Genetic parameters of feeding behaviour traits in parental lines of a mule duck

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Abstract

Automatic feeders were used to characterize the feeding behaviour traits of two populations of ducks (White Pekin and Muscovy). In addition to feed conversion ratio, six phenotypes were derived at the scale of the day and the meal and genetic parameters were estimated. Feeding rate in the Pekin population was twice as large as in the Muscovy population (19 g/min vs. 9 g/min). Feeding traits exhibited moderate (0.38) to high (0.67) heritabilities. A similar pattern of correlations could be observed between these traits in the two populations. Feed conversion ratio did not show any remarkable correlation with feeding traits in the Pekin line, except with daily feed intake, but was negatively correlated with the number of meals and meal feed intake in the Muscovy population (0.68). Further studies will be needed to decipher how these traits can be incorporated in breeding programs without impairing ducks' abilities to produce fatty liver.

Introduction

The mule duck contributes to more than 90% of the production of French fatty liver. It is a sterile hybrid obtained by crossing common duck females (*Anas platyrynchos*) and Muscovy drakes (*Cairina moschata*). Selection to improve fatty liver production is carried out on its parental populations, and only limited knowledge is available about the relationships between parental and crossbred traits. In addition, as recording individual feed intake in both parental populations is still a challenge, feed efficiency remains poor. We set up a design of purebred ducks to investigate detailed feeding traits to improve feed efficiency. We computed feeding behaviour traits using automated feeders (Bley and Bessei, 2008) and estimated genetic parameters for these traits in the parental populations, and their relationships with feed efficiency.

Materials & Methods

The present study was conducted in agreement with the 2010/63/EU regulation for use of animals for research purposes. Animals were bred at the INRAE Duck farm (UEPFG, Benquet, France) which has been approved for animal experimentation (C40-037-1).

Birds and housing. Three successive generations of animals were produced in a dam White Pekin (PEK) common duck line and in a sire Muscovy (MUS) line. Electronically tagged animals were reared up to the age of 7 (PEK) or 8 (MUS) weeks in a 96 m² pen equipped with 6 automatic feeders similar to those used by Basso *et al.* (2014), including animal weighing at each visit. To facilitate duck management, the area was divided in two parts with a barrier, so each bird had effective *ad libitum* access to 3 feeders. In the PEK line, we reared 273 males and 467 females, while only males (n=460) were studied in the MUS line.

Data acquisition. The date and time at the beginning and end of each visit to the feeder was recorded. Animal weight and feed consumption were recorded for each visit. Feeding behaviour traits were then computed. Daily Feed Intake (DFI) and Daily Feeding Time (DFT) definitions are straightforward. Feeding Rate (FR) was computed as the ratio of feed intake over feeding time for each visit and averaged over the whole period. Following Howie et al.'s (2009) method 3 to compute the so-called "meal criterion", visits were aggregated into meals in order to allow for reliable comparisons of feeding behaviours between the two populations. For each duck, visits were defined as part of a single meal if the interval between visits was lower than the meal criterion (1616 s in PEK, 2113 s in MUS). We therefore recorded the number of meals per day (NM), Meal Duration (MD) and Meal Feed Intake (MFI). Feed efficiency was addressed through computation of feed conversion ratio (FCR), as the ratio of total feed intake over the observed weight gain. Average Daily Gain was also computed. We planned to collect and analyse early feed and growth data over a 5-week span (*i.e.* 35 days). In order to limit the occurrence of misidentified visits, which were found numerous at early age in the Muscovy population (Cobo *et al*., 2017), the 35-day control period spanned from Day22 to Day56 in the MUS line, while it started at Day15 and ended at Day49 in the PEK line.

Statistical analysis. The phenotypic comparison of performances between lines was obtained through a linear model accounting for the effects of batch and sex in the PEK line. Then, genetic parameters were estimated using ASRemL (Gilmour *et al*., 2015), with the model:

$$\mathbf{y} = \mu + \boldsymbol{\beta}_{\text{batch}} \; (+ \boldsymbol{\gamma}_{\text{sex}}) + \mathbf{u} + \mathbf{e} \qquad (1)$$

where **y** is the phenotype, μ the general mean, $\boldsymbol{\beta}_{\text{batch}}$ and $\boldsymbol{\gamma}_{\text{sex}}$ are the fixed effects of batch and sex (PEK line only), respectively, **u** the additive genetic effects, and **e** the residual effects. In order to normalize the data, DFT and MD were log-transformed prior to analyses. Values more than three standard deviations from the mean were considered as outliers and removed from the analysis. First, univariate analyses were run to compute heritabilities, and next multivariate models were applied with the same effects to obtain correlations.

Results

The least squares means of the linear model applied for phenotypic line comparisons are given in Table 1. MUS ducks spent daily almost twice as much time feeding as PEK ducks, while the amount of feed they consumed was 12% lower. This resulted in a feeding rate more than twice as great for the PEK ducks, as reported in Cobo *et al.* (2017) where only male data were considered. Compared to the MUS line, the number of meals per day was greater and meal duration was roughly 2.5 times shorter in the PEK line (Table 1). FCR was better (*i.e.* lower) in the Muscovy line. The average daily gain was greater in the MUS line. Yet, it should be remembered that the cut-off points occurred one week earlier in the PEK population.

Table 1. Mean values (Least squares means[1] ± standard error) of feeding behaviour traits.

Trait	PEKIN dam line	MUSCOVY sire line	*P* line
Daily Feed Intake (g/d)	225.00 ± 0.72	200.00 ± 1.16	<0.0001
Daily Feeding Time (s/d)	811.0 ± 12.1	1,595.0 ± 19.5	<0.0001
Feeding Rate (g/min)	18.84 ± 0.15	8.86 ± 0.24	<0.0001
Number of daily meals/d	4.46 ± 0.03	3.54 ± 0.05	<0.0001
Meal Feed Intake (g)	53.2 ± 0.5	59.1 ± 0.8	<0.0001
Meal Duration (s)	191.00 ± 3.98	470.00 ± 6.41	<0.0001
Feed Conversion Ratio (kg/kg)	3.25 ± 0.01	2.56 ± 0.01	<0.0001
Average Daily Gain (g/d)	69.1± 0.24	79.7± 0.38	<0.0001

[1] Least squares means from a linear model including the fixed effect of batch (PEK and MUS) and sex (MUS).

The genetic parameters are displayed in Table 2. In both lines, feeding traits were highly heritable; most heritabilities were higher than 0.5, such as NM and MFI in both populations.

DFT and FR exhibited remarkably high heritability values (~0.6) in the PEK line and around 0.4 in the MUS line.
In PEK, DFI was moderately correlated with MFI and FCR (~0.35), while these correlations were much higher in MUS (~0.70). DFI and MD were positively but not significantly correlated in PEK, while the correlation was positive in MUS. In both lines, DFT and FR were strongly and negatively correlated.

Table 2. Genetic parameters of feeding traits[1] in two duck lines.

	DFI	DFT	FR	NM	MFI	MD	FCR
PEKIN							
DFI	**0.49±0.08**	0.13±0.13	0.12±0.13	-0.15±0.13	0.36±0.12	0.24±0.14	0.33±0.12
DFT		**0.57±0.07**	-0.95±0.01	0.44±0.10	-0.41±0.11	0.61±0.08	-0.05±0.13
FR			**0.61±0.07**	-0.43±0.10	0.48±0.09	-0.57±0.08	0.06±0.13
NM				**0.57±0.07**	-0.95±0.08	-0.42±0.08	-0.06±0.08
MFI					**0.63±0.07**	0.44±0.08	0.10±0.08
MD						**0.48±0.07**	0.01±0.08
FCR							**0.48±0.07**
MUSCOVY							
DFI	**0.54±0.12**	0.23±0.20	0.18±0.20	-0.20±0.18	0.69±0.10	0.50±0.19	0.73±0.15
DFT		**0.43±0.11**	-0.88±0.05	0.52±0.17	-0.10±0.20	0.68±0.12	0.32±0.24
FR			**0.39±0.11**	-0.49±0.18	0.41±0.18	-0.60±0.14	-0.06±0.26
NM				**0.54±0.11**	-0.90±0.04	-0.31±0.18	-0.44±0.21
MFI					**0.67±0.11**	0.44±0.16	0.68±0.16
MD						**0.38±0.11**	0.01±0.08
FCR							**0.25±0.09**

[1]DFI = Daily Feed Intake; DFT = Daily Feeding Time; FR = Feeding Rate; NM = Number of daily meals; MFI = Meal Feed Intake; MD = Meal Duration; FCR = Feed Conversion Ratio.

Discussion

The lower FCR in the MUS line compared to the PEK line was expected, as Muscovy duck is known to produce a leaner meat than the White Pekin and is popular in France for this very reason. Here we studied only males in the MUS population, which is known to exhibit a larger sexual dimorphism for body weight than the PEK line (Tai and Rouvier, 1998). This may contribute to the difference in FCR observed between lines.
We computed a meal criterion within each batch using Howie et al.'s (2009) method 3. This method is based on analyses of the probability for an animal to start feeding given the time since the last visit. This requires finding the nadir of a potentially flat curve, which may be not precisely estimated. For the PEK line, the meal criterion was close to the value of 1,725 seconds found by Howie et al. (2009) in another Pekin duck population.
Our genetic parameters for feeding behaviour traits were in good agreement with those obtained on Pekin broilers by Le Mignon et al. (2017) and Thiele (2017). With a heritability of 0.33±0.11 for feed intake from Day15 to Day42, Zhang et al. (2017) obtained a slightly lower value than ours. Some common features can be noted between our study and that of Le Mignon et al. (2017): (1) Strong negative correlations between the number of meals and the meal size, reflecting that an increase in the meal number does not lead to increased feed intake. If the animal has reached satiety, an increase in the number of meals does not respond to an urge to eat more feed but simply illustrates a variability in feeding behaviour; (2) Moderately negative correlations between number of meals and feeding rate. Birds exhibiting a large FR may swiftly reach satiety and not feel the need to start another feeding sequence; (3) A large and positive,

but significantly different from unity, correlation between meal duration and total time spent feeding, emphasizing an exploitable variability of feeding behaviours. As expected, the latter is also strongly negatively correlated with FR. These three points are also common to our two populations, which might suggest some generality about ducks' feeding behaviours.

For feed efficiency, we focused on FCR. Feed efficiency could also be profitably addressed through the fraction of feed intake that is not explained by maintenance and production requirements, *aka* Residual Feed Intake (RFI). Yet, in the case of fatty duck production, attention should be paid to an adequate derivation of RFI*, i.e.* accounting for body lipid composition, as in Drouilhet *et al.* (2014). With estimates of 0.24 and 0.31, FCR was less heritable in the two Pekin lines studied by Le Mignon et al. (2017) than in our study. In the PEK line, our estimates of the correlation between FCR and feeding behaviour traits are in accordance with those obtained by Thiele (2017) and Le Mignon et al. (2017): they are of low magnitude (<0.20), except for DFI. Conversely, in the MUS line, FCR exhibited strong correlations with DFI and MFI, which may suggest a larger part of feed allocated to growth compared with the PEK line. In addition, in MUS, the negative correlation between NM and FCR, though not accurately estimated, could indicate that selecting for increased number of meals would improve FCR, which contradicts the literature in which efficient animals generally show less feeding activity.

These first genetic analyses of a large design focusing on feeding characteristics of the parental lines of the mule duck show that feeding traits are heritable in these lines, and some are correlated to feed efficiency. Further studies will be conducted to decipher how these traits can be incorporated in breeding programs without impairing the ducks' abilities to produce fatty liver.

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