WORLD RABBIT SCIENCE 2000, VOL. 8 (1), 23-32.

RECENT ADVANCES IN RABBIT NUTRITION : EMPHASIS ON FIBRE REQUIREMENTS. A REVIEW.

GIDENNE T.

Institut National de la Recherche Agronomique, INRA, Centre de Toulouse, Station de Recherches Cunicoles, BP 27, 31326 CASTANET-TOLOSAN Cedex, France
Email : gidenne@toulouse.inra.fr

ABSTRACT : The rabbit meat production knew deep modifications during the ten last years, on the techniques of breeding as well as on the genetic potentialities of growth or reproduction. The techniques of feeding (adapted feed formulation etc.) also strongly progressed, in order to obtain a better adjustment of feeds to the animals needs, e.g. according to their physiological stage. This paper summarised the recent advances and perspectives, which we consider significant in the field of the nutrition of growing rabbits and reproductive females. Particular attention will be devoted to the dietary fibre definition and requirements and to the relationship with digestive pathology, as mortality by diarrhoea is still a major question in rabbit breeding.

RÉSUMÉ : Dernières avancées en nutrition du lapin – le point sur le besoin en fibre.
Durant les dix dernières années, l'élevage du lapin de chair a connu de profondes modifications, tant sur les techniques d'élevage (usage répandu de l'insémination artificielle, élevage en bande) que sur les potentialités génétiques de croissance ou de reproduction des animaux issus des souches commerciales hybride. Les techniques d'alimentation (fabrication, formulation adaptée...) et les besoins des animaux ont donc également fortement évolué, afin d'obtenir un meilleur ajustement des aliments aux besoins des animaux, en fonction de leur stade physiologique. Cet article a pour but de présenter, les progrès récents que nous jugeons significatifs dans le domaine de la nutrition du lapin de chair et de la femelle reproductrice. Nous soulignerons plus particulièrement la définition des besoins en fibres et les relations avec la pathologie digestive, sachant que la mortalité par diarrhée du lapin en croissance est toujours un problème majeur en élevage cunicole.

INTRODUCTION

During the ten last years, rabbit breeding knew deep modifications, on the techniques of breeding (widespread use of artificial insemination, breeding in batches) as well as on the genetic potential of growth or reproduction of animals resulting from the hybridization of commercial stocks. The techniques of feeding (manufacture, adapted formulation...) and the recommendations for the animals thus also strongly evolved, in order to obtain a better adjustment of feeds to the needs of the animals, according to their physiological stage.

Our intention is not to summarise the whole of progress in rabbit nutrition, knowing that a book on the nutrition of the rabbit was published in 1998 (DE BLAS and WISEMAN, 1998). We will present on the other hand, the recent progress, which we consider significant in the field of the nutrition of rabbit. We will more particularly underline the definition of the fibre requirements and the relationships to digestive pathology, as mortality by diarrhoea is always a major problem in rabbit breeding.

METHODS FOR MEASURING FEED DIGESTIVE EFFICIENCY

We would first mention a recent effort of standardisation of measurements of faecal apparent digestibility (PEREZ *et al.*, 1995), within the framework of a research group EGRAN (GIDENNE, 1999). This standardisation of measurements, currently limited to in-vivo measurement of the dry matter digestibility, should be implemented by recommendations on major nutrient analyses.

The overall digestion of a feed does not seem being affected by the genetic type of growing rabbit (PEREZ *et al.*, 1999). On the other hand, the digestion in the doe is lower (-3 to -5 units) than that of the growing rabbit (PEREZ *et al.*, 1996a), and this could depend on the energy level of the diet. Consequently, if the digestion of a diet adapted to lactating females is determined on growing rabbits, that would lead to an overestimation of the level of digestible nutrients. Similarly, if the needs of the females are determined from their performances, we overestimate their requirement in digestible nutrients, if the latter are calculated from growing digestibility values. That reinforces the need for expressing the requirements in digestible nutrients (cf. table 1), but obtained with appropriate measurements.

REQUIREMENTS IN PROTEIN AND ENERGY

The proteic and energetic needs of the doe are relatively high, in particular when simultaneously pregnant and lactating (XICCATO, 1996). However, since work of MAERTENS and DE GROOTE (1988), the recommendations in term of relative supply in digestible protein (DP) compared to digestible energy (DE) are unchanged. A ratio between 12.5 and 11.0 g

This paper was presented in part at the Portuguese Congress of Animal Husbandry (APEZ), held in Porto (11-13 November 1999).

Table 1 : Requirements in energy, protein and in some major amino acids.
(as concentration per kg of raw feed, corrected for a dry matter content of 900 g/kg)

		Fattening rabbits		**Breeding does**		
	Unit	**Post weaning** (till 45d of age)	**End of fattening**	**Young Does**	**Intensive rhythm**	**Semi-Intensive**
DE : Digestible Energy	*Kcal* *MJ*	2250-2350 9.4-9.8	2350-2450 9.8-10.3	2150-2250 9.0-9.4	2600-2700 10.9-11.3	2500-2600 10.5-10.9
Digestible protein "DP" (Nx6.25)	g g/MJ DE	≥ 115 12.0-12.5	110-115 11.5-12.0	100-110 10.5-11.5	130-140 11.8-12.5	125-130 10.5-11.5
Lysine *total* digestible	g/MJ DE	*≥ 0.78* ≥ 0.62 (1)	*≥ 0.70* ≥ 0.52 (1)	?	*0.61-0.69* 0.44-0.50 (2)	*0.64* 0.46 (2)
Metionine+ Cystine *total* digestible	g/MJ DE	*0.67-0.80* 0.50-0.60 (3)	*0.60-0.70* 0.45-0.52 (3)	?	*0.49-0.59* 0.36-0.43 (4)	*0.49-0.51* 0.36-0.38 (4)
Threonin *total* digestible	g/MJ DE	*0.62-0.66* 0.42-0.45 (5)	*0.55-0.60* 0.37-0.41 (5)	?	*0.56-0.61* 0.37-0.41 (6)	*0.58* 0.38 (6)

1): digestibility estimated to 74% ; (2): digestibility estimated to 72% ; (3): digestibility estimated to 75% ; (4): digestibility estimated to 73% ; (5): digestibility estimated to 68%; (6): digestibility estimated to 66% .

DP/MJ DE is proposed, respectively for an intensive rhythm of reproduction or not (table 1). The impact of the source of energy (lipids vs starch) on the gestation and lactation was specifically treated by FORTUN-LAMOTHE *et al.* (1999).

The requirements in energy and protein for growth depend on several factors, such as the weight at weaning and the growth rate. Since the studies of DE BLAS *et al.* (1981, 1985), few works were devoted to the relationship between energetic and proteic supply. A supply of 10g DP/MJ DE had then been defined for optimal performances, but the growth rate was lower than 40g/d. Presently, a commercial feed often presents a higher ratio DP/DE (11.5 to 12.5). It is now necessary to validate these recommendations for actual rabbit hybrid lines, having a higher growth rate (meanly between 45 and 50g/d) particularly during the post-weaning period, when the rabbit fully expresses its growth potential (> 50g/d). MAERTENS *et al.* (1997, 1998) show that the reduction of ratio DP/DE mainly affects the growth during the 3 weeks after weaning. Moreover, it confirms that the nitrogen retention increases with the proteic dilution of the diet, and thus reduced the nitrogen excretion. According to MAERTENS, it seems possible to reduce the protein supply in finishing rabbit (from 12.5 to 11.5 g DP/MJ DE), without increasing the fatness of the carcasses, nor affecting the performance. It could thus lead to a significant reduction of nitrogen output (-10%) in the environment.

On the other hand, very few studies concerned the effects of the ratio DP/DE on digestive pathology and mortality in fattening rabbits.

AMINO ACID REQUIREMENTS

New recommendations for the major amino acids (AA) were proposed recently by Madrid University (team of Prof. DE BLAS). The methodology was based on an evaluation, for female and growing rabbits, of the same dietary model (range of AA supply), relatively rich in digestible energy (10.7 MJ/kg), in which the formulation was adapted to the lactating female (intensive reproduction rythm). This can present a disadvantage in estimating the needs with a level of ingestion relatively low for the growing rabbit, and thus to over-estimate slightly the requirements. Indeed, if the dietary concentration in digestible energy were weaker, the ingestion of the animal would be higher, as would its ingestion of AA. We–could thus recommend a lower dietary level of AA, in proportion of the rise of the feed intake; or requirements must be expressed in g/day of AA, or as presented in table 1 in g/MJ DE.

Similarly in these studies, feed digestibility was measured only on growing rabbits (live-weight = 1.6-1.8 kg), having a higher digestive efficiency (+3 to +5 units) than that of females (PEREZ *et al.*, 1996a). The requirement in digestible AA estimated here for the females is in fact probably slightly lower.

We thus presented in the table 1 recommendations, which take account of the previous remarks. Furthermore to be consistent with the recommendations for digestible protein, and to avoid excess or deficiency in the real intake of AA, we proposed to use for AA the following unit: g/MJ DE.
The optimum lysine level was estimated to be between 0.71 and 0.76% to maximise the growth rate and feed

conversion (TABOADA *et al.*, 1994). The authors proposed a lysine recommendation of 0.75% (raw basis), if the digestibility of lysine is 74% (synthetic acid amino equal to 15% of the total, i.e. a crude protein digestibility of approximately 70%). The authors pointed out that it is preferable to express this requirement using digestible lysine and recommended a supply of 0.59% digestible lysine in the feed.

For the breeding doe (receiving a feed with 10.71 MJ DE/kg) the requirement in digestible lysine was estimated at 0.52% (0.68% crude lysine) to obtain maximum reproductive performance (e.g. kits weaned per doe/perlitter) (TABOADA *et al.*, 1994). In addition, the authors showed that at levels between 0.64 and 0.76% of crude lysine, the milk production increased noticeably as well the litter weight (at 21d.). If we would promote a high milk production and a high litter weight for females in intensive reproduction rhythm, these data indicate to retain an optimum crude lysine level of 0.75% (i.e. 4.1% of rough proteins). It is lower than the level of 0.84% proposed by De Blas and MATEOS (1998), as well as at the level of 0.85% proposed by XICCATO (1996) or of 0.9% (5% of rough Proteins) proposed by MAERTENS and DE GROOTE (1988).

The requirements in sulphur amino acids (SAA) were evaluated by TABOADA *et al.* (1996) using a range from 0.48 to 0.72% SAA (with at least 50% synthetic methionine), and adapted for females in lactation (10.76 MJ rough DE/kg). For the female, the needs are estimated to be 0.64 % crude SAA (0.49% digestible SAA, with a digestibility coefficient of 75%), when maximum productivity is the aim (without differential effect on the milk production and on the performances of reproduction). However, the increase in productivity is weak beyond a rate of 0.54% of SAA (0.40% digestible SAA), which is a lower level than that of 0.62 proposed by MAERTENS (1996).

For the growing rabbit, the minimum need for SAA would be 0.64% (TABOADA *et al.*, 1996). However a favourable effect on the growth rate was observed with the addition of SAA till the maximum rate tested in this study (either 0.58% of digestible SAA). This effect was more marked during the 2 weeks following weaning, thus stating that the requirement in SAA would be lower for finishing growing rabbit. The effect of the age was confirmed by the recent study of MAERTENS *et al.* (1998), indicating a greater sensitivity of the young rabbits to low protein diet, during the post-weaning period. These recommendations in SAA are close to those (0.62%) previously proposed for the growing rabbit by BERCHICHE and LEBAS (1994).

The requirements in threonin were evaluated using range of 5 diets containing 0.54 to 0.72% for crude threonin (DE BLAS *et al.*, 1998). Reproductive performance evolved quadratically with the dietary threonin level, i.e. for a high level (0.72%) a reduction of the performances was observed. The minimum threonin requirement was estimated to 0.63% (0.43% digestible). However, a slight rise of productivity was observed until a rate of 0.68%. These values were slightly lower than the level of 0.70% suggested by Lebas (1989).

The growth rate of fattening rabbits answers also according to a quadratic rule with the rate of threonin, and there was no more improvement beyond a rate of 0.63% (digestible 0.43%) (DE BLAS *et al.*, 1998). The optimum need in crude threonin was thus estimated at 0.60% (digestible 0.40%). It is slightly higher than the level of 0.55% proposed by LEBAS (1989), but similar to that proposed in 1996 by BRIENS (0.60% or 3.75% of crude protein). Moreover, BRIENS (1996) indicates that the addition of synthetic AA, highly digestible, led to better performances. This confirms the need for expressing the requirements in digestible nutrients.

FIBRE REQUIREMENTS

The digestion of fibre in the rabbit was subjected to several recent reviews (GIDENNE, 1996; GIDENNE *et al.*, 1998d; DE BLAS *et al.*, 1999), as the dietary fibre supply is implicated in the prevention of the digestive disorders (GIDENNE, 1997). However, the favourable effect of fibres with respect to resistance to pathogenic agents was clearly shown only recently (LICOIS and GIDENNE, 1999). On the other hand, a high fibre supply leads to an energy dilution of the diet. The animal thus attempts to increase its feed intake to satisfy energetic needs, and the feed conversion is reduced. When the dietary fibre level is very high (>25% ADF), the animal cannot increase its intake sufficiently to meet its energetic needs, thus leading to a lower growth rate.

Dietary fibres correspond to several components (belonging mainly to the plant cell wall), whose analysis remains difficult (GIDENNE *et al.*, 1998d). The sequential procedure of VAN-SOEST *et al.* (1991), officially recognised by AFNOR (1997), presents the advantage of estimating several fibrous fractions from only one sample, such as hemicelluloses (NDF-ADF), cellulose (ADF-ADL) and lignins (ADL). Although biochemically imperfect, these criteria have the advantage of a rather good reproducibility for a classical laboratory in feedingstuffs analysis. The interest of these criteria to establish fibre recommendations for the growing rabbit (table 2) was addressed by recent studies, which we present below, and which take into account the quantity, nature and the botanical origin of fibres.

The need of fibre is more particularly expressed during the post-weaning period. Low fibre intake, without variations of fibre nature or origin, involves lower growth rate during the 2 weeks after weaning

Table 2 : Requirements in fibre and starch (as concentration per kg^{-1} of raw feed, corrected to a dry matter content of 900 g/kg^{-1})

	Unit	Fattening rabbits		Does	
		Post weaning (till 45d of age)	**End of fattening**	**Young does**	**Breeding does**
Lignocellulose "ADF"	g	≥190	≥170	*> 200*	*>140*
Lignins "ADL"	g	≥55	≥50	*?*	*?*
Cellulose "ADF-ADL"	g	≥130	≥110	*?*	*?*
Ratio Lignins/ Cellulose		>0.40	>0.40	*?*	*>0.30*
Hemicelluloses "NDF-ADF"	g	>120	>100		
DF/ADF		≤1.3	≤1.3	*?*	*?*
Starch	g	<140	≤180	*?*	*?*

Fibre requirements are established mainly for preventing digestive troubles of the growing rabbit, and also for improving performances of does. They have been validated on growing rabbits with a feed intake of 90 to 120 g/d in post-weaning period, and 120 to 160 g/d in finishing period.
ADF : Acid Detergent Fibre ; ADL : Acid Detergent Lignin (Van-Soest *et al.*, 1991 ; AFNOR, 1997; séquential procedure).
DF : digestible fibres (pectins + hemicelluloses).

(GIDENNE and JEHL, 1999; PINHEIRO and GIDENNE, 1999) that are often associated with intake troubles or digestive disorders.

The botanical origin of fibres can influence digestion and cæcal microbial activity, independently of the quantity or the nature of fibres. Thus, supplying fibre from a single botanical origin (e.g. wheat: straw + bran) does not favour caecal fermentations nor the health status (GIDENNE *et al.*, 1998c). This situation is however unusual in rational breeding, where the rabbits received pelleted feeds containing plants of diversified origin.

To take into account the nature of fibres and the interactions with starch, it is necessary to respect four points (see table 2):

1. the minimum quantity of lignocellulose (ADF).
2. the quality of lignocellulose, i.e. the lignins ratio / cellulose.
3. the quantity of digestible fibres (DF = hemicelluloses and pectins) compared to lignocellulose (low digestible fibres), by calculating the ratio " DF/ADF ".
4. the quantity and the nature of the starch (particularly during the period around weaning).

1. Requirements of lignocellulose (ADF) : impact of the quality of ADF.

The favourable effect of ADF supply on the frequency of the digestive disorders and mortality in fattening rabbits was shown by MAÎTRE *et al.* (1990) using an adequate experimental design (380 rab./diet, in 5 sites). More recently, and with a similar design, GIDENNE *et al.* (1998b) showed that the sanitary risk (SR = mortality + morbidity) increased from 18 to 28% when the dietary ADF content decreased from 19 to 15%.

However, in a second step to improve fibre recommendations, the following question was examined : is a single criterion, such as the supply of lignocellulose, be sufficient enough to define the fibre contributions and the " level of security " of a feed for the growing rabbit ? Apart from the quantity of lignocellulose, other studies attempted to specify the effects of the quality of the ADF, i.e. the respective effects of lignins and cellulose (according to the Van-Soest procedure).

The nutritional role of the lignins was first addressed (GIDENNE and PEREZ, 1994; PEREZ *et al.*, 1994). The intake of lignins (criterion ADL = Acid Detergent Lignin) involves a sharp reduction of the feed digestibility (see figure 1, slope = - 1.6), associated with a reduction of the digesta retention time in the whole tract (-20%), and with a rise of the feed conversion ratio. On this last point, the botanical origin of lignins seems to modulate the effects observed. In parallel, a linear relationship (R^2=0.99; fig.1, n=5 feeds) between a chemical criterion of the plant cell wall (ADL) and mortality in fattening (by diarrhoea) were outlined for the first time (without major effect of the botanical origin of lignins). The favourable effect of the dietary ADL level on the SR was then confirmed with other experiments, as indicated in figure 2 (R^2=0.79; n=11 diets).

The effects of cellulose intake are less important than for ADL, regarding the decrease of the digestibility (see fig.1: slope = -1) or that of retention time (GIDENNE and PEREZ, 1996; PEREZ *et al.*, 1996b). The cellulose also favours the health status, but compared to lignins, the effects seems less important. These two components of lignocellulose exhibit similar effects for the prevention of the digestive disorders in rabbit. But, a major role is attributed to lignins, since the reduction of the ratio lignins/cellulose (L/C) involves a rise of the digestive disorders, as shown recently by GIDENNE *et al.* (1999a). Furthermore, when the ratio L/C is lower than 0.4, a reduction of the growth rate (-5%) and a higher digesta retention time are observed. Similarly, for the doe, a recent study (NICODEMUS *et al.*, 1999) showed a favourable effect of a linear rise of the ratio L/C (from 0.14 to 0.31) on the dairy production of the females and on the litter weight.

Globally, the lignins requirement (ADL) for the growing rabbit, can be assumed as to 5 to 7g/d, and

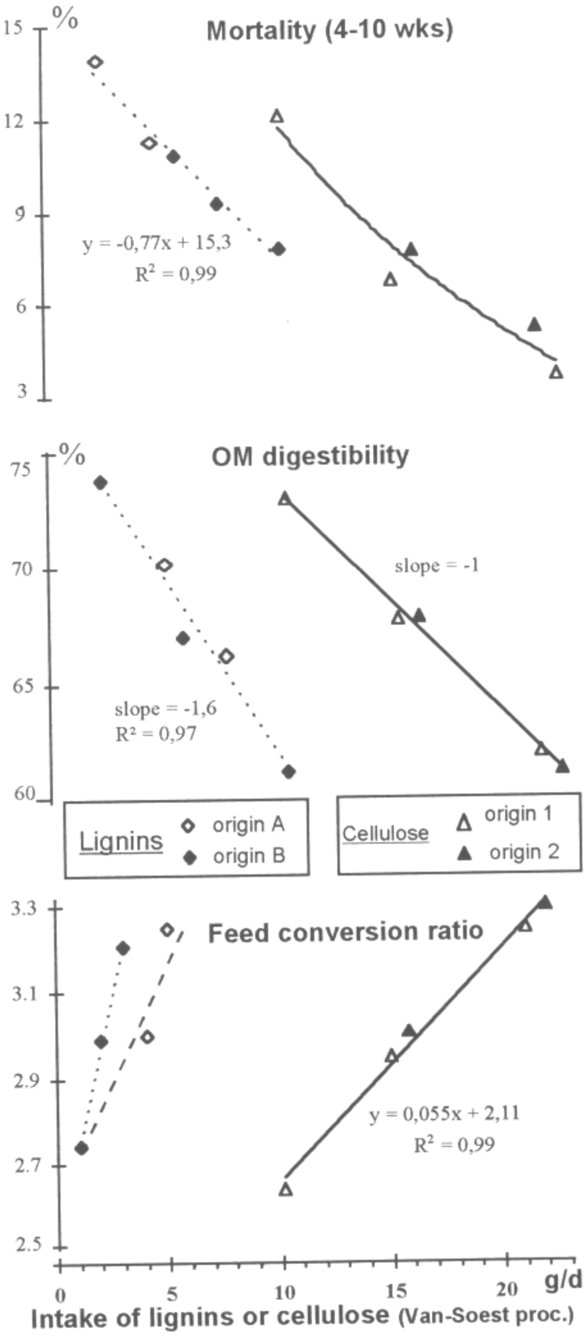


Figure 1 : Nutritional role of lignins and cellulose in the growing rabbit. (GIDENNE *et al.*, 1998b)

that out of cellulose (ADF-ADL) from approximately 11 to 12 g/d.

By comparing mixtures of fibre sources, we observed that the botanical origin of lignins (figure 1) could affect the feed conversion, but would not have a major effect on mortality by diarrhoea. However, to date, no correct and quick analytical method for lignins is available. Consequently, estimating the amount of lignins in a raw material remains difficult, particularly in tannin-rich ingredients (grape marc, etc.), and caution must be taken to fit requirements with such ingredients.

2. Effects of fibre fractions more digestible than lignocellulose.

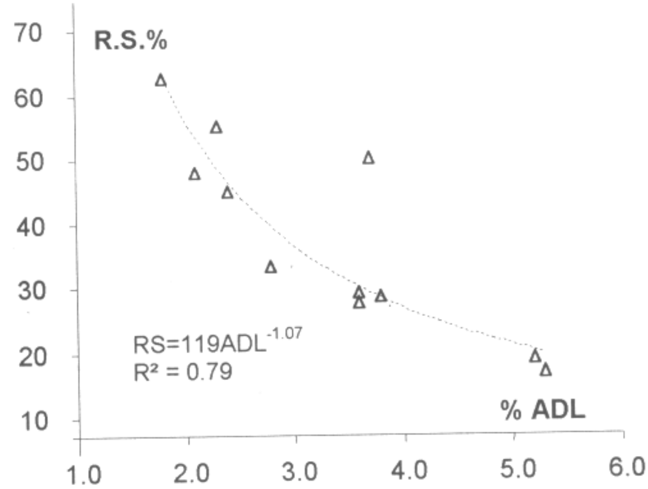
A third step in evaluating the fibre requirements for growing rabbit was to test the following hypothesis: apart from quantity and quality of ADF, is it necessary to specify the effects of more digestible fibres, such as hemicelluloses and pectins?

Digestible fibres "DF" fraction could be estimated by the sum of the two fractions hemicelluloses (NDF-ADF, according to the sequential procedure of VAN-SOEST) and water insoluble pectins (GIDENNE, 1996). The procedure of analysis of pectins remains complex, it is nevertheless possible to estimate their value in ingredients from tables (IO7, 1993; BACH KNUDSEN, 1997). Compared to lignocellulose, the DF fraction is highly digested by the rabbit (35 to 50%, GIDENNE, 1997).

As shown in figure 3, a large variation (20 to 50%) of the sanitary risk "SR" (JEHL and GIDENNE, 1996) was observed according to the ratio DF/ADF, and with a constant ADF level (± 20%). This confirmed that fibre requirement cannot be fulfilled only through requirement in lignocellulose.

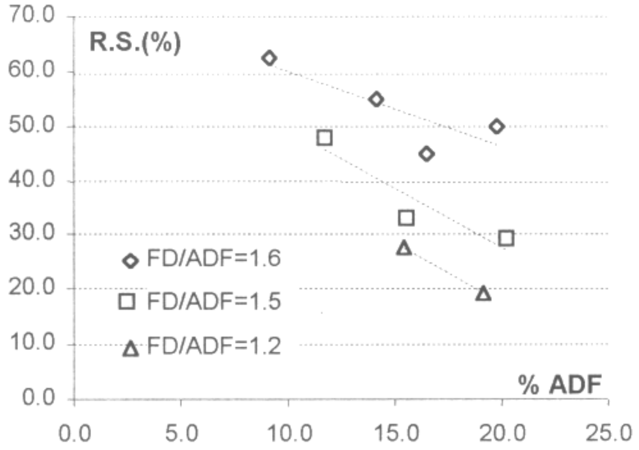
On the other hand, for diets with a ADF level over 15%, we observed a very close relationship (R^2=0.88) between the rise in ratio DF/ADF and the SR (figure 4). It would thus be advisable to maintain a ratio DF/ADF lower than 1.3.

Besides, when starch is substituted by DF, the growth performances (i.e. feed conversion, growth rate) are not greatly affected (JEHL and GIDENNE, 1996; GIDENNE *et al.*, 1998b) ; illustrating that digestible fibres are efficiently utilised by the growing rabbit.



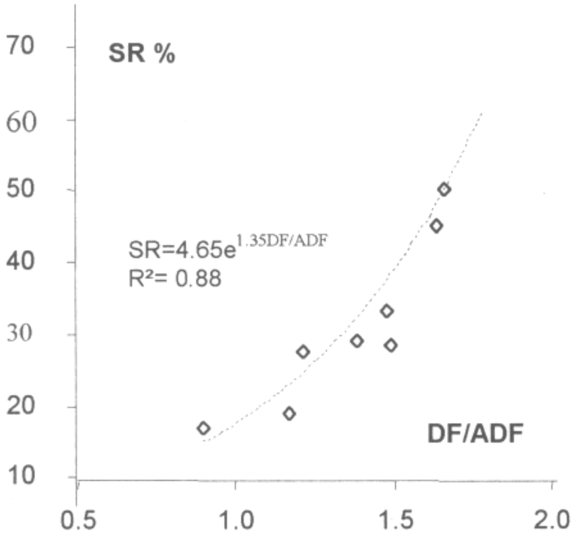
(SR= Mortality + morbidity rate, measured from 28 to 70d of age, on at least 40 rabbits/diet; one point = one diet) ; (Gidenne et Jehl, 1999; Pinheiro et Gidenne, 1999; Gidenne et al., 1998b).

Figure 2 : Sanitary risk "SR" according to dietary lignin (ADL) level.



SR= Mortality + morbidity rate, measured from 28 to 70d of age, on at least 40 rabbits/diet; one point = one diet) ; (Gidenne et Jehl, 1999; Pinheiro et Gidenne, 1999; Gidenne et al., 1998b).

Figure 3 : Sanitary risk "SR" according to dietary lignocellulose (ADF) level.



DF : digestible fibre = pectins + hemicelluloses (NDF-ADF) ; ADF = lignocellulose.
(SR= Mortality + morbidity rate, measured from 28 to 70d of age, on at least 40 rabbits/diet; one point = one diet) ; (Gidenne et Jehl, 1999; Pinheiro et Gidenne, 1999; Gidenne et al., 1998b).

Figure 4 : Sanitary risk "SR" according to the ratio DF / ADF (and ADF>15%)

3. Effects of starch supply ; interaction with fibre supply.

A fourth step in the evaluation of fibre needs, was to estimate if starch supply could interact or not with fibre supply (particularly ADF). For diets respecting the preceding constraints (> 18% ADF and DF/ADF < 1.3), the starch substitution (24 to 12%) by digestible fibres " DF " (ratio hemicelluloses / pectins = 75/25), led to a decrease in mortality after weaning (from 10.1 to 4.6%; GIDENNE *et al.*, 1998b). This mortality associated to an excessive starch supply was higher during the post-weaning period. It would thus be advisable to respect in diets a starch level lower than 14% during this period. Recently, GIDENNE *et al.* (1999) estimated that the starch ileal flow in finishing growing rabbit remained very weak (<2g/d), even for high starch level (30%). At the end of the fattening period, the starch supply would be thus only a secondary factor in the determinism of digestive disorders, the major factor remaining the fibre intake.

It has also been hypothesised that incorporating resistant starch in feeds would favour enteritis. However, when comparing iso-ADF feeds (16.5% ADF) having starch from maize or from wheat, only a slight reduction (P=0.25) in mortality was registered for "wheat" (5.6%, with 518 rabbit per diet) compared to "maize" diet (8.5%). Compared to the effects of the fibre supply, the nature of starch seemed not a primary factor in the determinism of digestive disturbances in the growing rabbit.

EFFECTS OF FEED PARTICLE SIZE.

Since the work of BJÖRNHAG (1972), we know that in period of hard faeces excretion, the proximal colon act as a sieve: largest particles (diam. >0.3mm) being excreted in hard faces, whereas finest one are driven back towards the caecum. Thus, it is acknowledged that the particle size distribution of a feed could affect the digestive motility and more particularly the cæcal physiology (transit, pH, fermentative activity, development of the caecal wall, etc.).

The measurement of the particle size distribution must be performed after the pelleting stage, since pelleting largely modifies the size of particles (LEBAS and LAMBOLEY, 1999). Such a measurement would improve the nutritive evaluation the sources of fibre, as suggest by GARCIA *et al.* (1999). However, the diets used in this study were very atypical, since the sources of fibres were incorporated at a high level (60 to 75%). It would thus be advisable to confirm these assumptions using more classical dietary model.

A fine grinding (screen size ≤ 1mm) of the raw materials leads to longer retention time (LAPLACE and LEBAS, 1977; GIDENNE *et al.*, 1991), but are not associated with a rise in feed digestibility (Lebas *et al.*, 1986; GIDENNE and SCALABRINI, 1990), nor with a negative effect on the health status. Only a very fine grinding (screen size = 0.25mm) led to a significant rise of digestibility (LAPLACE and LEBAS, 1977).

More recently, the effects feed particle size on the digestion and on the performances of growing rabbit were studied, by comparing feeds with different particles size obtained through a controlled choice of ingredients, and without changes in grinding procedure (NICODEMUS *et al.*, 1997a, b). However, in these experiments, the feed composition changed parallel to the particle size profile, making the interpretation of the results difficult. We can however mention that a variation from 18 to 24% of the level of coarse particles (>0.315mm) does not significantly affect mortality rate in fattening period. On the other hand, when this rate is lower than 18% (and although the rate of ADL is 6.1%), a reduction of the dairy production of the females is observed, associated with a lower litter weight at weaning and to a lower post-weaning growth rate.

Compared to a standard grinding (3mm holes), a coarser one (8mm) does not affect performances or digestion (DIAZ ARCA *et al.*, 1989). Thus only a very low rate of large particles would have a negative impact on the performances. Nevertheless, a rate of coarse particles lower than 25 % is very improbable in practice, since on a series of 77 commercial feeds the average proportion of coarse particles is 38.8% (minimum = 22.7%, mean minus 2 sd = 27%; Lebas 1999). Moreover, it is unlikely to meet a real excess in fine particles, knowing that a fine grinding of ingredients is relatively expensive (energy cost, rise of "fines"...). It thus does not seem necessary to propose a recommendation in term of size of particles, at least for standard commercial pelleted feeds.

FAT ADDITION AND INTERACTIONS WITH FIBRE SUPPLY.

For the growing rabbit, adding fat in the feed aims to increase the level of digestible energy, without reducing the fibre level. It is an approach for reducing the antagonism between growth performances and sanitary risk. The effects of the fat addition were reviewed recently (DE BLAS and MATEOS, 1998; MAERTENS, 1998b). We can outline that adding fat in iso-NDF feeds (but with a rise of the digestible protein " DP ", such as ratio DE/DP remains constant) has a favourable effect on digestion of energy and on the feed efficiency. However, in parallel, the animals reduce their feed intake so that growth rate is not improved, and the carcass fatness is increased.

A recent study of FALCAO E CUNHA *et al.* (1998) indicates a positive interaction between fat addition and the digestion of hemicelluloses (NDF-ADF). For diets rich in fibre (ADF>20%), a strong fat addition (up to 7%) reduced the feed intake only slightly, and thus led to a rise in DE intake and performances. However, MAERTENS *et al.* (1998) showed with iso-energetic feeds, that starch substitution by lipids (4 to 4.5% of the diet) would affect moderately the growth performances, but resulted in a rise of the carcass fatness, as shown previously by OUHAYOUN (1986). Nevertheless, in the case of moderate fat addition (≤ 3%), XICCATO *et al.* (1998) showed that DE intake remain unaffected, but feed conversion is improved without changes in carcass fatness.

To our knowledge, only FERNANDEZ CARMONA *et al.* (1998) studied the impact of dietary fat addition, in interaction with fibre supply, on the health status of growing rabbits. Results showed that fat addition in alfalfa rich diets (88%) reduced mortality, without a major fall of the performances compared to a standard commercial feed. However, further studies are necessary to confirm these results, particularly with more classical dietary model.

Fat addition in doe feeding is now widespread, because it allows an increase of the DE intake and milk production, but it failed to reduce the negative energy balance of the primiparous doe simultaneously pregnant and lactating (FORTUN LAMOTHE, 1997; Fortun-Lamothe *et al.*, 1999). From several recent studies, we can retain that fat addition leads to a rise in the milk production and to a modification of the chemical composition of milk (higher level of dry matter and energy). In addition, the fatty acids profile of milk is affected by the nature of the dietary fat. On the other hand the effects of fat on prolificity seems not reliable according to authors.

PASCUAL *et al.* (1998, 1999) studied the barley replacement by vegetable oils or animal fat, for feeds with up to 10% fat. As feed intake was unchanged, the DE intake increased, resulting in higher body reserves, a higher milk production, a rise of the litter weight at weaning (+400g), and a reduction of mortality before weaning. On the other hand, a negative effect on mortality of kits was observed by Lebas & Fortun-Lamothe (1996), with iso-energetic diets having a high-fat content, compared to a high-starch content.

The nutritional preparation of the female before mating (i.e. flushing) appears an interesting way to support the performances of reproduction (fertility etc., FORTUN-LAMOTHE, 1998; MAERTENS, 1998a; FORTUN-LAMOTHE *et al.*, 1999; LUZI *et al.*, 1999). In the same way, the nutritional preparation of the young doe (before the first mating) seems of interest for improving the body reserves and the performances of the doe. For instance, between weaning and the first kindling, feeding the young doe with a high fibre diet would increase the body reserves at the end of the first lactation (XICCATO *et al.*, 1999). This confirms the results of NIZZA *et al.* (1997) showing that a fibre rich diets given to young does (between 50d of age up to 10 days of gestation) had a favourable effect on the reproductive performances. Besides, the favourable effect of a high fibre feed (18% ADF vs 7% ADF) on the maternal behaviour (quality of the nest) and with the viability of kits should be confirmed (KAMEL *et al.*, 1993).

NUTRITIVE VALUE OF RAW MATERIALS.

Least-cost formulation of complete feed implies use of various ingredients, particularly to cover the fibre requirements. These raw materials are often by-products of the agro-industry (processing of cereals, oilseeds, etc.), and still recently their nutritive value for rabbit were imprecise or not reliable according to studies. Because, methodology for measuring nutritive value of ingredients is heavy and costly, the research group EGRAN (European Group for Rabbit Nutrition; GIDENNE, 1999) undertook a methodological program for evaluating and predicting value for complete feeds and raw materials. A first objective was to elaborate European tables of nutritive values for raw materials. The first release of these tables, based on a bibliographical review was recently published (PEREZ *et al.*, 1998a ; VILLAMIDE *et al.*, 1998), and reports the value in digestible energy, as well as an estimate of the digestion of proteins. On this latter point, the study of VILLAMIDE and FRAGA (1998) presents prediction equations of the protein digestion of feed ingredients, based on an exhaustive bibliographical review.

Dehydrated alfalfa, usually incorporated in rabbit feeds, was thoroughly studied (PEREZ, 1998; PEREZ *et al.*, 1998b). We can outlined that its DE content (on average = 7.66 MJ/kg DM) can be calculated from its crude fibre content (DE kcal/kg DM=3330 - 46.8 CF (%DM) ; r=-0.94), and that it does not vary according to the level of incorporation in feed. Likewise, the digestibility of alfalfa proteins seems moderate (59%). Garcia *et al.* (1995) studied the nutritive value of alfalfa hay, and estimated that the best predictor of the DE content was the NDF content of the hay.

Recently, the nutritive value of brewer's grains (MAERTENS and SALIFOU, 1997) and of Milurex® (PEREZ and GIDENNE, 1997) were specified. The replacement of cereals (corn or barley) by beet pulps was also recently studied, taking into account that this by-product presents a high level of digestible fibre (hemicelluloses + pectins) potentially well utilised by rabbits. The energetic value of beet pulps would vary according to their quality from 8.79 to 11.72 MJ/kg (DE BLAS and CARABAÑO, 1996). Moreover, JEHL *et al.* (1998) show that the DE content would decrease for a high incorporation rate of over 30%. These authors proposed an average DE content of 11.09 MJ/kg, higher than that proposed in the most recent tables (VILLAMIDE *et al.*, 1998), but in agreement with MAERTENS (1990). Several agro-industrial by-products (Soya bean hulls, sunflower hulls, paprika meal) were also evaluated by GARCIA *et al.* (1996, 1997a b, 1999), with respect to their effects on rabbit digestion or their DE value.

CONCLUSIONS AND PERSPECTIVES

In the past ten years, our knowledge appreciably progressed with respect to nutritional requirements of the weaned rabbit and of reproductive females. Several research programmes now address the improvement of the body reserves of the doe, with 2 major approaches: 1) genetic improvement, in particular for intake capacity ; 2) nutritional preparation of the young doe (from its weaning). On the other hand, little is still known about the digestion and nutritional requirements of the young rabbit before weaning. The nutritional preparation of the young rabbit before its weaning should be improved to reduce the digestive disorders in post-weaning period. Moreover, the relationship between nutrition and digestive pathology of the growing rabbit must be more fully documented. These studies will be useful within the frame of the future legislation for animal feeding that would favour the reduction of drugs such as antibiotics.

Likewise, legislation regarding animal breeding will take more and more account of the animal excreta (nitrogen, minerals) and of its negative impact on the environment. Studies on the mineral requirements are presently scarce, and it would be appropriate to develop them. Some studies have already proposed practical solutions to reduce the nitrogen excretion. Moreover, studies of amino acids digestion (contributions to be expressed in digestible form) in the small intestine, will optimise the use of proteins. On this point, work of group EGRAN aims to standardise and improve methodology of ileal digestibility measurements.

Acknowledgement : The author is grateful to Dr. F. LEBAS and Dr. L. FORTUN-LAMOTHE (Station de Recherches Cunicoles, INRA Toulouse, France) for their helpfull advices in the preparation of the manuscript.

Received : December 15th, 1999
Accepted : February 8th, 2000

REFERENCES

A.F.N.O.R., 1997. Norme Française homologuée, Aliments des animaux. Détermination séquentielle des constituants pariétaux. Méthode par traitement aux détergents neutre et acide et à l'acide sulfurique. *AFNOR publ., Paris. NF V 18-122, pp11.*

BACH KNUDSEN K.E., 1997. Carbohydrate and lignin contents of plant materials used in animal feeding. *Anim. Feed Sci. Tech., **67**, 319-338.*

BERCHICHE M., LEBAS F., 1994. Supplémentation en méthionine d'un aliment à base de féverole : effects sur la croissance, le rendement à l'abattage et la composition de la carcasse chez le lapin. *World Rabbit Sci., **2**, 135-140.*

BJÖRNHAG G., 1972. Separation and delay of contents in the rabbit colon. *Swed J. Agric. Res., **2**, 125-136.*

BRIENS C., 1996. Threonine requirement of growing rabbits. *Proc. 6th Congress of the World Rabbit Sci. Ass, Toulouse, France, 9-12 july 1996. F. Lebas Ed., A.F.C Lempdes, France. Vol. **1**, 117-120.*

DE BLAS J.C., CARABAÑO R., 1996. A review on the energy value of sugar beet pulp for rabbits. *World Rabbit Sci., **4**, 33-36.*

DE BLAS C., MATEOS G.G., 1998. Feed formulation. In: *The nutrition of the rabbit. C. De Blas and J. Wiseman Eds, Wallingford, CABI Publ., UK. Chapter **13**, 241-254.*

DE BLAS C., WISEMAN J., 1998. The nutrition of the rabbit.

Wallingford, CBAI Publ. UK. pp 344.

DE BLAS C., GARCIA J., CARABAÑO R., 1999. Role of fibre in rabbit diets. A review. *Ann. Zootech., **48**, 3-13.*

DE BLAS J.C., PÉREZ E., FRAGA M.J., RODRIGUEZ M., J.F. G., 1981. Effect of diet on feed intake and growth of rabbits from weaning to slaughter at different ages and weights. *J. Anim. Sci., **52**, 1225-1232.*

DE BLAS J.C., FRAGA M.J., RODRIGUEZ J.M., 1985. Units for feed evaluation and requirements for commercially grown rabbits. *J. Anim. Sci., **60**, 1021-1028.*

DE BLAS J.C., TABOADA E., NICODEMUS N., CAMPOS R., PIQUER J., MENDEZ J., 1998. Performance response of lactating and growing rabbits to dietary threonine content. *Anim. Feed Sci. Technol., **70**, 151-160.*

DIAZ ARCA J.F., PEREZ ALBA L.M., CEJAS MOLINA M.A., PEREZ HERNANDEZ M., 1989. Grinding and food utilization by growing rabbits. 1. The effect of using 3 and 8 mm sieves. *Archives de Zootecnia, **38**, 73-78.*

FALCAO E CUNHA L., FERREIRA P., BENGALA FREIRE J.P., 1998. Etude de l'effet de l'interaction fibres x lipides dans l'alimentation du lapin : croissance, digestibilité et paramètres fermentaires. *7ème J. Rech. Cunicoles Fr., 13-14 mai, Lyon. ITAVI publ. Paris, p155-158.*

FERNANDEZ-CARMONA J., BERNAT F., PASCUAL J.J., 1998. High lucerne diets for growing rabbits. *World Rabbit Sci., **6**, 237-240.*

FORTUN-LAMOTHE L., 1997. Effects of dietary fat on reproductive performance of rabbit does : a review. *World Rabbit Sci., **5**, 33-38.*

FORTUN-LAMOTHE L., 1998. Effect of pre-mating energy intake on reproductive performance of rabbit does. *Anim. Sci., **66**, 263-269.*

FORTUN-LAMOTHE L., PRUNIER A., BOLET G., LEBAS F., 1999. Physiological mechanisms involved in the effects of concurrent pregnancy and lactation on foetal growth and mortality in the rabbit. *Livest. Prod. Sci., **60**, 229-241.*

GARCIA J., PÉREZ-ALBA J., ALVAREZ C., ROCHA R., RAMOS M., DE BLAS C., 1995. Prediction of the nutritive value of lucerne hay in diets for growing rabbits. *Anim. Feed Sci. Technol. **54**, 33-44.*

GARCIA J., VILLAMIDE M.J., DE BLAS J.C., 1996. Energy, Protein and fibre digestiblity of sunflower hulls, olive leaves and NaOh-Treated Barley straw for rabbits. *World Rabbit Sci., **4**, 205-209.*

GARCIA J., VILLAMIDE M.J., DE BLAS J.C., 1997a. Energy, protein and fibre digestibility of paprika meal for rabbits. *World Rabbit Sci. **5**, 139-141.*

GARCIA J., VILLAMIDE M.J., DE BLAS J.C., 1997b. Energy, protein and fibre digestibility of soya bean hulls for rabbits. *World Rabbit Sci. **5**, 111-113.*

GARCIA J., CARABAÑO R., DE BLAS J.C., 1999. Effect of fiber source on cell wall digestibility and rate of passage in rabbits. *J. Anim. Sci. 77, 898-905.*

GIDENNE T., 1996. Conséquences digestives de l'ingestion de fibres et d'amidon chez le lapin en croissance: vers une meilleure définition des besoins. *INRA Prod. Anim. **9**, 243-254.*

GIDENNE T., 1997. Caeco-colic digestion in the growing rabbit: impact of nutritional factors and related disturbances. *Livest. Prod. Sci. **51**, 73-88.*

GIDENNE T., 1999. EGRAN : an European group for rabbit nutrition - Presentation and activity. *World Rabbit Sci. 7, 101-106.*

GIDENNE T., SCALABRINI F., 1990. Effet du taux et de la finesse de broyage de la luzerne chez le lapin en croissance. 1) Performances zootechniques et digestibilité de la ration. *5ème J. Rech. Cunicoles Fr., 12-13 dec. Paris. ITAVI publ., France, Vol. **2**, 51.1-51.9.*

GIDENNE T., PEREZ J.M., 1994. Apports de lignines et alimentation du lapin en croissance. I. Conséquences sur la digestion et le transit. *Ann. Zootech. **43**, 313-322.*

GIDENNE T., PEREZ J.M., 1996. Apports de cellulose dans l'alimentation du lapin en croissance. I. Conséquences sur la digestion et le transit. *Ann. Zootech. **45**, 289-298.*

GIDENNE T., JEHL N., 1999. Réponse zootechnique du lapin en croissance face à une réduction de l'apport de fibres, dans des régimes riches en fibres digestibles. *8ème J. Rech. Cunicoles Fr., 9-10 juin Paris, ITAVI publ. Paris, p109-113.*

GIDENNE T., CARRÉ B., SÉGURA M., LAPANOUSE A., GOMEZ J., 1991. Fibre digestion and rate of passage in the rabbit: effect of particle size and level of lucerne meal. *Anim. Feed Sci. Technol. **32**, 215-221.*

GIDENNE T., MADEC O., ARVEUX P., 1998a. Effets de la nature de la lignocellulose sur la digestion et les performances zootechniques du lapin en croissance. *7ème J. Rech. Cunicoles, 13-14 may Lyon France. ITAVI publ., p151-154.*

GIDENNE T., PEREZ J.M., LEBAS F., 1998b. Besoins en constituants pariétaux du lapin de chair. *Ed. By B. Archambeaud, Fonds SYPRAM, SOFIPROTEOL publ. Paris, 2p.*

GIDENNE T., BELLIER R., VAN EYS J., 1998c. Effect of the dietary fibre origin on the digestion and on the caecal fermentation pattern of the growing rabbit. *Anim. Sci. **66**, 509-517.*

GIDENNE T., CARABAÑO C., GARCIA J., DE BLAS C., 1998d. Fibre digestion. in: The nutrition of the rabbit. *C. De Blas and J. Wiseman Eds. CABI Publ. Wallingford UK, Chapter 5: 69-88.*

GIDENNE T., PINHEIRO V., FALCAO E CUNHA, L. 1999. A comprehensive approch of the rabbit digestion. Effect of a reduction of the dietary fibre supply. *Livest. Prod. Sci., (in press)* .

IO7, 1993. La banque de données de l'alimentation animale (V2.5). Association Française de zootechnie, Paris.

JEHL N., GIDENNE T., 1996. Replacement of starch by digestible fibre in the feed for the growing rabbit. 2. Consequences for microbial activity in the caecum and on incidence of digestive disorders. Anim. Feed Sci. Tech. 61: 193-204.

JEHL N., GIDENNE T., LE ROUX J.F., 1998. Emploi de rations à fortes proportions de fibres digestibles: effets sur la digestion et le transit du lapin en croissance. 7ème J. Rech. Cunicoles Fr., 13-14 may Lyon, ITAVI publ., p137-140.

KAMEL M.M., MYERS L.J., CUMMINS K.A., 1993. Influence of dietary fibre on maternal behaviour in rabbits. Vet. Med. J. Giza 41: 23-29.

LAPLACE J.P., LEBAS F., 1977. Le transit digestif chez le lapin. 7) Influence de la finesse de broyage des constituants d'un aliment granulé. Ann. Zootech. 26: 413-420.

LEBAS F., 1989. Besoins nutritionnels des lapins. Revue bibliographique et perspectives. Cuni-Sci 5: 1-27.

LEBAS F., 1999. Granulométrie et nutrition du lapin. CAAA, INA-PG, Paris, 1er Juin.

LEBAS F., LAMBOLEY B., 1999. Méthode de détermination par tamisage en phase liquide, de la taille des particules contenues dans un aliment granulé pour lapins. *World Rabbit Science, 7, 229-235.*

LEBAS F., FORTUN LAMOTHE L., 1996. Effects of dietary energy level and origin (starch vs oil) on performance of rabbits does and their litters : average situation after 4 weanings. In : *Proc. 6th Congress of the World Rabbit Sci. Ass., Toulouse, AFC publ. Lempdes France. Vol. **1**, p217-222.*

LEBAS F., MAÎTRE I., SEROUX M., FRANCK T., 1986. Influence du broyage des matières premières avant agglomération de 2 aliments pour lapins différant par leur taux de constituants menbranaires : digestibilité et performances de croissance. *4ème J. Rech. Cunicole Fr., 10-11 dec. Paris, ITAVI publ. Paris, Vol. **l**, p9.1-9.13.*

LICOIS D., GIDENNE T., 1999. L'emploi d'un régime déficient en fibres par le lapereau augmente sa sensibilité vis à vis d'une infection expérimentale par une souche d'Escherichia coli entéropathogène. *8ème J. Rech. Cunicoles Fr., 9-10 juin Paris, ITAVI publ. Paris. p.101-104.*

LUZI F., BARBIERI S., LAZZARONI C., CAVANI C., ZECCHINI M., CRIMELLA C., 1999. Flushing method to improve the reproductive efficiency in rabbit does. *50th EAAP meeting, 22-26 august, Zurich, Switzerland. p.112*

MAERTENS L., 1996. Nutrition du lapin: connaissances actuelles et acquisitions récentes. *Cuniculture **23**, 33-35.*

MAERTENS L., 1998a. Effect of flushing, mother-litter separation and PMSG on the fertility of lactating does and the performance of their litter. *World Rabbit Sci **6**, 185-190*

MAERTENS L., 1998b. Fats in rabbit nutrition: a review. *World Rabbit Sci.* ***6**, 341-348.*

MAERTENS L., DE GROOTE G., 1988. The effect of the dietary protein energy ratio and lysine content on the breeding results of does. *Arch. Geflüegelkd.* ***52**, 89-95.*

MAERTENS L., SALIFOU E./, 1997. Feeding value of brewer's grains for fattening rabbits. *World Rabbit Sci.* ***5**, 161-165.*

MAERTENS L., JANSSEN W.M.M., STEENLAND E., WOLTERS D.F., BRANJE H.E.B., JAGER F., 1990. Tables de composition, de digestibilité et de valeur énergétique des matières premières pour lapins. *5ème J. Rech Cunicoles, 12-13 dec. Paris, ITAVI publ. Paris, Vol.***2** *p.57.1-57.3.*

MAERTENS L., LUZI F., DE GROOTE G., 1997. Effect of dietary protein and amino acids on the performance, carcass composition and N-excretion of growing rabbits. *Ann. Zootech.* ***46**, 255-268.*

MAERTENS L., CAVANI C., LUZI F., CAPOZZI F., 1998. Influence du rapport protéines/énergie et de la source énergétique de l'aliment sur les performances, l'excrétion azotée et les caractéristiques de la viande des lapins en finition. *7ème Journ. Rech. Cunicole Fr., 9-10 juin, Lyon, France, ITAVI publ. Paris, p.163-166.*

MAÎTRE I., LEBAS F., ARVEUX P., BOURDILLON A., DUPPERAY J., SAINT CAST Y., 1990. Taux de lignocellulose (ADF de Van Soest) et performances de croissance du lapin de chair. *5èmes J. Rech. Cunicoles Fr., 12-13 Déc. Paris, ITAVI Publ., Vol.***2***, p56.1-56.11.*

NICODEMUS N., GARCIA J., CARABAÑO R., DE BLAS J.C., 1997a. Efecto del tamaño de particula sobre la productividad en conejos. *VII Jornadas sobre produccion animal, ITEA Spain. Vol.* ***18**, p181-183.*

NICODEMUS N., GARCIA J., CARABAÑO R., MENDEZ J., DE BLAS J.C., 1997b. Efecto del tamaño de particula sobre la digestion en conejos. *VII Jornadas sobre produccion animal, ITEA Spain. Vol.* ***18**, 184-186.*

NICODEMUS N., CARABAÑO R., GARCIA J., MENDEZ J., DE BLAS J.C., 1999. Performance response of lactating and growing rabbits to dietary lignin content. *Anim. Feed Sci. Technol.* ***80**, 43-54.*

NIZZA A., DI MEO C., ESPOSITO L., 1997. Influence of the diet used before and after the first mating on reproductive performance of rabbit does. *World Rabbit Sci.* ***5**, 107-110.*

OUHAYOUN J., KOPP J., BONNET M., DEMARNE Y., DELMAS D., 1986. Influence de la composition des graisses alimentaires sur les caractéristiques physico-chimiques des lipides corporels du lapin. *4èmes J. Rech. Cunicoles Fr., ITAVI publ., 10-11 dec. Paris. Vol.* ***1**, p6.1-6.13*

PASCUAL J.J., CERVERA C., BLAS E., FERNANDEZ CARMONA J., 1998. Effect of high fat diets on the performance and food intake of primiparous and multiparous rabbit does. *Anim. Sci.* ***66**, 491-499.*

PASCUAL J.J., CERVERA C., BLAS E., FERNANDEZ CARMONA J., 1999. Effect of high fat diets on the performance, milk yield and milk composition of multiparous rabbit does. *Anim. Sci.* ***68**, 151-162.*

PEREZ J.M., 1998. Valeur nutritive de la luzerne déshydratée au sein d'un régime complexe pour le lapin : influence du taux d'incorporation et de la méthode d'estimation. *7èmes Jour. Rech. Cunicole Fr., 13-14 mai, Lyon. ITAVI publ. Paris, p133-136.*

PEREZ J.M., GIDENNE T., 1997. Valeur nutritive du Milurex® pour le lapin. Cuniculture 24: 15-18.

PEREZ J.M., GIDENNE T., LEBAS F., CAUDRON I., ARVEUX P., BOURDILLON A., DUPERRAY J., MESSAGER B., 1994. Apports de lignines et alimentation du lapin en croissance. II. Conséquences sur les performances de croissance et la mortalité. *Ann. Zootech.* ***43**, 323-332.*

PEREZ J.M., LEBAS F., GIDENNE T., MAERTENS L., XICCATO G., PARIGI-BINI R., DALLE ZOTTE A., COSSU M.E., CARAZZOLO A., VILLAMIDE M.J., CARABAÑO R., FRAGA M.J., RAMOS M.A., CERVERA C., BLAS E., J. F.C., FALCAO E CUNHA L., BENGALA FREIRE J., 1995. European reference method for in-vivo determination of diet digestibility in rabbits. *World Rabbit Sci.* ***3**, 41-43.*

PEREZ J.M., FORTUN-LAMOTHE L., Lebas F., 1996a. Comparative digestibility of nutrients in growing rabbits and breeding does. In : *Proc. 6th Congress of the World Rabbit Sci. Ass., 9-12 july, Toulouse, ed. by F. Lebas, AFC publ. Lempdes, France. Vol.* ***1**, p267-272.*

PEREZ J.M., GIDENNE T., BOUVAREL I., ARVEUX P., BOURDILLON A., BRIENS C., LE NAOUR J., MESSAGER B., MIRABITO L., 1996b. Apports de cellulose dans l'alimentation du lapin en croissance. II. Conséquences sur les performances et la mortalité. *Ann. Zootech.* ***45**, 299-309.*

PEREZ J.M., MAERTENS L., VILLAMIDE M.J., DE BLAS C., 1998a. Tables de composition et de valeur nutritive des aliments destinés au lapin : conclusions d'un groupe de travail Européen. *7èmes J. Rech. Cunicoles Fr., 13-14 mai, Lyon, ITAVI publ. Paris, p141-146.*

PEREZ J.M., LAMBOLEY B., BERANGER C., 1998b. Digestibilité et valeur énergétique de différentes luzernes déshydratées utilisées seules ou en mélange dans le régimes du lapin en croissance. *7èmes J. Rech. Cunicoles Fr., 13-14 mai, Lyon, ITAVI publ. Paris, p129-132.*

PEREZ J.M., CARDINALE S., JUIN H., LAMBOLEY B., DE ROCHAMBEAU H., 1999. Influence du type génétique sur l'efficacité de la digestion chez le lapin: Comparaison de 10 souches mâles de croisement terminal différant par leur format adulte. *8èmes J. Rech. Cunicoles Fr., 9-10 juin Paris, ITAVI publ. Paris, p113-116.*

PINHEIRO V., GIDENNE T., 1999. Conséquences d'une déficience en fibres sur les performances zootechniques du lapin en croissance, le développement caecal et le contenu iléal en amidon. *8èmes J. Rech. Cunicoles Fr., 9-10 juin, Paris, ITAVI publ. Paris, p105-108.*

TABOADA E., MENDEZ J., DE BLAS J.C., 1996. The response of highly productive rabbits to dietary sulphur amino acid content for reproduction and growth. *Reprod. Nutr. Dev.* ***36**, 191-203.*

TABOADA E., MENDEZ J., MATEOS G.G., DE BLAS J.C., 1994. The response of highly productive rabbits to dietary lysine content. *Livest. Prod. Sci.* ***40**, 329-337.*

VAN SOEST P.J., ROBERTSON J.B., LEWIS B.A., 1991. Methods for dietary fiber, neutral detergent fiber, and non starch polysaccharides in relation to animal nutrition. *J. Dairy Sci.* ***74**, 3583-3597.*

VILLAMIDE M.J., FRAGA M.J., 1998. Prediction of the digestible crude protein and protein digestibility of feed ingredients for rabbits from chemical analysis. *Anim. Feed Sci. Technol.* ***70**, 211-224.*

VILLAMIDE M.J., MAERTENS L., DE BLAS C., PEREZ J.M., 1998. Feed evaluation. In: *The nutrition of the rabbit. C. De Blas and J. Wiseman Eds, Wallingford, CABI Publishing. Chapter* ***6**, 89-102.*

XICCATO G., 1996. Nutrition of lactating does. In *: Proc. 6th Congress of the World Rabbit Sci. Ass., 9-12 july Toulouse, France, ed. by F. Lebas, AFC publ. Lempdes, Vol.* ***1**, p29-48.*

XICCATO G., COSSU M.E., TROCINO A., QUEAQUE P.I., 1998. Influence du rapport amidon/fibre et de l'addition de graisse en post-sevrage sur la digestion, les performances zootechniques et la qualité bouchère du lapin. *7èmes J. Rech. Cunicoles Fr., 13-14 mai, Lyon. ITAVI publ. Paris, p.159-162*

XICCATO G., BERNARDINI M., CASTELLINI C., DALLE ZOTTE A., QUEAQUE P.I., TROCINO A., 1999. Effect of postweaning feeding on the performance and energy balance of female rabbits at different physiological states. *J. Anim. Sci.* ***77**, 416-426.*