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## Estimation of genetic parameters for growth, carcass and overfeeding traits in a white geese strain

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**Abstract** – In an experimental strain of white plumage geese created in 1989, two experiments were carried out from 1993 to 1995 in order to estimate genetic parameters for growth, and carcass composition traits in non-overfed animals, and genetic parameters for growth and fatty liver formation in overfed animals. Four hundred and thirty-one non-overfed animals were bred and slaughtered at 11 weeks of age; they were measured for forearm length, keel bone length, chest circumference and breast depth before and after slaughtering. The carcasses were partly dissected in order weigh breast, breast muscle and skin + fat, and abdominal fat. Four hundred and seventy-seven overfed animals were slaughtered at 20 weeks of age; they were measured for “paletot” (breast meat, bone and meat from wings, bone and meat from thigh and legs) weight and liver weight. In these two experiments, the weights had moderate to high heritability values. Breast depth measured on live animals showed a low heritability value. In overfed animals, liver weight showed a high heritability value. Liver weight could be increased by selection without a great effect on “paletot” weight. Thus, obtaining a white plumage geese strain for fatty liver production by selection would be difficult because only 20% of overfed animals had fatty liver. The results did not allow to conclude on the influence of selection on liver weight on carcass traits such as muscle or fatty tissue weight.

**geese / growth / carcass composition / hepatic steatosis / genetic parameters**

**Résumé** – Paramètres génétiques dans une lignée d'oie blanche : caractères de croissance et de composition de la carcasse chez des animaux non gavés, et de la croissance et de l'aptitude au gavage chez des animaux gavés. Dans une lignée d'oies blanches, créée en 1989, deux expériences ont été réalisées en vue d'estimer les paramètres génétiques des performances de croissance et des caractères de composition de la carcasse sur des animaux non gavés, et des

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performances de croissance et de gavage chez des animaux gavés. Les animaux non gavés (431) ont été élevés jusqu'à l'âge de 11 semaines, âge auquel ils ont été abattus. Sur ces animaux ont été mesurés la longueur de l'avant-bras, la longueur du bréchet, le tour de poitrine et la profondeur de poitrine, mesures effectuées avant et après abattage. La carcasse a été partiellement disséquée afin de peser le filet, le muscle du filet, la peau et le gras du filet ainsi que le gras abdominal. Les animaux gavés ont été abattus à l'âge de 20 semaines. La carcasse, le gras abdominal, le paletot et le poids du foie ont été mesurés. Dans ces deux expériences, les estimées des valeurs d'héritabilité de tous les poids ont été moyennes à élevées. La profondeur de poitrine mesurée à l'aiguille a une valeur d'héritabilité faible pour la mesure effectuée sur animaux vivants. Chez les animaux gavés, le poids du foie a une valeur d'héritabilité élevée. Le poids du foie peut être augmenté par sélection sans conséquences majeures sur le poids du paletot. Sélectionner une lignée d'oies blanches pour augmenter son aptitude à faire du foie gras devrait cependant être difficile dans la mesure où seuls 20 % des animaux gavés ont donné un foie gras. Les résultats n'ont pas permis de conclure quant à l'incidence d'une sélection sur le poids de foie sur les caractéristiques de la carcasse telles que le poids de muscle ou des tissus adipeux.

**oie / croissance / composition corporelle / foie gras / paramètres génétiques**

## 1. INTRODUCTION

In France, traditionally raised geese contribute, to fatty liver and preserved meat productions when they are overfed, and to meat production when they are not overfed. The Landaise grey coloured geese are used for fatty liver production and white plumage geese are required for meat production. In comparison with ducks, it seems that low meat yield, especially breast muscle yield and high fat yield, have become two of the limiting factors of these productions [1].

White plumage geese are preferred for carcass and meat presentation and for their feather and down value. Unfortunately, white plumage geese which are used for meat production do not exhibit a large genetic ability for liver fattening when overfed as do some grey geese strains selected for that purpose. A previous study [12] made on Polish white geese showed that these animals have higher growing performances and a higher proportion of breast muscle compared with Landaise geese, but also have a higher fatness and a lower fatty liver weight, though they show some ability to produce fatty liver.

A further development of goose production could be realised by increasing meatiness of white plumage animals and by developing their capacity for overfeeding and producing fatty liver. Thus, possibilities to select a dual purpose strain of white plumage geese were studied. Breeding for higher breast meat yield can be based on estimates of breast muscling in live birds themselves or on direct measurements of their relatives.

Previous studies were carried out to improve white plumage geese breeding performances [10], but little is known about the genetic variability of growth, meat and fatty liver traits in white plumage geese. Medium to high heritability values for body weights at a fixed age in growing White Italian geese have been reported in the literature [10]. Heritabilities, phenotypic and genetic correlations of live and carcass traits, and carcass part in ganders have only

Table I. Number of animals.

Year	Parents		Progeny	
	Sires	Dams	Males	Females
1993 <sup>(a)</sup>	22	71	115	111
1994 <sup>(b)</sup>	21	95	274	203
1995 <sup>(a)</sup>	17	63	107	98

(<sup>a</sup>) non-overfed animals; (<sup>b</sup>) overfed animals.

been estimated in a small sample size of animals from a synthetic strain [5], and Stasko and Masar [15], quoted by Pingel [10], estimated heritability of liver weight in White Italian geese.

The purpose of this work was to estimate the genetic parameters for body weights, body measurements on live animals and carcasses, and carcass traits in non-overfed Polish white plumage geese, and the genetic parameters of overfeeding traits in birds of the same experimental strain.

## 2. MATERIALS AND METHODS

### 2.1. Animals

Polish geese of white plumage were donated to the Institut national de la recherche agronomique in 1989, by the Koluda Wielka Experimental Station, National Scientific Institute of Animal Production within a cooperative research program, and they were raised at the Station expérimentale des palmipèdes à foie gras, INRA. The origin of the founders was a White Italian geese strain, selected in Poland for increasing meatiness of geese carcass. From 1993 to 1995, two separate experiments were carried out: one on non-overfed animals to study live and carcass traits, and a second on overfed animals to study overfeeding traits.

#### *Non-overfed animals*

In 1993 and 1995, two generations of the experimental strain of geese (226 and 205 animals, respectively) were studied (Tab. I). In two series per year, goslings from pedigree (one male and four females) hatches were raised in an intensive system and slaughtered at 11 weeks of age. Until 8 weeks of age, the animals were given a complete mixture ( $2\,900\text{ kcal ME} \cdot \text{kg}^{-1}$ , 16.5% crude protein). From 8 weeks of age to slaughtering at 11 weeks of age, they were given the same mixture, but restricted to 85% of the amount eaten at 8 weeks. The animals were slaughtered at 11 weeks of age after electronarcosis. They were bled and plucked and their carcasses were kept at 4 °C for 24 h.

### **Overfed animals**

In 1994, a total of 477 animals from two pedigree hatches were bred and overfed in two series (Tab. I). They were fed *ad libitum* with a complete mixture (2 900 kcal ME · kg<sup>-1</sup>, and 16.5% crude protein) until 8 weeks of age. From 8 weeks of age to the beginning of the pre-overfeeding period (118 days of age), they were fed one meal per day with 200 g of a complete mixture (2 600 kcal ME · kg<sup>-1</sup>, and 14.0% crude protein). During the pre-overfeeding period (10 days), they were given the mixture same once a day, but the amount increased daily. The animals were overfed for 13 days in two successive series of overfeeding. During this period, geese were overfed with corn 3 meals per day. In one series, two different crammers were used, and these crammers were the same for both series. Males and females were equally distributed between both crammers. At the end of the overfeeding period, animals were slaughtered after electronarcosis. They were bled and plucked. They were kept at 4 °C. The day after slaughtering, they were eviscerated, fat liver was extracted and "paletot" (breast meat, bone and meat from wings, bone and meat from thigh and legs) and abdominal fat were removed from the carcasses.

## **2.2. Traits**

### **Non overfed animals**

Live body measurements were made on all animals: body weight at 8 weeks of age, body weight at 11 weeks of age, chest circumference, keel length, forearm length, and depth of the breast muscle (including skin) by needle probe. A needle probe was used on the left side of the bird, perpendicularly to the breast from the skin down to the breast bone, at 3 cm from the head of the keel bone and 3 cm perpendicularly on the side, determined with a patch. On the day after slaughter, similar measurements were taken on the carcass: plucked-bled carcass weight, chest circumference, keel length, forearm length, depth of the breast muscle. Carcasses were cut and additional breast measurements were also taken: the weight of the *pectoralis minor* muscle, the weight of the *pectoralis major* muscle, and the weight of breast skin + fat, on the left side of the carcass.

### **Overfed animals**

Animals were weighed at 8 weeks of age, at the beginning (118 days of age) and at the end of the pre-overfeeding period (18 weeks of age), and at the end of the overfeeding period before slaughtering (20 weeks of age). Body weight gain was calculated as the difference between the weight at the end and at the beginning of overfeeding. Bled and plucked carcass was weighed, as well as the "paletot", abdominal fat and liver.

## **2.3. Statistical analysis**

Preliminary least squares analyses were performed using the GLM procedure of SAS® in order to determine the fixed effects which should be taken into

account in the following analyses. The model for all traits included the fixed effects of sex and year-series for traits measured on non-overfed animals; sex, series and crammer for traits measured on overfed animals; and the additive breeding value as the random effect for all animals.

Variance components were estimated using a restricted maximum likelihood (REML) applied to a multiple-trait individual animal model. All animals from pedigree file until founder animals were put in the relationship matrix. The estimation of genetic parameters was performed with the 4.2 version of the VCE computer package, using a quasi-Newton algorithm with exact first derivatives to maximise the log likelihood [8]. Although animals were from the same strain, genetic parameters between non-overfed and overfed traits could not be estimated with a convenient standard error, and were not consequently presented.

Breast muscle yield was defined by the ratio of the *pectoralis major* muscle weight to body weight at 11 weeks of age or to carcass weight. The heritability values of the ratio between these two traits were calculated by a formula established according to Sutherland [16]. The genetic correlation between a trait and the ratio of two traits was approximated by the formula from Pearson [9].

### 3. RESULTS

#### 3.1. Effect of sex, series and crammer

In 11-week-old geese (Tab. II), sex had a highly significant effect ( $P < 0.001$ ) on all traits except on breast depth measured *post mortem* and abdominal fat weight. Series also had an effect on all traits except on abdominal fat weight. No significant interaction between series and sex was observed, so this interaction was not retained for genetic parameter estimation. When considering the effect of sex, males were heavier than females, and all the body or carcass measurements were of higher value in males than in females.

In the overfed geese, series had a significant effect on all traits except liver weight (Tab. III). We verified that animals given to each crammer were of the same mean weight at the beginning of overfeeding (there was no crammer effect on the weight at the beginning of the overfeeding period, data not shown). The crammer had a significant effect on body weight gain during overfeeding, carcass weight, paletot weight and liver weight. Sex had a significant effect on all traits except on body weight gain during overfeeding and liver weight. No significant interactions between these effects were observed.

#### 3.2. Heritabilities

For non-overfed animals, traits measured on live animals slaughtered at 11 weeks of age had high heritability values (Tab. IV), from 0.46 to 0.73 for chest circumference and forearm length respectively. Only the heritability value estimated for breast depth was found to be low ( $h^2 = 0.13$ ).

For traits measured on carcass (Tab. V), heritability values were from medium (0.29 for breast depth) to high (0.73 for *pectoralis major* muscle

**Table II.** Means, phenotypic standard error, level of significance for sex and series (non-overfed geese).

Traits	$\mu^{(a)}$	$\sigma^{(b)}$	sex	series
<b>Live Body traits</b>				
Body weight 8 wk (g)	4 801	354	***	***
Body weight 11 wk (g)	5 534	391	***	***
Keel bone length (mm)	177.5	8.0	***	***
Forearm length (mm)	189.8	6.4	***	***
Chest circumference (mm)	475.9	15.3	***	***
Breast depth (mm)	24.24	2.39	**	***
<b>Carcass traits</b>				
Carcass weight (g)	4 621	332	***	***
Keel bone length (mm)	171.1	7.6	***	***
Forearm length (mm)	189.2	5.7	***	***
Chest circumference (mm)	421	12	***	***
Breast depth (mm)	28.80	2.69	NS	***
Abdominal fat weight (g)	221	44.0	NS	NS
Pectoralis minor muscle weight (g)	34.62	3.38	***	***
Pectoralis major muscle weight (g)	260.7	24.4	***	***
Breast skin + fat weight (g)	86.0	12.3	***	***

<sup>(a)</sup>  $\mu$ : mean; <sup>(b)</sup>  $\sigma$ : phenotypic standard deviation.

Level of significance: \*\*\*  $P < 0.001$ ; \*\*  $P < 0.01$ ; \*  $P < 0.05$ ; NS: not significant.

weight). For both live and dead animals, breast depth had a lower heritability value than animal weight, keel bone or forearm length and chest circumference. When considering the same trait measured on live body or on carcass, heritability values were very similar for lengths. Heritabilities of chest circumference and breast depth were higher when measured on carcass.

Heritabilities of all traits measured on overfed animals are given in Table VI. All measured traits had high heritability values, from 0.39 to 0.63, for weight gain during overfeeding and weight at the beginning of overfeeding, respectively. Before pre-overfeeding, heritability values of weights were slightly higher than after overfeeding.

### 3.3. Genetic correlations

Genetic correlations between traits measured on non-overfed live animals (Tab. IV) were high, except for genetic correlations between chest circumference and forearm length ( $r_g = 0.55$ ). Breast depth was moderately related to other traits ( $r_g < 0.5$ ) including body weights.

The genetic correlations between the traits measured for carcasses tended to be lower (Tab. V), from  $-0.35$  to  $0.58$ , and the genetic correlations between breast depth and lengths were negative. Abdominal fat weight was not or

**Table III.** Means, phenotypic standard error, level of significance for sex, series and crammer (overfed geese).

Traits	$\mu^{(a)}$	$\sigma^{(b)}$	sex	series	crammer
Body weight at 8 weeks (g)	4 615	393	***	*	—
Body weight, beginning of pre-overfeeding (g)	4 418	441	***	***	—
Body weight, beginning of overfeeding (g)	4 744	495	***	***	NS
Body weight at slaughtering (g)	7 363	751	***	*	NS
Body weight gain during overfeeding (g)	2 622	458	NS	***	***
Bled and plucked carcass weight (g)	6 418	667	***	**	**
“Paletot” weight (g)	3 035	341	**	*	**
Abdominal fat weight (g)	419	69	*	***	NS
Liver weight (g)	411	119	NS	NS	***

(a)  $\mu$ : mean; (b)  $\sigma$ : phenotypic standard deviation.

Level of significance : \*\*\* P < 0.001; \*\* P < 0.01; \* P < 0.05; NS: not significant.

**Table IV.** Genetic parameters and their standard errors (heritabilities on the diagonal) for live body traits in non-overfed geese slaughtered at 11 weeks of age (standard errors for heritabilities varied from 0.07 to 0.15 and standard errors for genetic correlations were from 0.02 to 0.19).

Traits <sup>(a)</sup>	BW8	BW11	KBL	FL	CC	BD
BW8	0.64	0.92	0.86	0.80	0.84	0.31
BW11		0.68	0.89	0.83	0.86	0.50
KBL			0.60	0.78	0.64	0.46
FL				0.73	0.55	0.24
CC					0.46	0.42
BD						0.13

(a) BW8: Body weight at 8 weeks of age; BW11: Body weight at 11 weeks of age; KBL: Keel bone length; FL: Forearm length; CC: Chest circumference; BD: Breast depth.

moderately correlated with other traits. The *pectoralis major* muscle weight was only moderately genetically related to carcass breast depth and very lowly related to abdominal fat weight. The genetic correlations between skin + subcutaneous fat weight and abdominal fat weight or the *pectoralis major* muscle weight were also moderate.



**Table V.** Genetic parameters (heritabilities on the diagonal) for *post mortem* traits in non-overfed geese slaughtered at 11 weeks of age (standard errors for heritabilities varied from 0.07 to 0.11 and standard errors for genetic correlations were from 0.03 to 0.20).

Traits <sup>(a)</sup>	CW	KBL	FL	CC	BD	AFW	PMiW	PMaW	SF
CW	0.63	0.74	0.75	0.89	0.18	0.25	0.71	0.71	0.84
KBL		0.59	0.55	0.52	-0.28	0.21	0.54	0.57	0.48
FL			0.63	0.58	-0.35	-0.16	0.37	0.44	0.35
CC				0.64	0.38	0.42	0.64	0.79	0.90
BD					0.29	0.44	0.45	0.51	0.37
AFW						0.36	0.01	0.27	0.42
PMiW							0.38	0.80	0.48
PMaW								0.73	0.54
SF									0.46

<sup>(a)</sup> CW: Bled-plucked carcass weight; KBL: Keel bone length; FL: Forearm length; CC: Chest circumference; BD: Breast depth; AFW: Abdominal fat weight; PMiW: *Pectoralis minor* muscle weight; PMaW: *Pectoralis major* muscle weight; SF: *Pectoralis* skin + subcutaneous fat weight

**Table VI.** Genetic parameters (heritabilities on the diagonal) for traits measured on overfed animals (standard errors for heritabilities varied from 0.07 to 0.09 and standard errors for genetic correlations were from 0.02 to 0.17).

Traits <sup>(a)</sup>	BW8	BW16	BW18	BW20	BWG	CW	PW	AFW	LW
BW8	0.62	0.88	0.88	0.90	0.51	0.91	0.88	0.58	0.08
BW16		0.63	0.99	0.94	0.45	0.96	0.96	0.62	0.07
BW18			0.59	0.87	0.33	0.89	0.89	0.65	0.10
BW20				0.54	0.78	0.99	0.90	0.81	0.23
BWG					0.39	0.75	0.59	0.66	0.30
CW						0.55	0.90	0.77	0.25
PW							0.53	0.57	-0.06
AFW								0.49	-0.10
LW									0.52

<sup>(a)</sup> BW8: Body weight at 8 weeks of age; BW16: Body weight at the beginning of the pre-overfeeding period; BW18: Body weight at the beginning of the overfeeding period; BW20: Body weight at the end of the overfeeding period; BWG: Body weight gain during the overfeeding period; CW: bled and plucked carcass weight; PW: "Paletot" weight; AFW: Abdominal fat weight; LW: Liver weight.

When considering the genetic correlations between traits measured on live animals and on carcasses (Tab. VII), keel bone length, forearm length and chest circumference measured *post mortem* were highly correlated to the same measurement made on live animals ( $r_g = 0.97$  to  $0.99$ ) whereas breast depths,

**Table VII.** Genetic correlations between live body and *post mortem* traits (standard errors varied from 0.02 to 0.25).

Traits <sup>(a)</sup>	CW	KBL	FL	CC	BD	AFW	PMiW	PMaW	SF
BW8	0.93	0.72	0.78	0.82	0.03	0.29	0.67	0.69	0.77
BW11	0.99	0.78	0.77	0.85	0.10	0.17	0.68	0.68	0.81
KBL	0.86	0.98	0.67	0.62	-0.26	0.14	0.55	0.65	0.62
FL	0.80	0.67	0.97	0.58	-0.32	-0.21	0.49	0.53	0.38
CC	0.89	0.50	0.51	0.99	0.41	0.63	0.69	0.79	0.93
BD	0.45	0.45	0.03	0.41	0.56	0.07	0.50	0.84	0.39

<sup>(a)</sup> Cf. Tables III and IV

**Table VIII.** Genetic correlations between live measurements and *pectoralis major* muscle ratio over body weight at 11 weeks of age, and between carcass measurements and *pectoralis major* muscle ratio over carcass weight.

	PMa/BW11 <sup>(a)</sup>	PMa/CW <sup>(b)</sup>
$h^2$ <sup>(c)</sup>	0.75	0.65
Weight <sup>(d)</sup>	-0.07	0.00
BD	0.65	0.54
KBL	0.00	0.06
FL	0.22	-0.13
CC	-0.07	0.22

<sup>(a)</sup> with live body measurements; <sup>(b)</sup> with carcass measurements; <sup>(c)</sup> heritability value of the ratio; <sup>(d)</sup> BW11 for PMa/BW11 and CW for PMa/CW.

measured on live animals and on carcasses, were only moderately related. The *pectoralis major* muscle weight was moderately related to live body measurements. It was more closely related to chest circumference and breast depth than to length measurements.

Genetic correlations between body measurements and ratio of breast muscle over body or carcass weight are presented in Table VIII. These correlations were of medium value.

Genetic correlations for overfed animals are included in Table VI. The different live body weights were highly genetically correlated to each other (from 0.88 to 0.99), as well as carcass weight and "paletot" weight. Weight gain during overfeeding was moderately genetically correlated with body weights before overfeeding. The highest correlation was found with body weight at the end of the overfeeding period. When considering the abdominal fat weight, it was moderately to highly genetically correlated with body or carcass weights. Liver weight was not significantly genetically correlated with live body weights before overfeeding. It was moderately correlated with weight at slaughtering

and weight gain during overfeeding, or with carcass weight ( $0.23 \pm 0.13$ ). It was not significantly correlated with "paletot" weight and abdominal fat weight.

## 4. DISCUSSION

### 4.1. Effect of sex, series, and crammer

For geese slaughtered at 11 weeks of age, the differences between males and females could be partly explained by the difference of body weight at slaughtering. When analysing the differences between both sexes and considering body weight as a covariate, differences still remained for lengths: males had longer measurements than females, but females had more abdominal fat, heavier *pectoralis minor* muscle and heavier breast skin + fat. Females also had a thicker breast muscle but only when measured *post mortem*. Thus, at constant body weight, females had more muscular and adipose tissue, but shorter bones. Similar results have been obtained by Poujardieu *et al.* [12] except that the proportion of muscle in males and females was similar.

For overfed animals, it has been well documented that males are heavier than females, whereas it is not obvious that fatty liver weight are the same in both sexes. Studying several genotypes, Poujardieu *et al.* [12] found a significant difference between males and females for liver weight. No significant sex difference was observed for liver weight, which probably depends on the strain as shown by Rouvier *et al.* [13].

### 4.2. Heritabilities

The heritability values estimated for live body weight at 8 weeks of age in both samples, *i.e.* non-overfed and overfed animals (Tabs. IV and VI), were the same, in accordance with the common origin of these animals. In comparison with other estimated values of heritability for live body weight at 7–8 weeks of age in white Italian geese, our values were in the upper range [15]. These values were higher than the heritability values ( $h^2$  from 0.2 to 0.3) estimated for this trait in Cuban geese [10,14]. At 8 weeks of age, these Cuban geese were lighter than Italian geese, and possibly more mature. In our study, heritability values for body weights at 8 weeks and 11 weeks of age were similar (0.64 and 0.68, respectively). In previous studies, in Italian as well as in Cuban geese, heritability values for body weights were about the same when estimated between 8 and 12 weeks of age [10,14,15].

In the literature, heritability values for body traits are reported for several ages and different breeds. In general, heritability values estimated in the present study were in accordance with the results previously presented by Grunder *et al.* [5] on geese from a synthetic line slaughtered at about 19 weeks of age. In particular, they found high estimated heritability values for body, carcass and breast weights ( $h^2 = 0.67$ ,  $h^2 = 0.72$ , and  $h^2 = 0.72$  respectively), and a lower heritability value for breast depth ( $h^2 = 0.12$ ). They concluded that this trait was more difficult to measure. Smalec and Mazanowski [14] estimated lower heritability values for keel bone length, forearm length and breast muscle

depth ( $h^2 = 0.37$ ,  $h^2 = 0.20$ , and  $h^2 = 0.13$ , respectively), in a Cuban geese line slaughtered at 12 weeks of age. In all these studies, breast muscle depth measured by needle probes on live animals had low heritability values. On the contrary, in ducks, this trait had medium heritability values ( $h^2 = 0.51$ ,  $h^2 = 0.32$ , [10]), and selection on this trait in order to increase breast muscle proportion has been proven to be efficient [10]. In geese in France, this kind of selection on breast muscle thickness to improve breast muscle proportion has never been applied.

For liver weight, the heritability value found in the present study was higher than values previously estimated in Pekin ducks for overfed mule ducks [11]. Mignon-Grasteau *et al.* [7] found a heritability value for fatty liver weight of  $0.39 \pm 0.10$  for overfed Muscovy male ducks. In an Italian strain, Stasko and Masar [15] found heritability values for liver weight between 0.42 and 0.48. When considering the values of liver weight (Tab. III), obtaining fatty liver in a white geese strain can be envisaged: about 20% of animals produced fatty livers (> 500 g), even though this strain was selected for meatiness and not for fatty liver production. Previously, Poujardieu *et al.* [12] found that it was possible to produce fatty liver with this white plumage geese strain, but not with a White Italian strain. With the heritability value estimated in the present study, even though the white plumage geese were not particularly able to produce fatty liver, they could be selected to improve the ability to produce fatty liver when being overfed by selection on fatty liver weight.

### 4.3. Genetic correlations

In non-overfed animals, the low genetic correlation between *pectoralis major* muscle weight and abdominal fat weight on one hand and the moderate genetic correlation between *pectoralis major* muscle weight and skin + subcutaneous fat weight on the other hand, meant that it was possible to increase muscle weight while limiting the increase of carcass fatness. Unexpectedly, muscle weight was more related to breast depth measured on live animals than on carcasses. That could be linked to *post mortem* muscle contraction which puts the breast muscle out of shape.

Because of the low heritability value for breast depth recorded on live animals, selection on this trait would not be efficient. Thus, when considering the same traits at constant carcass weight (Tab. VII), the results were not of the same order. In this case, the breast depth measurement was the trait the most genetically correlated to the ratio of the *pectoralis major* muscle over animal weight, in live or slaughtered animals, whereas the other traits were only lowly genetically related to this ratio. Thus selecting on breast muscle depth should lead to an increase of the proportion of muscle in the carcass. This selection would be less efficient than direct selection on breast proportion but would not require slaughtering animals to be measured. From these correlations, it could also be expected that a selection on body weight or carcass weight at 11 weeks of age would not lead to an evolution of muscle proportion.

In overfed animals, with low genetic correlations with liver weight, selection for increasing fatty liver weight would have little effect on other traits (body weight, or abdominal fat weight). In fact, the genetic relationship between

liver weight and "paletot" weight is still controversial. Estimated values of this correlation in Muscovy duck populations show from high negative [2] to high positive values [3]. In this study, we did not determine if muscle or subcutaneous fat weights in the "paletot" would be modified by selection on liver weight.

Physiological studies [4,6] tend to show that geese which are able to produce fatty liver are also able to synthesize more triglycerides and do not export these triglycerides to other tissues including adipose tissue.

## 5. CONCLUSION

Live body measurements, in particular breast depth, are possible selection criteria to improve breast muscle proportion in white plumage geese. This was shown when measuring breast depth with a needle probe. But in order to improve animal welfare, a noninvasive method for measurement of that trait should be studied, *i.e.* using an ultrasound probe. This study also confirmed that in a white geese population it was possible to obtain fatty liver in a strain with a low ability to produce fatty liver. In our strain, about 20% of the animals gave a fatty liver, even though the weights of these livers were still too light. Thus, the heritability value found for liver weight showed that it should be possible to select this white plumage geese strain for fatty liver production, and the genetic correlations with this trait showed that this selection would not depreciate the carcass or "paletot" weights. Further studies have to be conducted to estimate the genetic relationship between non-overfeeding and overfeeding characteristics.

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