16 Nutritional Recommendations and Feeding Management of Angora Rabbits

F. Lebas,[1] R.G. Thébault[2] and D. Allain[1]
[1]INRA, Toulouse, France; [2]INRA Centre Poitou-Charentes, Centrel Surgères, France

16.1 Introduction

The Angora rabbit produces 1.0–1.4 kg year^{-1} of pure fine animal fibre without grease or plant material contamination, named 'Angora wool'. This represents some 0.30 of its live weight, the highest keratin production to live-weight ratio found in any fibre-producing animal. In sheep, goat or camelids, this figure is generally <0.10.

The capacity of the Angora rabbit to convert food to keratin requires that particular attention be given to its nutrition. There are two important nutritional objectives:

1. To provide all the nutrients the rabbit needs to realize its genetic potential for wool production.
2. To avoid any disorder that may reduce the life-time performance of the animal.

Individual productive longevity (3–4 years on average) is an important economic parameter in the Angora production system.

There is a considerable paucity of information on Angora rabbit nutrition compared with published work on the production of meat from rabbits or wool from sheep. This applies to the genetics and physiology of Angora wool growth, as well to other areas of study such as pathology. In practice, producers have observed that the nutrient requirements of Angora rabbits bred for wool production are similar to those of breeding does kept for meat production and consequently have used this knowledge as a basis for diet formulation. Nevertheless, some specific modifications are necessary.

For a long time, Angora rabbits were fed in the same way as rabbits kept for meat production on a mixture of cereals (oats, barley or wheat), lucerne hay and fresh forages such as cabbage or fodder beet. Since the 1960s, complete diets based on pelleted concentrates have been used extensively in rabbit meat systems; Angora rabbit farmers, however, continued with the traditional feeding method through the 1970s, while Angora wool yields remained <850 g year^{-1}. To improve wool yields, a mixture of 0.75 traditional feed and 0.25 supplementary feed pellets was subsequently used in some practical systems (Rougeot and Thébault, 1984). Other producers began using pelleted concentrates alone for Angora breeding does. By the beginning of the 1980s, as the genetic potential for wool production exceeded 1 kg per animal year^{-1}, the use of specific pelleted diets formulated for Angora production became general practice as feed quality and safety (absence of induced disorders) were also improved. Schlolaut (1985) quantified the production advantages of concentrate feeds. Taking the Angora wool yield obtained with these as 1.00, mixed feeding (raw products plus cereals) and hay-based feeding reduced the yearly wool production to 0.85 and 0.72, respectively.

16.2 Nutritional Requirements

This chapter considers the nutrient requirements of Angora wool-producing females, since males are not frequently employed because of their lower wool production (5–10% less). Animals producing Angora wool are assumed to be adults with no production other than wool. For breeding does or growing animals, the recommendations are those proposed for meat production rabbits (see Chapters 10 and 14).

16.1.1 Consequences of daily variations in wool production

The amount of hair covering the body plays an important role in thermal insulation and heat loss. In France, Angora rabbits are de-fleeced every 3 months and are consequently completely or relatively naked and without thermal protection for 2–3 weeks. Vermorel *et al.* (1988) demonstrated a large increase in heat production just after the harvest (Tables 16.1 and 16.2). To reduce heat loss, some form of protection is often provided, either in the form of a woollen jacket ('jersey rabbits') or by leaving a strip of fleece on the back ('strip rabbits'). Such techniques are less common with the German strain because the animals are shorn (i.e. a few millimetres of stubble is always left above the skin), which limits heat loss. In addition, German Angora rabbits have a higher proportion of down in the fleece, which improves thermal insulation. Nevertheless, whatever the Angora strain, the period of 2–3 weeks after harvesting is when energy requirements for thermal regulation are at their highest.

A further source of variation for nutrient requirements is the hair growth rate (i.e. the rate of keratin synthesis). The highest growth rate is observed during the fourth week after harvesting (31.7 g week^{-1}), with a reduction in the weekly wool output after this period (Fig. 16.1). Between weeks 4 and 14, the wool output is halved.

According to these data, nutrient and energy requirements appear to be maximum for energy, protein and sulphur amino acids (SAA, the main components of keratin) in the first month following fleece harvesting. The weekly requirements vary during the 3 months between two consecutive harvests (Table 16.3) and have been summarized by Rougeot and Thébault (1984).

16.1.2 Nutrient recommendations

As previously mentioned, Angora rabbits are now fed with balanced pelleted feeds. The desirable composition of such feeds has

Table 16.1. Skin temperature and total and net radiative heat flow of Angora rabbits before and after de-fleecing, with or without a strip of hair on the back or a jersey jacket (means of six different spots measured during the 2 days following harvest ± standard deviations) (from Vermorel *et al.*, 1988).

			'Strip rabbits'		'Jersey rabbits'	
	Before harvest	After complete de-fleecing	On the hair strip	Naked areas[a]	With woollen jacket	Without woollen jacket
No. of animals	6	6	9	9	6	6
Skin temperature at 10°C	38.8 ± 0.4	36.5 ± 0.6	–	37.9 ± 0.6	31.9 ± 0.5[b]	36.4 ± 0.7
Total radiative heat flow at 15°C (W m^2)	422 ± 5	513 ± 12	416 ± 7	519 ± 7	479 ± 6	515 ± 7
Net radiative heat flow at 15°C (W m^2)	23 ± 6	176 ± 7	35 ± 6	187 ± 12	24 ± 12	177 ± 7

[a]Means of values obtained on the thigh, thorax and abdomen.
[b]Temperature on the jersey jacket.

Table 16.2. Heat production (kJ kg^{-1} $W^{0.75}$ h^{-1}) of Angora rabbits before de-fleecing (at 10°C) and after de-fleecing, with or without a strip of hair or a jersey jacket (for 2 days) and after harvesting the strip of hair or removing the jersey jacket (for 2 days) (means ± standard deviations) (from Vermorel *et al.*, 1988).

	‘Strip rabbits’				‘Jersey rabbits’			
			Strip of hair				Jersey jacket	
Environmental temp.	*n*	Before de-fleecing	With	Without	*n*	Before de-fleecing	With	Without
15°C	2	18.1 ± 2.0[a]	20.8 ± 0.2[a]	29.9 ± 1.3[b]	–	–	–	–
10°C	4	16.7 ± 0.3[a]	23.2 ± 2.4[b]	32.6 ± 1.5[c]	5	17.6 ± 1.0[a]	28.9 ± 1.7[b]	32.8 ± 2.0[c]
5°C	3	16.3 ± 2.6[a]	25.5 ± 3.3[b]	35.6 ± 2.7[c]	–	–	–	–

[a,b,c]For the same type of animals and the same environmental temperature, values with different superscripts are significantly different (P <0.05 or P <0.01).

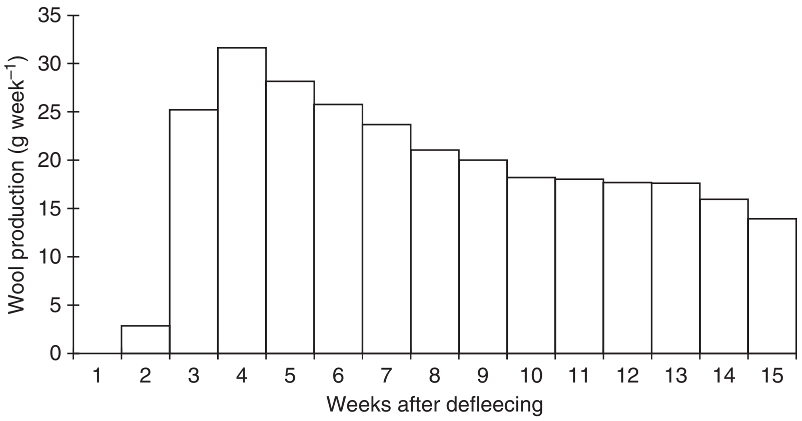

Fig. 16.1. Variations in wool production (g $week^{-1}$) between two harvests. From Rougeot and Thébault (1984).

Table 16.3. Monthly variations in nutrient and energy requirements for French Angora rabbits between two wool harvestings (recalculated from Rougeot and Thébault, 1984).

	Month 1	Month 2	Month 3
Crude protein (g)	190	175	160
Fat (g)	37	34	31
Crude fibre (g)	205	190	170
Sulphur amino acids (g)	10	9	8
Digestible energy (MJ)	12.6	11.6	11.5

been the object of specific experiments. The recommendations proposed by different authors are a combination of the results of a critical analysis of the available ‘Angora’ data and of the recommendations proposed for meat rabbits. Table 16.4 presents the recommendations of German and Chinese authors, where available, and the recommendations proposed by the authors of the current chapter.

16.1.3 Energy

Recommendations for dietary digestible energy (DE) content are in the same range for German (Schlolaut, 1985), Chinese (Liu *et al.*, 1992) and French authors (Rougeot and Thébault, 1984; Charlet-Lery *et al.*, 1985). Nevertheless, German and Chinese data are not very precise since the variation between the proposed minimum and maximum

Table 16.4. Nutrient recommendation for adult Angora rabbits.[a]

Nutrients	Unit kg^{-1}	Source of recommendations Germany[b]	China[c]	Current work
Digestible energy	MJ	9.6–10.9	10.0–11.7	10.5
	Kcal	2,300–2,600	2,400–2,800	2,500
Lipids	g	20	30	30
Crude fibre	g	140–160	120–170	140
Crude protein	g	150–170	150–160	160
Digestible protein	g	–	110	122
Lysine	g	5	7	7
Methionine + cystine	g	7	7	8
Arginine	g	6	7	6
Minerals				
Calcium	g	10	–	8
Phosphorus	g	3–5	–	4
Sodium	g	2.5	–	3
Potassium	g	7	–	13 maximum
Chloride	g	4	–	4
Sulphur	mg	–	–	400
Magnesium	mg	300	–	300
Iron	mg	50	–	50
Copper	mg	10	–	50
Zinc	mg	50	–	50
Manganese	mg	10	–	10
Vitamins				
A	IU	6,000	–	10,000
D_3	IU	500	–	800
E	mg	20	–	40
K	mg	1	–	1

[a]As-fed basis with 890 g dry matter kg^{-1}.
[b]Schlolaut (1985).
[c]Liu *et al.* (1992).

represents 13–17% of the minimum. The Hungarian recommendations are also in the same range: 10.7 MJ kg^{-1} (Tossenberger and Henics, 1988; Henics *et al.*, 1989). The recommendation is accordingly 10.5 MJ kg^{-1} of feed on an as-fed basis.

According to Charlet-Lery *et al.* (1985), metabolizable energy (ME) represents 0.95 of DE content; in addition, the same authors have indicated that energy utilization by Angora rabbits, as DE or ME, is independent of the season or the time since the previous wool harvest.

16.1.4 Protein

Among German, Chinese and French data, there is agreement on dietary protein requirements, which are in the order of 160 g kg^{-1}. On the other hand, the Hungarian recommendations are higher at 196 g kg^{-1} (Tossenberger and Henics, 1988; Henics *et al.*, 1989). However, this latter recommendation is based on an experiment in which protein and SAA were studied simultaneously and where the lowest protein level tested was 175 g kg^{-1} with a relatively low SAA content. Thus, this recommendation for a very high concentration of protein seems unrealistic and has not been retained.

16.1.5 Crude fibre

No specific study has been published on dietary fibre content as a possible source of variation in Angora wool production. The recommendations of various authors are easily calculated from the analysis of practical diets employed. The available recommendations are currently expressed only in terms of the level of crude fibre. However, one of the roles of dietary fibre is to remove hair swallowed by the rabbit from the digestive tract. To achieve this objective, a significant proportion of dietary fibre must be non-digestible; a minimum level of lignin seems reasonable to reduce fibre digestibility and, to achieve this latter objective, a value of 40 g acid detergent lignin (according to the Van Soest methodology) kg^{-1} may be proposed.

16.1.6 Amino acids

Lysine

German recommendations for dietary lysine in Angora rabbit production are 5 g kg^{-1} diet, significantly lower than the 7 g kg^{-1} suggested by Chinese data; however, neither of these figures is based on direct experiments. Lysine is not an important component of keratin, but it does play a significant role in body protein turnover and assists the animal in restoring its live weight following the body weight loss observed after de-fleecing. Therefore, a level of 7 g of lysine kg^{-1} feed is recommended for Angora rabbits.

Methionine and cystine

Several studies have been undertaken in Germany (Schlolaut and Lange, 1983), Hungary (Henics *et al.*, 1990) and France (Lebas and Thébault, 1990) on the requirements for SAA. From this last work (Table 16.5), it has been concluded that, for a level of wool production >1000 g $year^{-1}$, SAA intake is an important limiting factor. Practical recommendations for SAA are 8 g kg^{-1} diet on an as-fed basis. A more recent study (F. Lebas and R.G. Thébault, unpublished data) indicates that efficient SAA supplementation can be achieved with either D,L-methionine or L-cystine. Under some conditions, a slight advantage can be attributed to cystine supplementation. Nevertheless, for economic reasons SAA supplementation, if necessary, is recommended in the form of D,L-methionine.

The Hungarian SAA recommendation is 9 g kg^{-1} diet (Henics *et al.*, 1990), but this figure was obtained after a comparison of only two SAA dietary levels: 5.6 and 9.0 g kg^{-1}. Because the highest level examined in the French study (8.8 g SAA kg^{-1}; Lebas and Thébault, 1990) failed to induce any improvement in wool production above that achieved with 8.0 g kg^{-1}, the Hungarian recommendation of 9 g kg^{-1} leads to a significant SAA wastage and is not considered practical.

Other amino acids

No specific evaluation has been undertaken for the other amino acids. The current die-

Table 16.5. Mean relative performances of Angora rabbits receiving sulphur amino acid (SAA) supplementation at different dietary levels (adjusted by co-variance analysis to an initial live weight of 4.128 kg). Fleece weight 1.00 = 264.2 g per harvest, feed intake 1.00 = 15.57 kg between two harvests. Other nutrients are as recommended in Table 16.4 (from Lebas and Thébault, 1990).

	Dietary SAA level (g kg^{-1})					
Performance	5.6	6.4	7.2 (control)	8.0	Residual coefficient of variation	Statistical probability
Number of harvests	69	62	76	60	–	–
Fleece weight	0.948^{a}	1.008^{b}	1.000^{b}	1.056^{c}	0.135	0.002
Feed intake	0.991	1.000	1.000	1.006	0.043	NS
Feed efficiency^{d}	0.951^{a}	1.005^{bc}	1.000^{b}	1.049^{c}	0.127	0.004
Live weight	0.990	1.020	1.000	1.006	0.07	NS

NS, not significant.

^{a,b,c}Values with different superscripts are significantly different (P <0.05 or P <0.01).

^{d}Calculated as g wool produced per g feed intake.

tary recommendation for arginine (7 g kg^{-1}) is based only on the actual content observed in adequate Angora diets. In the absence of further information, the recommendations for growing rabbits are suitable.

16.1.7 Minerals and vitamins

As for most of the amino acids, the current recommendations for minerals (Table 16.4) are derived from the observed composition of Angora diets and from knowledge of the mineral requirements of growing and adult meat rabbits.

The German recommendation for vitamin A (6000 IU kg^{-1}; Schlolaut, 1985) is lower than the recommendation of 10,000 IU kg^{-1} proposed in France by Rougeot and Thébault (1984). Hungarian experimental results (Table 16.6) indicate clearly that 5000 IU kg^{-1}, which is very close to the German recommendation, is not adequate for Angora wool production (Kovácsné-Virányi, 1990). By comparison with meat rabbit reproduction, it can be assumed that the maximum level employed in the Hungarian experiments is too large and the proposed recommendation is 10,000 IU vitamin A kg^{-1}, which is the same as for most meat rabbits. A complementary experiment included in the same Hungarian publication demonstrated that β-carotene can sometimes completely replace the supply of vitamin A, but the two experiments were not precise enough to support any calculation of the transformation of β-carotene into vitamin A.

It is important to note that dietary vitamin D levels should not exceed 800 IU kg^{-1}. Adult females that are not reproducing, lactating or growing are susceptible to heart valve and kidney calcification with D hypervitaminosis (Thébault and Allain, 1995).

16.2 Feeding Management

As mentioned in the introduction, in practice Angora rabbits are fed balanced pelleted feeds (3–5 mm pellet diameter). In addition, they must have permanent access to clean fresh water. Daily water intake is about 0.33 l per animal day^{-1}, with a large variation between animals and season. Significant mortality can be observed if insufficient water is available during a hot period. Dietary roughage, supplied once or twice a week as straw or hay or *ad libitum* as straw bedding, is not essential for health or wool production in the Angora rabbit (Rougeot *et al.*, 1980). However, when straw is fed, average daily intake falls from 19 to 13 g between the first and third months following the harvest. Greater variations are observed between individual rabbits (e.g. straw intakes from 43 to only 3 g day^{-1}) without any apparent effects on wool production.

16.2.1 Feed restriction

Preliminary studies showed that feed restriction decreases wool production by 14.7% (Rougeot and Thébault, 1977) or 9.2% (Schlolaut and Lange, 1983). In both of these studies, however, feed restriction was severe and no account was taken of the variability in hair growth rate between harvests. More recently, Lebas and Thébault (1988) have shown that feed intake can be reduced by 61% in winter

Table 16.6. Relative effect of dietary supplementation with vitamin A or β-carotene on the quantity of hair produced by a surface of 14 cm^2 of skin shaved once a week during 8 consecutive weeks (from Kovácsné-Virányi, 1990). Value for the control, 1.000 = 1.17 g.

	Control (5000 IU vitamin A kg^{-1})	Vitamin A + 15.000 IU kg^{-1}	β-Carotene + 45 μg kg^{-1}
No. of rabbits	5	7	7
Hair production	1.000^{a}	1.132^{b}	1.055^{ab}

a ≠ b ($P = 0.05$).

and 26% in summer with an adapted feed restriction (1200 g week^{-1}) during the first month following harvest without any adverse effects on wool production (Fig. 16.2 and Table 16.7).

However, the Angora rabbit seems unable to regulate daily intake and some does are able to consume >400 g day^{-1} and exceptionally 500 g day^{-1} during the first 2 weeks following harvest. This can cause nutritional disorders (e.g. enterotoxaemia), which occur when pellets are fed *ad libitum*.

A restricted feeding regime, as described in the next section, has been developed using the pattern (Fig. 16.1) of weekly hair production over the 3 months of hair growth between harvests (Rougeot and Thébault, 1984). This has now been adopted in commercial practice.

- First month: 1200 g per animal week^{-1}.
- Second month: 1100 g per animal week^{-1}.
- Third month: 1000 g per animal week^{-1}.

The weekly ration must be distributed equally over 6 days a week as Angora rabbits are not able to self-regulate their feed intake.

16.2.2 One fasting day a week

A fasting day is essential when fibres are long or when hair losses are observed. Angora rabbits, like most mammals, lick their fleece when grooming. Hair is swallowed, representing 0.3–0.4 g day^{-1} during the last month between harvests (Charlet-Lery *et al.*, 1985). As the rabbit is unable to vomit, long hair mixed with feed material is retained in the

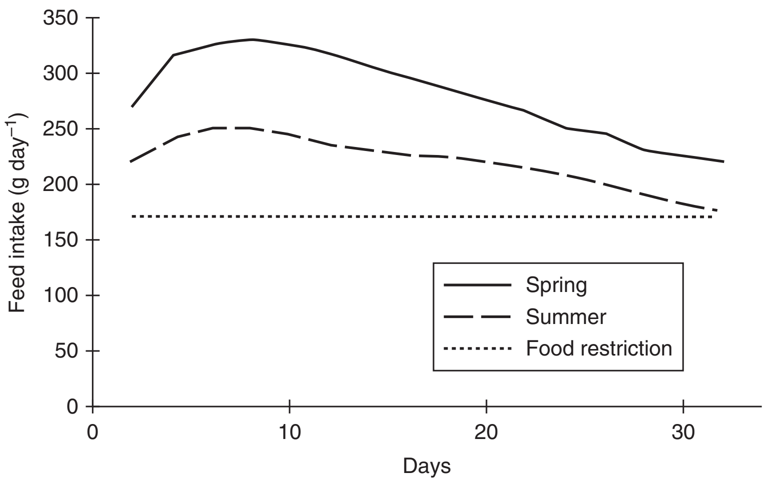

Fig. 16.2. Change in daily feed intake of Angora rabbits restricted-fed or fed *ad libitum* during the 5 weeks following de-fleecing, in spring and summer (from Lebas and Thébault, 1988).

Table 16.7. Live weight (g) 5 weeks after the last de-fleecing and wool production at the next harvest of Angora rabbits (mean ± standard error of the mean) with or without feed restriction during two different seasons (from Lebas and Thébault, 1988).

		Ad libitum	Feed restriction	Statistical probability
Live weight (g)	Spring	4457 ± 106	4244 ± 47	0.014
	Summer	4234 ± 73	4127 ± 44	0.08
Wool production (g)	Spring	258.3 ± 8.7	259.8 ± 6.6	NS
	Summer	235.9 ± 6.4	246.5 ± 8.7	NS

NS, not significant.

stomach. It rapidly forms a stomach hair ball (trichobezoar), which blocks the pylorus and prevents gastric emptying. The animal stops feeding and will die. Plitt-Hardy and Dolnick (1948) described this phenomenon and Rougeot and Thébault (1977) observed the death of five out of 11 females fed a pelleted diet *ad libitum*. Autopsy revealed the presence of a trichobezoar in the stomach of each animal. Feed restriction and fasting on 1 day week^{-1}, when only straw or bulky forage is available, will facilitate voiding of ingested hair in hard faeces. On the day following the fast, hard faecal pellets connected to each other are often observed.

16.3 Conclusions

As Angora rabbits are housed in individual cages, it is very easy to control their feeding regime. When traditional raw feeds such as hay and cereals are used, no specific nutritional problems occur. Angora rabbits that have been selected for wool production cannot, however, achieve their genetic potential on such a regime. In addition, when hay is floor-fed inside the cage or even distributed in a feeding rack, vegetable matter tends to 'contaminate' the fleece, which drastically reduces its commercial value. For these reasons, most commercial Angora rabbits are fed a specific pelleted balanced diet. Pelleted concentrates have the advantage that nutritional characteristics are precise and constant, feed storage is minimum and labour costs for feeding are reduced. Some precautions are necessary when using a complete pelleted diet. Finally, water must be supplied *ad libitum* using an automatic watering trough. To avoid wastage and nutritional disorders, a restricted feeding regime adapted to variations in both feed requirements and hair growth should be adopted. Fasting once a week will avoid the formation of a stomach hair ball, which, should it occur, is invariably fatal.

References

Charlet-Lery, G., Fiszlewicz, M., Morel, M.T., Rougeot, J. and Thébault, R.G. (1985) Variations annuelles de l'état nutritionel de la lapine angora durant les pousses saisonnières des poils. *Annales de Zootechnie* 34, 447–462.

Henics, Z., Tossenberger, J. and Gombos, S. (1989) [Digestion, and wool production of Angora rabbits depending on the energy, protein and methionine content of feeds]. *1. Nyultenyéstési Tudományos Nap, Kaposvar (Hungary) 26 Május 1989*, pp. 80–99.

Henics, Z., Biróné Németh, E., Szendrö, Z. and Tossenberger, J. (1990) [Effect of diet's sulphur amino acid content on wool production of males, female and castrated males Angora rabbits]. *2. Nyultenyéstési Tudományos Nap, Kaposvar (Hungary) 16 Május 1990*, pp. 68–74.

Kovácsné-Virányi, A. (1990) [Effect of vitamin A deficiency on the wool production of Angora rabbit]. *2. Nyultenyéstési Tudományos Nap, Kaposvar (Hungary) 16 Május 1990*, pp. 91–96.

Lebas, F. and Thébault, R.G. (1988) Influence of *ad libitum* feeding 5 weeks after plucking on wool production in Angora rabbits. In: *Proceedings of the 4th World Rabbit Congress, Budapest*, Vol. 3. Sandor Holdas, Hercegalom, Hungary, pp. 249–253.

Lebas, F. and Thébault, R.G. (1990) Besoins alimentaires en acides aminés soufrés chez le lapin Angora. In: *5èmes Journées de la Recherche Cunicole, Paris*. Communication no. 49, ITAVI, Paris, France.

Liu, S.M., Zang, L., Chang, C., Pen, D.H., Xu, Z., Wang, Y.Z., Chen, Q., Cao, W.J. and Yuan, D.Z. (1992) The requirements of digestible energy, crude protein, and amino acids for Angora rabbits. *Journal of Applied Rabbit Research* 15, 1615–1622.

Plitt-Hardy, T.M. and Dolnick, E.H. (1948) Angora rabbit wool production. US Department of Agriculture Circular no. 785, USDA, Washington, DC, USA, pp. 1–22.

Rougeot, J. and Thébault, R.G. (1977) Formation de trichobezoards chez le lapin Angora nourri *ad libitum* avec un aliment aggloméré. *Revue Médecine Vétérinaire* 153, 655–660.

Rougeot, J. and Thébault, R.G. (1984) *Le Lapin Angora, sa Toison, son Élevage*. Le Point Vétérinaire, Maisons Alfort, France.

Rougeot, J., Colin, M. and Thébault, R.G. (1980) Définitions de conditions expérimentales pour l'étude des besoins nutritionnels du lapin: nature de la litière et présentation du lest alimentaire. *Annales de Zootechnie* 29, 1–11.

Schlolaut, W. (1985) *Abrégé de Production Cunicole*. Deutsche GTZ GmbH, Eschborn, Germany, pp. 215–216.

Schlolaut, W. and Lange, K. (1983) Untersuchungen über die beeinflussung quantitiver merkmale der wolleistung beim Angorakanichen durch geschlecht, alter, fütterungstechnik und methioningehalt des futters. *Züchtungskunde* 55, 69–84.

Thébault, R.G. and Allain, D. (1995) Dietary requirements and feeding management of Angora rabbits. In: Laker, J.P. and Russel, A.J.F. (eds) *The Nutrition and Grazing Ecology of Speciality Fibre Producing Animals*. Occasional Publication No. 3, European Fine Fibre Network, Aachen, Germany, pp. 71–84.

Tossenberger, J. and Henics, Z. (1988) Effect of energy, protein and sulfur amino acids on wool production of Angora rabbits. In: *Proceedings of the 4th World Rabbit Congress, Budapest*, Vol. 3. Sandor Holdas, Hercegalom, Hungary, pp. 274–280.

Vermorel, M., Vernet, J. and Thébault, R.G. (1988) Thermoregulation of Angora rabbit after plucking. 2. Heat loss reduction and rewarming of hypothermic rabbits. *Journal of Animal Physiology and Animal Nutrition* 60, 219–228.