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CHARACTERISTICS OF ANGORA RABBIT FIBRE 1 - THE INFLUENCE OF FIBRE ORIGIN ON FIBRE AND MEDULLA DIAMETER IN ANGORA WOOL

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ABSTRACT : The quality of Angora rabbit fibre is known to vary between the countries in which it is produced. A study was made to quantify various parameters of angora fibre quality, including fibre and medulla diameter, and the proportion of medullated fibres, in samples of angora wool obtained from Germany, France and China. The mean fibre diameter of the French angora fleeces (19.8 µm) is significantly higher than in German (12.8 µm) which is related to the higher proportion of coarser hairs in the pelage of French Angora rabbits. French Angora rabbits have a characteristic fleece structure. The down fibres (mean fibre diameter: 14.1 µm) are coarser than in German (12.4 µm) and Chinese (11.8 µm) wool and the degree of medullation in awns and bristles is lower compared to the German and Chinese samples. The characteristics of the German and Chinese Angora coats appear to be very similar. The highest proportion of medullated fibres is observed in the French angora wool (99.9 %). Values of 90.5 % and 96.8 % in the German and Chinese samples are obtained, respectively. The samples of Chinese angora fibre are found to have the highest medulla content (down: 39.2 %; awn: 52.2 %; bristle: 71.9 %). The French angora, in contrast, has a comparatively low medulla content (down: 36.7 %; awn: 29.7 %; bristle: 36.6 %). The medulla content of awns and bristles for German fibres are intermediate to the values obtained from the other samples; the medulla content in the down fibres is relatively low (down: 33.4 %; awn: 41.4 %; bristle: 52.5 %).

RÉSUMÉ : Caractéristiques du poil de lapin angora
1- Influence de l'origine et du poil sur le diamètre des fibres et le type de médullation.
La qualité du poil angora varie selon le pays où elle est produite. Cette étude tend à définir divers paramètres de qualité des fibres - diamètre de la fibre et diamètre médullaire, quantité de fibres médullées - dans des échantillons provenant d'Allemagne, de France et de Chine. Le diamètre moyen du poil d'une toison d'Angora français (19.8 µm) est significativement plus élevé que celui d'une toison d'Angora allemand (12.8 µm) ceci résultant de la part plus importante de poil grossier contenu dans la toison française. La structure de la toison d'Angora français est très particulière : le duvet (diamètre moyen de la fibre : 14.1µm) est plus grossier que chez l'allemand (12.4µm) ou le chinois (11.8 µm) et le degré de médullation du duvet et des jarres est plus faible comparé aux échantillons allemands ou chinois. Les caractéristiques des fourrures allemandes et chinoises sont très similaires. La plus forte proportion de fibres médullées est observée chez l'Angora français (99.9 %) ; les échantillons allemands et chinois atteignent respectivement 90.5% et 96.8%. Le contenu médullaire le plus élevé à été trouvé dans l'échantillon d'Angora chinois (duvet : 39.2%, barbes : 52.2%, jarre : 71.9%). Au contraire, l'Angora français a un contenu médullaire relativement faible (duvet: 36.7%, barbe : 29.7%, jarre : 36.6%). Les valeurs du contenu médullaire des barbes et des jarres des toisons allemandes sont intermédiaires (duvet 33.4%, valeur relativement faible ; barbe 41.4% ; jarre : 52.5%)

INTRODUCTION

Because of its fineness, softness, lightness and good insulating properties, Angora rabbit hair is used in the production of high quality yarns for hosiery and knitting garments. The parameters by which the quality of an Angora rabbit fleece is determined are: fibre length, the proportions of the different types of fibres, mean fibre diameter, the proportion of medullated fibres, crimp and the absence of felt. Grading standards in Germany are generally based on fibre length, cleanness and felt proportion.

In performance tests conducted in 1930, animals with the finest wool (11 - 13 µm) and the lowest proportion of bristles were considered superior (TÄNZER, 1931). This extremely fine down, however, has a low tensile strength and is therefore prone to shedding and tends to wear out quickly. More recent breeding programs have favoured a coarser down which also helps to prevent felting in the fleece (DOTTERWEICH, 1946; NIEHAUS, 1955).

All types of Angora rabbit hairs have a medulla. The tiny air chambers that characterise the angora medulla give the hair its low specific weight (KETTNER, 1962; KOETTER, 1963). Homogeneity in fibre diameter distribution and fibre medullation are very important for uniform dyeing and finishing of fabrics This is because of differences in the dye absorption and light reflectance properties of medullated and non-medullated fibres (ARORA and GUPTA, 1977; GUPTA *et al.*, 1981).

The presence of the medulla also influences the mechanical properties of fibres. In general, partially or completely medullated fibres are harsh and brittle compared to non-medullated ones. Medullation reduces fibre stiffness and strength. This brittleness causes medullated fibres to break easily during processing and makes the spinning of Angora yarn difficult (ARORA and GUPTA, 1977; GUPTA *et al.*, 1981).

It is well known that wool production by Angora rabbits is influenced by genetic, nutritional and environmental factors (SCHLOLAUT and LANGE, 1973, 1983; SCHLOLAUT *et al.*, 1987). Angora wool production is mainly located in China. Because of its high technical and economic level, Angora rabbit breeding plays also a very important role in France and Germany. The present study was undertaken to determine to what extent the characteristics of Angora rabbit hair differ in samples obtained from these three geographic sources.

MATERIALS AND METHODS

The following three textile Angora wool samples [The investigated subsamples were drawn from homogenized mixtures of fleeces of the respective origins. Sampling was carried out considering the standardised method DIN 53803] which were kindly donated by the Hessische Landesanstalt für Tierzucht/Neu-Ulrichstein, are used to determine the fibre characteristics:

1.	German Angora wool,	1. Quality
2.	French Angora wool,	1. Quality
3.	Chinese Angora wool,	Super Grade

The samples were prepared and measured following the standard, IWTO-8-89(E). One thousand fibres of each sample were measured by light microscopy (microprojection) to determine fibre and medulla diameter. The measurements were carried out 1 cm above the base of the hairs. The results were subjected to analysis of variance and differences between means were determined using the Tukey-test.

RESULTS

The parameters of the descriptive statistics were initially calculated for each sample. The results are summarised in Table 1.

Table 1: Fibre and medulla diameter of angora fibre from different origins - Descriptive parameters

	Fibre diameter		Medulla diameter	
Origin	**$\bar{x}$ (µm)**	**s (µm)**	**$\bar{x}$ (µm)**	**s (µm)**
German	12.8	3.71	4.1	2.77
French	19.8	8.02	6.6	4.01
Chinese	12.6	4.70	5.1	4.10

($\bar{x}$ - arithmetic mean, s - standard deviation)

The analyses of variance of the fibre as well as of the medulla diameter measurements demonstrate that the effect of the influence factor *origin* is highly significant ($p < 0.001$). The multiple comparison test results show highly significant fibre diameter differences between the German and French as well as the Chinese and French sample ($p < 0.001$). Furthermore. the differences in medulla diameter between all samples reach statistical significance, also at the $p < 0.001$ level. These results are illustrated in Figure 1

The proportions of medullated fibres differ between the origins. In the German sample, about 90.5 % of fibres are medullated. This was higher in the Chinese (96.8 %) and reached approximately 99.9 % in the French fleeces. Table 2 summarises the mean fibre diameters and the deviation parameters of the medullated fibres of the three samples. As can be seen, the mean fibre diameter of medullated fibres of the French origin is similar to the value obtained for the whole fleece (medullated and unmedullated fibres, see table 1), because 99.9 % of the fibres are medullated. The

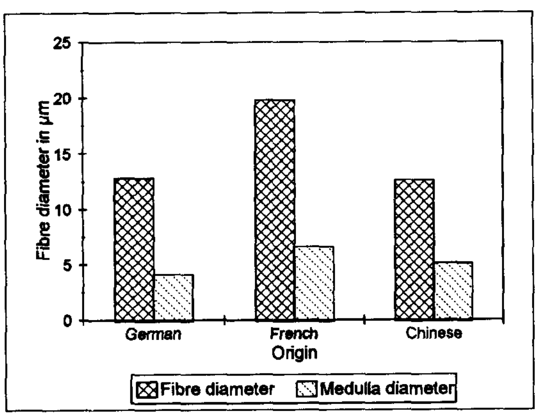

Figure 1 : Mean fibre and medulla diameters of different Angora wool samples

Table 2 : Fibre diameters of medullated fibres of angora fibre from different origins - Descriptive parameters

Origin	**Fibre diameter**	
	$\bar{x}$ (µm)	**s (µm)**
German	13.0	3.59
French	19.8	7.98
Chinese	12.7	4.72

mean fibre diameters of the medullated fibres from the other sources are higher in comparison to the diameter values for the whole sample.

Statistically significant differences were identified in the fibre diameters of medullated hairs from the three sources. The Tukey-test shows highly significant differences in fibre diameter between the German and French as well as French and Chinese samples ($p < 0.001$). The differences in fibre diameter between the German and Chinese sample reaches statistical significance at the $p < 0.05$ level.

Differences in the diameters of non-medullated fibres from China and Germany were not significant. This comparison does not consider the French sample because of the low proportion of unmedullated fibres. Table 3 gives the descriptive parameters.

Table 3 : Diameters of unmedullated fibres of angora fibre from different origins - Descriptive parameters

	Fibre diameter	
Origin	**$\bar{x}$ (µm)**	**s (µm)**
German	10.4	3.93
Chinese	9.4	3.01

The pelage of the Angora rabbit is composed of the following three kinds of fibre (VRILLON and THEBAULT, 1988):

- the bristle (thick and tight hair)
- the awn (medium hair with a thick and tight top and a thin curly body)
- the down (thin and curly hair from the top of the bottom)

To reflect this fleece structure, a more detailed investigation of the fibre type composition of the three samples was made. It was necessary to develop separation criteria to distinguish between these fibre types. After analysing the three samples, a specific fibre separation rule was established. This separation rule includes the following defined fibre diameter classes for the single hair types. These fibre diameter classes follow the mean fibre diameter specifications for different hair types given by SCHLOLAUT (1974): mean fibre diameter: down: 9 - 14 µm; awns: 20 - 30 µm; bristles: 25 - 100 µm.

fibre type	fibre diameter variation
down	6 - 18 µm
awn	16 - 30 µm
bristle	25 - 100 µm

Table 4 : Diameters of different fibre types for angora fibre from different origins. Descriptive parameters.

Origin	Down			Awn			Bristle		
	$\bar{x}$ (µm)	s (µm)	w (%)	$\bar{x}$ (µm)	s (µm)	w (%)	$\bar{x}$ (µm)	s (µm)	w (%)
German	12.4	2.78	95.8	21.7	2.85	4.0	47.0	11.0	0.2
French	14.1	2.78	51.7	23.3	3.44	39.6	38.1	7.02	8.8
Chinese	11.8	2.35	95.0	21.5	3.34	3.4	40.6	7.17	1.6

w = proportion by weight

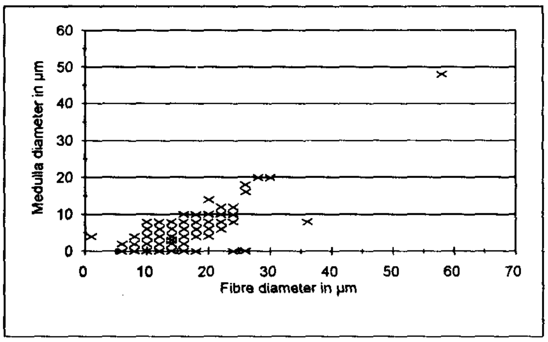

Figure 2 : Relationship between fibre and medulla diameter in German angora fibre

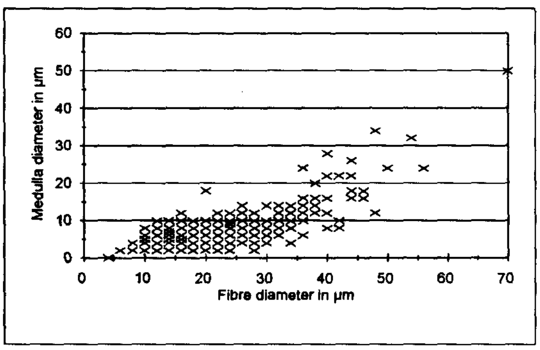

Figure 3 : Relationship between fibre and medulla diameter in French angora fibre

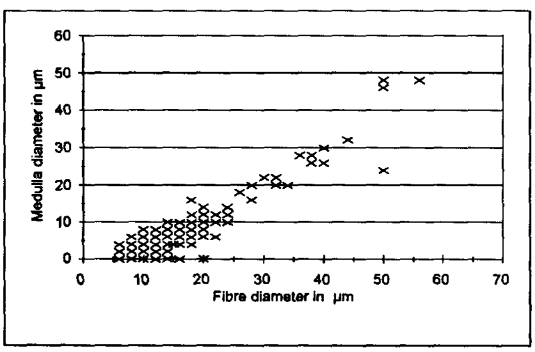

Figure 4 : Relationship between fibre and medulla diameter in Chinese angora fibre

The medullation percentage is used as a second criterion to discriminate fibres in the overlapping zones between the fibre diameter classes. Fibres with a mean fibre diameter between 16 and 18 µm are allocated to the "down class" if the medullation percentage is equal to, or lower than, 60 % and to the "awn class" if the medullation percentage is higher than 60 %. Fibres with a mean fibre diameter between 25 and 30 µm are bristles if the medullation percentage is higher than 80 %. The descriptive parameters for the individual fibre types of the different wool origins are given in Tables 4 and 5. As can be seen, the mean fibre and medulla diameters as well as the percentages of the different fibre types present in the fleece do not explicitly differ for the Chinese and the German origin. The French origin is characterised by a specific composition. It is observed, that the down and awn proportions are completely different compared to the fibre from the other sources and the bristle content is likewise significantly higher.

Table 5 : Medulla diameters of different fibre types of angora fibre from different origins Descriptive parameters -

Origin	Down		Awn		Bristle	
	$\bar{x}$ (µm)	s (µm)	$\bar{x}$ (µm)	s (µm)	$\bar{x}$ (µm)	s (µm)
German	3.8	2.03	8.9	4.38	28.0	20.0
French	5.1	2.06	6.8	2.40	14.4	7.67
Chinese	4.5	1.94	11.3	4.19	29.6	9.22

Figures 2 to 4 illustrate the relationships between fibre and medulla diameters in the whole fleece for the three samples. In each of the samples, there was a close, positive correlation between fibre and medulla diameter. The correlation coefficients were 0.7 for the German and Chinese and 0.6 for the French fibres.

DISCUSSION

The most important supplier of Angora wool is China, with a production of 7 - 8000 t wool per year (SCHLOLAUT, 1988). In Germany, the Angora rabbit breeders are mainly fancy breeders. With an average herd size of 20 animals, about 20 t of wool are produced annually (ROCHAMBEAU and THEBAULT, 1990). The French breeders are divided into farmers for whom the Angora rabbit wool production only constitutes a subsidiary activity and farmers for whom the rearing of this animals is the main source of income (ROCHAMBEAU *et al.*, 1988). France produce about 200 t of

Angora wool annually; the average herd size is 100 up to 150 animals (ROCHAMBEAU and THEBAULT, 1990).

Wool yield as well as guard hair proportion are the most meaningful criteria for the differentiation between the German, French and Chinese Angora rabbit population. The Chinese provenience yields only 52 % and the French population about 62 % of the wool yield compared to the German Angora rabbits (SCHLOLAUT, 1986). THEBAULT and ROCHAMBEAU (1989) observed differences in the wool yield between German and French Angora rabbits of 12 % for females and 26 % for males. Investigations of FLEISCHHAUER *et al.* (1988) showed, that the wool yield of German Angora rabbits (84 g wool per kg live weight) is significantly higher than the wool yield of the French population (44 g wool per kg live weight). The guard hair proportions of German Angora rabbit fleeces vary between 1 and 2 % (SCHLOLAUT, 1986). The values for Chinese Angora wool is about 3 - 5 % (SCHLOLAUT, 1986); the wool of the French origin shows a guard hair proportion of 10 - 12 % (SCHLOLAUT, 1981; YOU-ZHANG, 1992).

Our investigations of these origins show, that a further important differentiation criterion is the development of fibre and medulla diameter. The detailed examination of the different kinds of hair in the fleece demonstrate, that the French Angora wool is distinguished by a specific structure. It is shown that the downs in French fleeces (mean fibre diameter: 14.1 µm) are coarser than in German (12.4 µm) and Chinese (11.8 µm) ones. Furthermore, the lower medullation degree in awns and bristles of French wool compared to the German and Chinese samples, is notable. On the other hand the structure of German and Chinese Angora coats seems to be very similar.

In a comparison of German and French Angora rabbit hair, carried out by DAI *et al.* (1985), the mean fibre diameter values of the French fibres were about 15 % higher than the German hairs. Contrary to this, FLEISCHHAUER *et al.* (1988) could not find any significant wool diameter differences or differences in the proportion of multiple medullated fibres between the German and French Angora wool. In our investigation, it is shown, that the mean fibre diameter in French Angora fleeces (19.8 µm) is significantly higher than in German Angora wool (12.8 µm). This difference is related to the higher content of coarser hairs (awns as well as bristles) in the coat of French Angora rabbits. SCHLOLAUT (1986) observed a guard hair content of about 10 % for French wool. These coarser fibres have a mean fibre diameter of 25 - 100 µm; they are characterised by 3 - 8 medulla channels.

To evaluate the provenience differences, the Angora rabbit breeding aim has to be considered. In the course of the breeding process, generally two different genotypes are established. The objective of German Angora rabbit breeders was to select animals with very fine hairs and a low content of coarse hairs, i.e. Angora rabbits with a more homogenous coat. This wool is particularly processed into smooth, fine yarns for the production of underwear. On the other hand the French wool type is especially used in order to process fluffed yarns for knitwear; therefore Angora rabbits with a higher proportion of coarse hairs in the fleece are bred. The Chinese Angora wool is characterised by very thin, soft and short fibres. The observed conformity in fleece structure and composition of German and Chinese Angora wool results from the considerable Chinese import of German Angora rabbits over years, i.e. crossbreedings of German and Chinese animals and the intensive selection of genotypes with very fine and homogenous fleeces led to this high wool similarity (SCHLOLAUT, 1986).

The wool of German rabbits is gathered by shearing. In comparison, French Angora fleeces are harvested by plucking and Chinese wool by combing. Some authors describe in their investigations, that a further important factor influencing wool thickness is the harvesting method. Szendro *et al.* (1992) observed, that the mean fibre diameter of Angora wool of German rabbits as well as German and French crossbreedings, which is harvested by combing, is 0.53 µm thicker compared to sheared wool. In a population comparison, carried out by FLEISCHHAUER and SCHLOLAUT (1990), it is shown, that the proportion of multiple medullated fibres (guard hairs) and the mean fibre diameter values is influenced by the harvesting method. Plucking, compared to shearing, increased the proportion of multiple medullated fibres for French Angora rabbits (78 %) and French and German crossbreedings (34 %). The coarser hair content of German Angora rabbits was not affected. Likewise, a significantly lower down and guard hair mean fibre diameter could be observed for shorn German Angora rabbits in comparison to plucked animals. The differences in the mean fibre diameter values of our investigation, especially between the French and German as well as French and Chinese sample can also partly be related to the application of different wool harvesting method. Plucking is only practised in France. This method removes a considerable part of the hairs, which completed their growth cycle, including their hair roots. Therefore, the new fleece, growing after plucking, is characterised by juvenile fibres with tops. By contrast, if the fleeces are shorn, the hair roots remain in the follicle. In the shorn fleeces, the hairs were cut at different stages of their growth; the fibre roots remain in the follicles. After shearing, the remaining short hairs grow as long as their growth cycle is completed and the fibres are shed. That is the reason why most of the hairs do not have the thick head, that is typical for the plucked wool (SCHLOLAUT, 1990; FLEISCHHAUER and SCHLOLAUT, 1990). Therefore, it can be concluded, that the observed higher mean fibre diameter of downs (14.1 µm) and awns (23.3 µm) in the plucked French Angora wool compared to the values of the shorn German fleeces (down: 12.4 µm; awn: 21.7 µm) are also related to the harvesting method.

Angora wool of the French origin shows the highest proportion of medullated fibres in the whole fleece (99.9 %). Values of about 90.5 % in the German and approximately 96.8 % in the Chinese sample are found. If we compare the medulla content [The medulla content is calculated as follows: (BIANCA *et al.*, 1974) mean medulla diameter in µm / mean fibre diameter in µm x 100 %] of the three Angora wool origins, it is obvious, that Chinese Angora wool is characterised by the highest values for all fibre types (down: 39.2 %; awn: 52.2 %; bristle: 71.9 %). The French origin shows a comparatively low medulla content (down: 36.7 %; awn: 29.7 %; bristle: 36.6 %). The values of the medulla content of the awns and bristles of German wool lie between the other origins; the value for the downs is relatively low (down: 33.4 %; awn: 41.4 %; bristle: 52.5 %).

Generally, the increase in medulla content reduces the mechanical properties of wool (HOHLS, 1950; ARORA and GUPTA, 1977; GUPTA *et al.*, 1981). Because of the special fineness and the extremely high medulla content of the

Chinese Angora fibres, this wool must theoretically show the most unfavourable mechanical properties. With such a morphological fibre structure, dying of fabrics becomes difficult because of differences in the dye absorbing and reflecting capacities (ARORA and GUPTA, 1977; GUPTA *et al.*, 1981; WORTMANN *et al.*, 1986; SAKLI *et al.*, 1988).

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