body conformation traits have been observed in other species (Schenkel et al. (2004); Montanholi et al. (2009)).

The high positive genetic correlation between RFI and FCR can be expected given the inherent relationship between the traits and based on results from other species (Schenkel et al. (2004)) (Table 2). A negative correlation (-0.24) between FCR and WG was expected as faster growing birds will have better FCR. This relationship also exists in the chicken and beef cattle with stronger genetic correlations of -0.50 and -0.52, respectively (van Bebber et

al. (1994); Schenkel et al. (2004)). The phenotypic correlations between BWStart and both RFI and FCR were close to zero (Table 2). This was expected as both measures of feed efficiency were adjusted for body weight. The correlation between WG and RFI was -0.23 although a correlation close to zero would have been expected.

These results illustrate the importance of measuring feed intake to improve feed efficiency in a turkey breeding program. Previous research had demonstrated that feed efficiency is not important to include in a selection index as the accuracy of the index does not increase above an index that includes accurate measures of the component traits of feed intake, body weight, and growth (van der Werf (2004)). Genetic improvement for efficiency can be accomplished by including feed intake or an efficiency trait in a selection index, with the appropriate parameters as presented here. Measures such as RFI or FCR can be considered independently, unlike feed intake, which is difficult to interpret as a standalone trait independent of growth rate and body size. As a result of the moderate heritability of feed efficiency traits in the turkey and the genetic correlations to feed intake, weight gain, and body weight, selection programs incorporating either feed intake and the efficiency constituent traits or a direct measure such as RFI or FCR will result in genetic progress for efficiency.

Conclusion

Measures of feed efficiency, such as RFI or FCR, can be useful to determine the underlying traits which are components of a turkey's feed intake and efficiency. This information can then be utilized by incorporating the constituent traits into a selection index to improve the feed efficiency of the population. The moderate heritability values of RFI and FCR in the present study indicate that a selection program incorporating feed intake, body weight, and weight gain can be used to increase the feed efficiency of turkeys, thereby reducing the cost of production.

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