ANGORA RABBIT WOOL PRODUCTION : THE INHERITANCE OF WOOL QUANTITY AND DIFFERENT FLEECE CHARACTERISTICS IN ADULT DOES[1]

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Abstract - Data on 6523 fleece harvests produced by 1014 adult Angora does, from 187 sires and 373 dams were analyzed. These animals of the French breed were defleeced every 14 weeks. The following variables were recorded at each harvest: total fleece weight, the weight of the five different qualities constituting the fleece, the length of bristles and downs as well as the structure of the lock on the back and the haunch, tautness, compression and resilience. The live weight was measured nine weeks before each harvest.
Heritability estimates of these traits ranged from 0.15 to 0.25. There were high and positive genetic correlations between the weight of long and bristly wool (quality WAJ1), total fleece weight and homogeneity (0.89 and 0.65, respectively), as well as between fibre length and staple structure measured on the back and the haunch. Compression and resilience were genetically linked (r_g = 0.89). Genetic correlation estimates between tautness and the other variables were low to moderate. Similar estimates were observed with the live weight. These results are discussed in relation to selection goals of the French Angora rabbit.

INTRODUCTION

A knowledge of the extent of genetic variability is a prerequisite for genetic improvement of a particular trait. ROCHAMBEAU and THEBAULT (1990) have recently reviewed various aspects of the genetics of the wool-producing rabbit. There are two main breeds, which are produced using two different management systems. The German breed, which has a long, soft and wooly coat, is harvested by shearing and mainly raised in China and south America. The French breed, which is harvested by defleecing, has a long, bristly coat, which results in a fluffy yarn to make luxurious clothes. Little information is available on heritabilities, genetic and phenotypic correlations for Angora rabbit traits. All of them are based on the German breed.

The objective of this paper is to report results from the estimation of variance components and genetic parameters of fleece weight and different fleece characteristics when analyzing data from an experimental Angora rabbit flock of the French breed.

MATERIAL AND METHODS

Data

The data available were from the Angora rabbit farm of Institut National de la Recherche Agronomique at Le Magneraud, BP 52, 17700 Surgères, France. Wool production of a total of 1014 Angora does which have made at least one wool harvest from the third harvest and born between 1 January 1983 and 30 November 1995, was studied. The young rabbits were sexed at birth and most of the males were eliminated. In this way the size of the litters were reduced to less than six rabbits just after birth. The young rabbits were weaned four weeks later. At the age of eight weeks, the young rabbits were weighed and defleeced for the first time. At the age of 21 weeks, rabbits were weighed and defleeced a second time. Thereafter, they were defleeced every 14 weeks. The live weight was measured nine weeks before each harvest.

At each harvest, several variables were recorded:

- *the total fleece weight* as well as the *weight of the five qualities* constituting the fleece of the French breed (VRILLON and THEBAULT, 1992) *i.e:* quality WAJ1 includes long (over or equal 6 cm for downs) and

[1] The authors dedicate this paper to Gabriel BLANIE, technician of the experimental herd, who recently died.

bristly wool; quality **WAW1** includes long and woolly wool, quality **WAJ2** includes short wool (< 6 cm for down); quality **WAF**, clean felt wool and quality **WAS**, dirty wool ,

- *the length of downs and bristles,* measured on two locks respectively taken from the back and the haunch,
- *tautness rating* (roughness) before defleecing. This rating varies from one (bristly fleece) to five (woolly fleece) and is given by an expert after visual and manual assessment of the fleece in the areas where bristly hairs are to be found, i.e. the back and flanks; and,
- *Compression and resilience* - These two measurements are based on those used for objective measurement of quality in sheep wool. A sample of 10 g is taken from the rabbit's haunch. It was then compressed by a 3 kg weight inside a 43 mm diameter smooth walled cylinder, scaled from 0 to 90 mm. The height of the wool level thus obtained is the compression. The lock expands in the cylinder when the pressure was removed. This second value is the resiliency.

These parameters values are used to calculate the two first elements of the quality of a fleece: homogeneity and structure. The homogeneity is equal to the ratio of the weight of quality WAJ1 to the total weight of the fleece. The structure is equal to the ratio of the length of down to the length of the bristles. Structure values for the back and for the haunch are calculated separately. Tautness is the third element in the quality of a fleece. As the number of bristles present in a fleece is relatively constant (ROUGEOT and THEBAULT, 1983), it was assumed that it was the diameter of the bristles which distinguished bristly fleeces from woolly fleeces.

After the third harvest, which was after 35 weeks of age, the rabbits were ready for mating. Mating took place in the month following defleecing. The data set included all information available on 30 November 1995. At this date, certain animals were still producing. Causes of death or elimination were similar to those of a production farm.

Until September 1985, the rabbits were located in a closed building at INRA Jouy-en-Josas. This building was dynamically heated and ventilated. The lighting cycle followed the natural daylight cycle at the latitude of Paris. In October 1985, the experiment was transferred to the experimental farm at Le Magneraud in a naturally lighted building almost open to the air. There was no heating and no forced ventilation. The animals were raised in individual cement hutches on straw beds which were completely replaced once a month. Each had a creep feeder and an automatic drinking bowl with a constant level, arranged in such a way as to never wet the bedding.

The rabbits received a pelleted commercially available, mixed food which contained (per kg dry matter (DM)) on average 101 MJ digestible energy (DE), 140 to 150 g crude protein, 110 to 120 g digestible protein, 150 g crude fibre, 20 g lipid, 7 g sulphur amino acids. This food was distributed *ad libitum* to young growing rabbits between 4 and 8 weeks, as well as to lactating females. The other animals were fed 6 days a week and fasted on the 7th day. During the month following defleecing, the animals received 200 g food per day in the summer and 230 g in winter. During the following month, they received 180 g/day. During the last month they received 160 g/day. In the days preceding the defleecing, the animals received a depilatory treatment consisting of Lagodendron ®[2] (Proval Company, Paris) in order to greatly facilitate the wool harvesting.

Table 1 : Characteristics of the data structure.

No. records in data		6523
No. animals in total		2055
	with own records	1014
No. sires		187 or 200
	with own record	0
	with progeny in the data	164 or 163
No. dams		373 or 398
	with own record	270 or 272
	with progeny in the data	306 or 322

Characteristics of the data structure are summarized in Table 1.

Analysis model

The estimates of variance components for different variables were obtained by using REML VCE, a multivariate multi model restricted maximum likelihood variance component estimation (GROENEVELD, 1995) with an animal model.

[2] ® marque déposée

Earlier investigations using fixed models of variance analysis have shown that in Angora does, five fixed factors were considered to be important: harvest number, birth season, harvest season, year of harvest and reproduction (ROCHAMBEAU *et al.*, 1991).
The random part of the model consisted of a filial effect, related to the individual animal and a permanent environmental effect as up to 26 performances have been recorded on the same doe.
The general model is: $Y = Xf + Za + Qc + e$ where,

- Y is a vector of animal records,
- f, a vector of fixed effects consisting of:
- year of production (13 levels),
- harvest number-birth season- harvest season composite effect (24 levels; 1 to 4: birth season effect at the third harvest; 5 to 8: birth season at the fourth harvest; 9 to 24: birth season and harvest season at harvest which number is more than four) and,
- reproduction (2 levels: females which had litters or not).
- a, a random vector of direct additive genetic effects of animals,
- c, a random vector of permanent environmental effects of animals, and
- e, a random vector of residuals.

Heritabilities, genetic and phenotypic correlations have been estimated on a total of 13 different traits according to series of multivariate model analyses. Three or four traits were included in each analyze in order to estimate at least once time all phenotypic and genetic correlations between traits.

RESULTS AND DISCUSSION

Heritability and repeatability estimates (Table 2)

Some basics statistics (mean and standard deviation) of the different analyzed traits as well as REML animal heritability and repeatability estimates are given in table 2. As some variables were not systematically registered at each variable, the total number of analyzed records varied and missing values were used.
Most of the heritability estimates ranged from 0.15 to 0.25, with the exception of a higher heritability for live weight 9 weeks before defleecing (0.40) and lower estimates (0.09) for both haunch staple structure and tautness. Repeatability estimates ranged from 0.15 to 0.35. A high repeatability estimates (0.57) has been observed for live weight 9 weeks before defleecing. There are few estimates of genetic parameters in Angora rabbits. GARCIA and MĄGOFKE (1982) obtained mainly low and non-significant estimates. Our results estimated, under a REML animal model, were moderate, significant and consistent between the different analyses. Heritability and repeatability estimates of the live weight 9 weeks before defleecing were higher than expected. This probably indicates that an optimum body live weight has been reached in the French Angora rabbit breed. Similar high heritability estimates of body weight have been mentioned earlier (CARO *et al.*, 1984).

Table 2 : Mean, standard deviation, heritability and repeatability of the different traits studied in Angora rabbit does.

	Number of records	Mean	Standard deviation	Heritability	Repeatability
Fleece weight (g)	6523	235.1	45.2	0.23	0.36
Weight of Quality WAJ1 (g)	6523	157.2	41.3	0.22	0.32
Homogeneity (p. 1000)	6523	663.3	101.7	0.18	0.18
Back bristle length (mm)	5517	101.1	8.1	0.25	0.25
Back down length (mm)	5517	63.1	7.3	0.16	0.19
Back lock structure (p. 1000)	5517	625.5	68.7	0.17	0.20
Haunch bristle length (mm)	5406	103.7	8.1	0.25	0.29
Haunch down length (mm)	5408	65.6	5.9	0.15	0.16
Haunch lock structure (p. 1000)	5406	634.3	55.8	0.09	0.15
Compression (mm)	5522	26.9	2.0	0.19	0.22
Resilience (mm)	5521	64.0	5.3	0.12	0.15
Tautness	5526	3.1	0.6	0.09	0.15
Live weight (g)	6369	3902.9	441.5	0.40	0.57

Phenotypic and genetic correlations between traits related to the weight of the fleece (Table 3)

Genetic and phenotypic correlations between the total weight of the fleece and weight of quality WAJ1 were positive and high (0.89 and 0.86 respectively). Homogeneity which is the ratio of the weight of quality WAJ1 to the total fleece weight was highly and positively correlated to the weight of quality WAJ1 but not with the total fleece weight. This indicates that the weight of quality WAJ1 would be an adequate selection goal with the objective to produce long and bristly wool on Angora rabbits as there are high and positive genetic correlations between this trait and both total fleece weight and homogeneity of the fleece.

Phenotypic and genetic correlations between traits related to fibre length (Table 3)

Genetic and phenotypic correlations between the different fibre length type (bristle and down on both the back and the haunch) were high and positive within and between body locations. In this study, a lock was taken from the back and another from the haunch in order to study the length and the structure of the hair as there are differences in fibre length and lock structure between sampling sites (JADRIJEVIC *et al*, 1982; MONTOYA ONTATE, 1985; ROCHAMBEAU *et al*, 1991). These strong genetic relationships between length of the different fibre type whatever the fibre type and the body location suggest that in the French breed variations in fibre length over the body are small. Thus it does not need to measure fibre length in two different locations. The most important is to choice only one sampling site which is representative of the whole fleece.

Genetic and phenotypic correlations between the structure of the lock and down length were moderate and positive, but moderate and negative with bristle length, whatever the body location. This would indicate that this ratio of down length to bristle length is not constant as it is shown by low to moderate genetic correlations between these two traits. Thus there are possibilities to modify the structure of the lock by selection on the length of down or bristle respectively.

Genetic correlations between fibre length were positive and moderate to high with traits related to fleece weight and non significant with the homogeneity of the fleece. However, the highest correlations are observed between down length and fleece weight traits (0.66 and 0.67 for total fleece weight and weight of WAJ1 quality, respectively). Thus an improvement of fleece weight by selection would result from an increase in down length.

Phenotypic and genetic correlations between traits related to other fleece characteristics: compression, resilience and tautness (Table 3)

High and positive genetic and phenotypic correlations were observed between compression and resilience. In this study, both measurements of compression and resilience were recorded as it has been shown that bristly fleeces which are valued because of their aptitude to produce a fluffy yarn used for certain luxury knit products, compress more and relax less than woolly fleeces (ROCHAMBEAU *et al.*, 1991), and these parameters have a light influence on tautness (ALLAIN *et al.*, 1992). The strong and positive genetic correlation between compression and resilience indicates that these two traits are similar.

There were low and positive genetic and phenotypic correlations between tautness and both compression and resilience (0.23 and 0.30 respectively). However genetic correlations where higher than the corresponding phenotypic correlations. This means as expected and in agreement with earlier studies (ROCHAMBEAU *et al.*, 1991), that a rough fleece compresses more and relaxes less.

Most of genetic and phenotypic correlations between these three fleece characteristics (tautness, compression and resilience) and both fleece weight and fibre length traits were negative and moderate. However, genetic correlations between tautness on one hand and the weight of WAJ1 quality, homogeneity and bristle length are negative and nearly moderate (from 0.30 to 0.40). This would indicate that the heavier the fleece, the higher the homogeneity and the longer the bristles are, the rougher the fleece is. Tautness is subjectively determined by fingering the fleece, and seems to be the result of a general sensation concerning bristle characteristics (diameter, cross section shape) and fleece characteristics (compression, resilience, bristle rate, lock structure, total fleece weight and weight of quality WAJ1). An objective measurement of this trait is still required (ALLAIN *et al.*, 1992). As genetic correlations between tautness and these other traits are higher than phenotypic correlations, an indirect appreciation of tautness, could be obtained by measuring compression and/or resilience as well as the weight of WAJ1, homogeneity and bristle length.

Table 3 : Genetic (above) and phenotypic (below) correlation of fleece traits in A

	Fleece weight	Weight of Quality 1A	Homogeneity	Back bristle length	Back down length	Back lock structure	Haunch bristle length	Haunch down length	Haunch lock structure	Co
Fleece weight		0.89	0.26	0.31	0.66	0.42	0.24	0.37	0.12	
Weight of Quality 1A	0.86		0.65	0.15	0.67	0.55	0.18	0.34	0.20	
Homogeneity	0.28	0.71		- 0.18	0.31	0.47	-0.08	0.11	0.27	
Back Bristle length	0.14	0.15	0.11		0.48	- 0.40	0.93	0.70	- 0.59	
Back down length	0.03	0.09	0.13	0.42		0.58	0.54	0.81	0.21	
Back lock structure	- 0.07	- 0.02	0.05	- 0.29	0.74		- 0.28	0.22	0.72	
Haunch bristle length	0.11	0.14	0.11	0.62	0.27	- 0.17		0.76	- 0.58	
Haunch down length	0.05	0.08	0.10	0.32	0.64	0.44	0.48		0.07	
Haunch lock structure	- 0.05	- 0.04	- 0.01	- 0.23	0.41	0.60	- 0.43	0.58		
Compression	-0.11	- 0.10	- 0.06	0.05	0.05	0.01	0.08	0.06	- 0.01	
Resilience	0.01	0.03	0.03	0.07	- 0.12	- 0.18	0.14	- 0.08	- 0.21	
Tautness	- 0.31	- 0.33	- 0.22	- 0.10	0.06	0.13	- 0.05	0.07	0.12	
Live weight	0.43	0.35	0.08	- 0.05	- 0.19	- 0.17	- 0.11	- 0.21	- 0.12	

Phenotypic and genetic correlations between live weight and wool production (Table 3)

Phenotypic correlations between live weight and fleece weight were positive and moderate (0.43 and 0.35 for total fleece weight and weight of WAJ1 quality respectively) but genetic correlations were negative or insignificant. These results are in contradiction to observations made on the German breed (CARO *et al.*, 1984). However, it would indicate that an optimum body live weight has been reached in the French Angora rabbit breed and that no improvement of fleece weight production could be obtained by selection on live weight.

CONCLUSIONS AND IMPLICATIONS

More information is now available about genetic parameters in the Angora rabbit and more especially in the French Breed. Thus a knowledge of these phenotypic and genetic parameters estimated in this paper provide a basis for predicting the likely genetic consequences of including or removing measurements of fleece weight production and characteristics of the fleece in genetic programme for the Angora rabbit.

A selection scheme based on performance recording system with registration of pedigree and fleece weight by the farmer as well as a visual assessment of breeders by an expert was begun in France in 1956. This scheme has achieved some important improvements, both in regards to wool quantity and fleece quality and was well adapted to the Angora rabbit farming which was based upon marketing of raw wool. The economics of Angora rabbit breeding in France has deteriorated dramatically over the past years (OSSARD *et al.*, 1995) and the selection scheme was terminated in 1992. The remaining breeders are developing a new farming system based upon marketing of Angora finished products, and are establishing a new programme for genetic improvement programme including a new performance recording system with objective measurements of wool quantity and fleece quality.

The French Angora breed have a specific kind of fleece with well differentiated guard hair (ROUGEOT, 1986) and a long and bristly wool is produced. Such bristly fleeces are valued because of their aptitude to produce a fluffy yarn used for certain luxury knit products. In order to take account this feature THEBAULT and ROCHAMBEAU (1988) put forward 3 Fleece quality criteria: homogeneity, lock structure and tautness. This latter criterion which characterizes the roughness of a fleece need to be objectively evaluated. An indirect appreciation could be obtained through measurements of the weight of bristly wool, homogeneity, bristle length, compression and resilience. These 2 latter criteria can only be measured in a laboratory or within an experimental research programme. But the others traits can be easily measured directly at farm during the fleece harvest. Thus by taking account genetic parameter estimates of this study, it would be easy to develop a new selection scheme with performance recorded directly by the farmer: pedigree, total fleece weight and weight of WAJ1, as well as measurements of both bristle length and down length from a lock taken from the back. Such a performance recording system would be efficient with regard to a genetic improvement programme which aimed to increase both quantity and quality of a bristly Angora wool production.

Acknowledgements - The authors gratefully acknowledge the assistance of Mr. M. BONNET, G. BLANIE, G. AUVINET, B. BAYLE and J.C. MUSSEAU, who managed the experimental farm and recorded all the different parameters of the Angora fleece characteristics during the whole conduct of this study.

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Production de lapin Angora : héritabilité de la production quantitative de poils et différentes caractéristiques de la toison chez les lapines adultes - Nous avons étudié 6523 récoltes de poils, produites par 1014 femelles Angora adultes, issues de 187 pères et 373 mères. Ces animaux de souche française sont dépilés toutes les 14 semaines. Nous avons mesuré à chaque récolte le poids total de la toison, celui des cinq qualités, la longueur des jarres et des duvets ainsi que la structure sur le dos et la hanche, la dureté ainsi que la compression et la résilience d'une mèche. Les animaux ont été pesés 9 semaines avant chaque récolte.

Les héritabilités de ces caractères sont comprises entre 0,15 et 0,25. Il existe une corrélation génétique positive et élevée entre le poids de la qualité WAJ1, le poids total de la toison et l'homogénéité (r_g = 0,89 et 0,65). Il en va de même pour les longueurs et les structures mesurées sur le dos et la hanche. La compression et la résilience sont génétiquement liées (r_g = 0,89). Les corrélations génétiques entre la dureté et les autres variables sont faibles à modérées. Il en va de même pour le poids corporel.

Nous discutons les conséquences de ces résultats sur le choix des critères de sélection de l'Angora français.
