Genetic parameters of mule ducks' meat and fatty liver performances simultaneously estimated in both parental liness

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Abbreviated title: Genetic parameters of duck meat quality

Summary

Genetic parameters of traits related to hepatic lipid metabolism, carcass composition and products quality of overfed mule ducks were estimated on both parental lines of this hybrid: the "common duck" line (C), for the maternal side and the "Muscovy" line (M), for the paternal side. The originality of the statistical model was to include simultaneously the additive genetic effect of the common ducks and that of the Muscovy ducks, revealing a higher genetic determinism in C than in M. Reported estimates have to be multiplied by 4 to get equivalent to intra-population estimates. Carcass composition traits were highly heritable in C with values ranging from 0.16 for liver weight, 0.24 for carcass weight and 0.25 for abdominal fat weight to 0.32 for breast muscle weight. Heritabilities of technological outputs were higher for the fatty liver (0.17 and 0.09 respectively on C and M sides for liver melting rate) than for the *Pectoralis major* muscle (0.03 either on C or M sides for cooking losses). The liver melting rate was strongly correlated with the liver lipid contents (about +0.90). The fact that most parameters are heritable in both

lines allows more effective schemes of genetic improvement by selection. However, traits such as breast meat quality with low heritability will be hard to improve by selection.

Keywords: genetic parameter – heritability – duck – meat quality – fatty liver

Introduction

In France, fatty liver production has largely increased for the last decade, with an average of about 6% per year. So, today's duck breeding is directed mainly towards the fatty liver production, being fat meat - a co-product of fatty liver. As the quantity of product increased, the quality of products became a crucial point. However, meat quality traits remain expensive and difficult to measure on a large number of overfed animals: very few genetic variability studies have been published on this field. This communication presents relevant genetic parameters of quality of "Foie gras" and "magret" and of kinetics of plasmatic parameters during overfeeding period, in order to ascertain the percentage of the traits determined by genes and also to ascertain the genetic links between traits.

Another feature of this production is that about 95% of duck fatty liver production comes from the mule duck, an infertile hybrid duck between a female common duck (*Anas Platyrhynchos*) and a Muscovy drake (*Cairina moschata*). So, the genetic improvement of mule performances is done by selecting in the parental populations on traits measured on their mule progenies : therefore it is necessary to know the genetic parameters (heritabilities and genetic correlations) in pure parental strains of production traits measured in mule crossbred populations (Marie-Etancelin *et al.*, 2008). By using the model proposed by Lo et al. (1997), as applied by Chapuis and Larzul (2006), we estimated jointly in the 2 parental lines of the mule ducks the genetic parameters of quality traits expressed in the mule performances. This communication aims to compare the estimates obtained on common versus Muscovy lines.

Materials and methods

Animals

The experimental design consisted of 1600 overfed mule ducks, hatched in 2 years, and each year in 2 pedigree batches of 400 ducklings. These mule ducks were hybrids between 2 experimental populations: the dams of the mule ducks, were 382 back-cross (BC) common ducks (*Anas Platyrhynchos*) and the sires of the mule ducks, were 56 Muscovy drakes (*Cairina moschata*). At 80 days of age, the 400 mule ducks were bred in collective pens of 4 or 5 ducks. They were overfed twice a day with a mix (35% corn-flour, 25% corn-grain and 40% water) during 12 days, in two overfeeding series with a crammer by series. At the end of the overfeeding period, the animals were slaughtered after electronarcosis, at 92 days of age. They were bled and plucked, and kept 24 hours at 4°C. Then, they were eviscerated: fatty liver, breast muscle, legs and abdominal fat were excised from the carcasses.

Traits

Three main groups of traits were recorded on all these 1600 mule ducks. First, blood samples were collected 3 hours after the meal at 3 times during the overfeeding period (after the 2^{nd}, the 10^{th} and the 20^{th} meal) to appraise the kinetics of glucose, triglycerides and cholesterol plasma contents during overfeeding. Second, the ducks' overfeeding ability was appreciated by weighing the carcass, the fatty liver, the thigh+shank, the abdominal fat, the *Pectoralis major* (*pm*) muscle and the skin and fat covering the *pm* muscle. Third, the quality of fatty liver and fattened breast muscle were appreciated. The colour L* (lightness), a* (redness) and b* (yellowness) was recorded with a chromameter (CR 300 Minolta). The lipids and protein (only for the liver) contents were estimated by spectrophotometer in the near infra red technique (FOSS NIRSystem) on samples of ground muscle and liver. The technological properties of fatty liver and "magret" were measured by a cooking test: the liver melting rate (percentage of fat releases after sterilisation of 60g of liver) and the muscle cooking losses (at 85°C in a water bath). For muscle, temperature and pH at 20 minutes and 24 hours *post mortem* were measured in the *pm* muscle. Drip losses of *pm* muscles wrapped under a plastic film were measured after 6 days storage at 6°C. Last, tenderness of raw meat was measured with the Warner-Bratzler test: from the force deformation curve, maximal shear force and energy at the maximum were obtained.

Statistical analysis

Genetic parameters were estimated simultaneously in both parental population (common and Muscovy) from mule duck performances (Lo et al., 1997). The model included a random effect, corresponding to the additive genetic values in the 2 parental populations, and a fixed effect corresponding to the combination of year, batch and crammer effects (12 levels). Pedigrees were traced back up to 5 generations of ancestors on both parental lines and consisted on 596 animals in the common line and 201 animals in the Muscovy line. Computations were performed via Gibbs sampling using the program "gibbsf90" (Misztal, 1999).

Results

Tables 1, 2 and 3 give the zootechnical results for the 3 groups of studied traits.

Table 1: Glucose (Gluc), Triglyceride (TG) and Cholesterol (Ch) plasma contents after the 2nd, the 10th and the 20th over-feeding meals.

		N	Mean	Standard deviation	Minimum	Maximum
Gluc	2nd M	1500	2.20	0.27	0.19	3.54
	10th M	1498	2.69	0.56	1.24	6.91
	20th M	1451	3.13	1.08	0.28	9.54
TG	2nd M	1499	4.27	1.00	1.15	6.94
	10th M	1498	4.61	1.08	1.65	11.59
	20th M	1443	4.89	1.52	1.74	20.17
Ch	2nd M	1501	1.71	0.25	0.95	2.88
	10th M	1499	2.11	0.32	1.01	3.14
	20th M	1433	2.46	0.47	0.76	6.56

Plasmatic contents of glucose, cholesterol and triglycerides increased with overfeeding progress. Glucose and cholesterol increase was about 40% from the 2nd to the 20th meal, whereas triglyceride content was more stable with an increase of 15% during the same period. For these 3 blood parameters, the variability of measurements (CV ranging from 16 to 28% on average) increased with overfeeding stage.

Table 2: Overfeeding ability traits

	N	Mean	Standard deviation	Minimum	Maximum
Carcass W (g)	1474	4902	329	3675	5812
Fatty liver W (g)	1492	568	115	195	933
Abdo Fat W (g)	1476	175	29	86	271
pm Muscle W (g)	1476	256	24	147	335
pm skin + fat W (g)	1476	152	20	90	228
Thigh+ Shank W (g)	1476	482	45	351	633

Despite of a low carcass weight of 4.9 kg, due to their dam line, mule ducks produced a fatty liver of about 570 g and a "magret" of 408 g (37% of the weight corresponded to the skin). The carcass weight was more strongly related to the thigh+shank weight (+0.63) than to the liver weight (+0.44). Otherwise, the intra abdominal fat weight was logically linked to the *pm* skin and fat weight (+0.54).

Concerning "Foie Gras" quality, the melting rate, with a mean value of 38.7%, had a particularly high variability (CV of 32%). The liver lipid content was logically very high (80% on average) and few variable, whereas the liver protein content was very low (12%) but quite variable. We confirmed the known correlation between liver weight and melting rate, but with a value of +0.67, lower than previous estimates (+0.97 in Babilé *et al*., 1987; +0.89 in Poujardieu *et al*., 1994). Moreover, we showed that melting rate was better correlated with liver lipid and protein contents (+0.74 and -0.79, respectively), than with the liver weight. The liver lipid and protein contents seemed also to impact on the liver lightness (+0.50 and -0.49, respectively) and the redness (-0.40 and +0.33, respectively).

Table 3: “Foie Gras” (L) and “magret” (M) quality traits

		N	Mean	Standard deviation	Minimum	Maximum
	Melting rate (%)	1472	38.7	12.4	7.4	70.9
	L*	1476	72.4	2.4	59.9	79.0
L	a*	1476	9.2	1.8	4.4	17.5
	b*	1476	31.2	2.9	20.7	40.8
	Lipid content (%)	1476	80.0	2.8	59.1	86.8
	Protein content (%)	1476	12.0	2.3	7.0	28.0
	Cooking losses (%)	1437	22.10	3.84	1.10	34.84
	L*	1476	47.3	3.4	37.6	60.1
	a*	1476	20.4	2.5	9.0	25.8
	b*	1475	7.6	1.5	1.8	12.5
M	Lipid content (%)	1476	4.9	0.7	2.4	7.7
	pH20m	1476	6.01	0.18	5.58	6.96
	pH24h	1476	5.72	0.14	5.21	6.15
	Drip losses (%)	1462	1.58	0.84	0.07	9.19
	Force max (N)	1443	42.5	7.6	20.2	75.5
	Energy at max (mJ)	1442	149.6	40.2	65.0	304.4

Concerning “magret” quality, the pH at 24 h *post mortem* of 5.7 was closed to values observed in poultry meat, but the value of the pH 20 min *post mortem* of 6.0 was low, suggesting a fast *post mortem* fall of the duck meat pH. Drip losses were low (1.6%) and comparable to those obtained in chicken meat (Debut *et al*., 2005). The shearing force and to a lesser extent the cooking losses were higher than those obtained by Larzul *et al*. (2002) on INRA mule ducks. A low and negative correlation (-0.31) connected the cooking losses and the pH 24 h *post mortem*. The average muscle lipid content was 4.9% and presented a low variability. Lastly, the most variable chromatic colour traits were the liver redness and the muscle yellowness. The muscle lipid content seemed to be link with the lightness (+0.41) and the

yellowness (+0.39). For the liver, the lightness and redness were linked with the melting rate (+0.40 and -0.30, respectively) whereas for the muscle, these two colour criteria were linked with the cooking losses (+0.38 and -0.43, respectively).

Figure 1 and table 4 give the genetic parameters for the 3 groups of studied traits on the 2 parental lines.

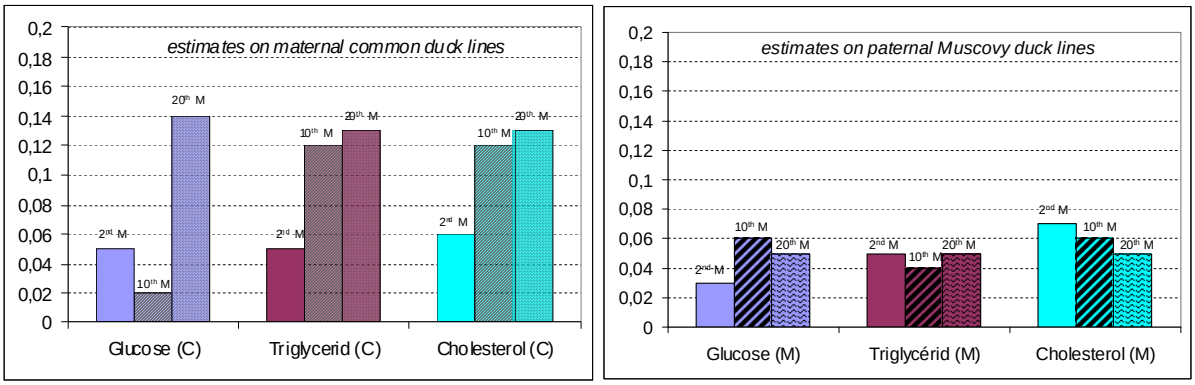
Table 4: Heritabilities(*) of overfeeding ability and meat and fatty liver quality on both parental lines

	Common duck line	Muscovy duck line
Carcass W	0.24	0.07
Fatty liver W	0.16	0.09
pm Muscle W	0.32	0.10
pm skin + fat W	0.17	0.14
Abdo Fat W	0.25	0.11
Thigh + Shank W	0.20	0.07
Melting rate	0.17	0.09
Liver L*	0.11	0.05
Liver a*	0.09	0.06
Liver b*	0.13	0.12
Liver lipid content	0.15	0.06
Liver protein content	0.16	0.10
pH 20min	0.07	0.06
pH 24h	0.02	0.04
Muscle L*	0.12	0.09
Muscle a*	0.15	0.12
Muscle b*	0.13	0.06
Muscle lipid content	0.24	0.13
Drip losses	0.02	0.06
Cooking losses	0.03	0.03
Force max	0.06	0.05
Energy at max	0.04	0.02

Standard errors ranging from 0.02 to 0.04

(*) heritabilities correspond to the ratio between additive maternal/paternal variance (1/4 of the pure line additive genetic variance) and the total variance

Figure 1: Heritabilities(*) of glucose, triglyceride and cholesterol plasma contents according to the overfeeding stage (2nd, 10th or 20th meal) on common and Muscovy ducks parental sides.



Standard error ranging from 0.01 to 0.03

Plasma glucose, triglycerides and cholesterol contents which were measured at the 2nd, 10th and 20th meals have low to moderate heritabilities (Figure 1). For each of these 3 plasmatic traits, the highest heritability was obtained at the 10th overfeeding day (the 20th meal); the heritabilities on the 1st overfeeding day (2nd meal) being always lower than 0.05. Whatever the plasmatic trait considered, the estimates obtained on the paternal side of the mule duck were definitely lower than those estimated on the common maternal side.

After slaughtering (table 4), the heritabilities of carcass weight and of weights of carcass pieces were moderate to high in the common line, ranging from 0.16 (fatty liver weight) to 0.32 (*pm* muscle weight). The *pm* muscle weight was more heritable than the *pm* "skin+fat" weight, itself having a similar heritability to fatty liver weight. The weight of abdominal fat, despite the difficulty of measurement, showed a suggestive heritability. In the Muscovy line, the heritabilities were again low with few variations, ranging from 0.07 (carcass and thigh+shank weights) to 0.14 for the *pm* skin and fat weight. Regarding genetic correlations, fatty liver weight was slightly opposed to the *pm* muscle weight in both parental lines (- 0.16 ± 0.14 and -0.11 ± 0.25 respectively in the common line and in the Muscovy line). The link between fatty liver weight and *pm* skin and fat weight was variable according to the parental lines: -0.29 ± 0.17 in the common line and +0.36 ± 0.23 in the Muscovy line. Last, *pm* muscle weight appeared to be linked to the *pm* skin and fat weight, in the same direction in the common line (+0.51 ± 0.11) and in the opposite direction in the Muscovy line (-0.21 ± 0.30).

Concerning fatty liver quality, the melting rate had an intermediate heritability on the maternal line and a small one on the paternal line (0.17 versus 0.09, respectively). Nevertheless, the genetic correlation between fatty liver weight and melting rate was high, positive and similar for both parental lines: +0.80 ± 0.07 in the common line and +0.78 ± 0.13 in the Muscovy line. The liver lipid content had a comparable genetic variability than melting rate, but we noticed that lipid and protein contents were highly correlated to the melting rate (+0.87 and -0.86, respectively in the common line; +0.94 and – 0.88, respectively in the Muscovy line). For the 3 colour traits (L*, a* and b*), heritabilities were moderate on the common line (from 0.09 to 0.13) and slightly weaker on the Muscovy line (0.05 to 0.12): only the yellowness had a comparable heritability on both parental lines.

Regarding the muscle quality, the muscle lipid content has the highest genetic variability with heritability of 0.24 and 0.13 respectively on the common and Muscovy lines. The 3 colour traits had moderate heritabilities with, once again, highest values on maternal mule duck line. The muscle redness (as for the liver yellowness) had similar heritability estimates on both lines. We have shown that muscle lipid content is genetically linked with the drip losses (-0.81 and -0.72, respectively on the common and Muscovy lines) and with the muscle yellowness (+0.90 and +0.82, respectively on the common and Muscovy lines). For others muscle quality traits (the ultimate pH, the drip losses, the cooking losses and the shearing energy), whatever the lines studied, genetic parameters estimates were very low, and not significantly different from zero.

Discussion

In our approach, the total genetic variability of mule traits was divided into the paternal and the maternal lines, as done by a “father-mother” model in a pure population, the father and the mother taking of account each one a quarter of the additive variance of the trait.

The comparison of estimates obtained on each parental line reveals that the values were systematically higher in the common maternal line. This difference of heritability values according to the transmission way had already been highlighted for carcass and muscle weights by Chapuis and Larzul (2006). It became widespread to all the traits in our study.

We could give 2 assumptions for this genetic determinism disequilibrium between parental lines. Firstly, these lower heritabilities from the Muscovy line is just scarcity of data (there were only 56 Muscovy sires against 382 common dams), which could induce that estimates of heritabilities are poor and tend to zero. Nevertheless, Chapuis and Larzul showed the same tend, with a large number of data. Secondly, we could hypothesize that the higher heritabilities estimates on the common line results from a maternal effect absorption in the additive genetic effect of the female duck: the heritability is then artificially emphasized on the maternal common line. As this explanation couldn't be relevant for all traits, it seems more efficient to select mule ducks traits (as overfeeding ability traits or liver and muscle quality traits) on the maternal common line rather than on the paternal Muscovy line.

To our knowledge, it is the first genetic parameters published for some plasma parameters during overfeeding: the glucose, triglycerides and cholesterol contents were heritable, in particular at the end of overfeeding period, and the level of heritabilities increased with the overfeeding stage.

The study of the genetic correlations between these metabolic indicators and overfeeding ability traits or products quality traits must be thorough. Our fatty liver weight heritability of 0.16 on the maternal line was higher than the estimates of Larzul *et al*. (2002) and Chapuis and Larzul (2006) which amounted respectively to 0.10 and 0.06, but strictly conformed to that estimated by Poujardieu *et al*. (1994). We confirmed the moderate heritability of the melting rate (0.17), as well as the strong genetic correlation between fatty liver weight and its melting rate (+0.89) already estimated by Poujardieu *et al*. in 1994. Moreover, we showed that this correlation was comparable in both parental lines. The *pm* muscle weight and, to a lesser extent, the *pm* skin and fat weight were heritable, but our estimates appeared to be slightly higher than those previously published (Poujardieu *et al*., 1994). On the common line, our correlation between the fatty liver weight and the *pm* muscle weight was similar to that published by these same authors. Lastly, we published new results showing that the abdominal fat weight and the thigh+shank weight were also heritable: it is thus also possible to genetically improve them.

Among product quality traits, the visual appearance was one of the most important traits. We have shown, for the first time in overfed waterfowl, that the 3 colour traits either for the fatty liver than for the *pm* muscle were heritable on the common line, as the liver yellowness and the muscle redness on the Muscovy line. These original results are strengthened by published estimates on broiler meat (heritabilities ranging from 0.25 to 0.35; Debut *et al*. 2005) and

on turkey meat (heritability just below 0.20, Renand *et al*., 2003 ; heritabilities ranging from 0.10 to 0.32, Le Bihan-Duval *et al*., 2003).

Finally we obtained singular results on the *pm* muscle quality. First of all, muscle lipid contents were highly heritable: it could be interesting to estimate the genetic correlation between muscle lipid contents and meat gustative quality. Otherwise, the pH 20 minutes or 24 hours *post mortem* of red duck meat was not heritable, which is conflicting with the poultry literature in which estimates range from 0.30 to 0.49 (Le Bihan-Duval *et al*., 2001, Debut *et al*., 2005), but is confirmed with estimates on bovine red meat (0.11 ± 0.05 for pH 24 hours, Renand, 1985). The genetic determinism of duck meat is more linked with its red colour than in the poultry species. The meat quality appraisal criteria (like texture and cooking losses), usually dependent on the pH and its falling speed, were also very few heritable. This aspect remains to be deepened to confirm the original genetic determinism of duck meat.

Conclusion

Our animal experimental design allowed the genetic parameters estimates on traits whose determinism was not known in overfed duck. Thus, if the overfeeding stage is sufficient, the metabolism physiological indicators during overfeeding are heritable, as well as the meat lipid content or the colour of the fatty liver and the *pm* muscle. The differences between the 2 parental lines estimates remain to be explored.

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