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TOWARDS REDUCED FEEDING COSTS, DIETARY SAFETY AND MINIMAL MINERAL EXCRETION IN RABBITS : A REVIEW [2]

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ABSTRACT : This article reviews some actual trends in rabbit nutrition. To be more competitive with poultry and pig production, a further reduction of the overall feed conversion rate of rabbitries till 3.25 is necessary. Genetic, management and nutritional improvements are simultaneously possible to achieve this goal and are discussed in this paper. A trend towards phase feeding is observed in rabbit nutrition. Several arguments are given: (i) requirements of fatteners are different shortly after weaning compared to the finishing period; (ii) by matching the dietary protein (amino acids) to the age related requirements, diets with a lower protein level can be fed, resulting in a significant reduced N-excretion. This is of special importance to reduce the environmental pollution, in areas with a high density of animal production. Finally, (iii) energy concentrated diets can be fed in the finishing period to improve the feed conversion rate. A policy till a further banning of feed additives can be expected. Disease control, including dietary safety will be of increasing interest. The role of dietary fibre and starch on rabbit health has recently been better defined. Lignin has a predominant role on the transit time and to reduce the incidence of enterits. A lignin (ADL>5%), starch (<13.5%) and cellulose constrain (>15%) is suggested in diet formulation for young rabbits instead of a single recommendation for crude fibre or ADF. However, dietary fibre and starch recommendations are depending from age and physiological status.

RESUME : Vers la réduction du coût de l'alimentation, des aliments fiables, et une excrétion minérale minimale chez le lapin : une revue.
Cet article passe en revue quelques unes des tendances actuelles de l'alimentation du lapin. Pour être plus compétitif vis à vis du poulet et du porc, une réduction de l'indice de consommation globale vers 3,25 est nécessaire chez le lapin. Ce but peut être atteint par des améliorations, qui sont discutés dans cet article, dans les domaines de la génétique, de la gestion et de la nutrition. On observe une tendance vers une alimentation « multi-phase » du lapin. Plusieurs arguments sont donnés : (i) les besoins des lapins en engraissement sont différents dans la période proche du sevrage de ceux de la période de finition, (ii) en adaptant les protéines du régime (amino acides) en fonction des besoins liés à l'âge, il est possible de donner des aliments moins riches en protéines, ayant pour résultat une réduction significative de l'azote excrété. Ceci est d'une importance capitale, afin de réduire la pollution environnementale, dans les régions à fortes production animales. Enfin (iii) des aliments riches en énergie peuvent être distribués durant la période de finition pour améliorer l'indice de consommation. Une politique bannissant les additifs alimentaires sera de plus en plus nécessaire. Un contrôle sanitaire, incluant la sécurité des aliments, se révèle d'un intérêt croissant. Le rôle des fibres alimentaires et de l'amidon sur la santé des lapins a été mieux décrit récemment. La lignine a un rôle prédominant sur le temps de transit et sur la réduction des risques d'entérite. Pour les lapereaux, un aliment formulé avec des contraintes de lignine (ADL>5%), d'amidon (<13,5%) et de cellulose (>15%) est préconisé à la place de la seule recommandation de fibres brutes ou ADF. Cependant les recommandations pour les fibres et l'amidon de l'aliment sont dépendantes de l'âge et du statut physiologique.

INTRODUCTION

In rabbit meat production, as in other animal species, feeding costs represent the largest part of the production costs. Depending on the initial investment costs, they amount to 70% of the total costs. Actually, the production costs of meat rabbits are twice as high as for broilers and 20-30% higher than in pigs. To be more competitive with those animal productions, a reduction of the feeding costs is of primarily importance. Different possibilities to reduce the amount of feed/unit of meat production will be discussed.

A second item with increasing interest in the EEC and mainly in areas with a high density of animal production, is the sensitivity to protect the environment. In some regions (Belgium, The Netherlands, Germany...) manure is not considered not only as a fertilizer, but as a polluter of the environment. Agricultural ammonia production is partly responsible for the acidification problems (acid rains) and heavy metals (N, P) are linked with decreasing quality of surface and drinking water. Future animal nutrition has to try to minimise these wastes to the environment. Also in rabbits, adapted feeding programs can manipulate to a large extent the utilisation of N and phosphorus.

Rabbits are considered to be very sensitive animals. One of the characteristics of rabbit production are the high losses, which amounts to approximately 20% (KOEHL, 1997). Recently, a new disease has stressed the weak digestive equilibrium (COUDERT *et al.*, 1997). Dietary safety and the link between nutritional factors and digestive disorders are very important items in rabbit feeding.

(1) Note of the Editor-in-Chief : This special new section "POSITION PAPERS" is devoted to papers in which the authors expressed their position about evolution of rabbit production or biology under light of one part of the published literature and of their up-to-now-unpublished own experience. Clearly, such papers don't represent the official position of the World Rabbit Science Association, but may stimulate debates and scientific discussions. Scientifically well argued answers are eligible for publication in this Journal.

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Animal proteins are produced for human consumption. The desires of the consumers are changing and the production has to fulfill, even to anticipate to the consumer's wishes. In several Northern European countries, the consumption of meat is decreasing (increasing number of vegetarians) while it stabilizes in the EEC. Consumers become more and more sensitive to the animal production conditions (welfare). They further claim residue free meat and a dietetic quality. Especially an increasing trend to leaner meat is observed with increasing live standard. Cholesterol and polyunsaturated fatty acids (PUFA) levels determines to a large amount the consumer's behaviour. Also rabbit nutrition has to play its role to produce meat that is perfectly adapted to the standards of the actual and future consumer. This topic has recently been reviewed by XICCATO (1999).

The objective of this paper is to emphasise on rabbit nutrition in view of the above mentioned items.

1. Improvement of the feed efficiency

1.1. By genetic possibilities

The production of rabbit meat is, even in countries considered as «big» producers (Italy, France, Spain ...), a minor production compared to pig, poultry and cattle production. To maintain its position, rabbit meat production costs have to develop at least in a way comparable with other competitive meat productions. However, the production performances of rabbits have not increased like in other animal species (Table 1).

Between the start of the intensive meat production (in the 1960's in Western Europe) and the present day, production performances have doubled, even tripled (broilers) in other livestock. However, the production performance in rabbits has not increased proportionately, but limited to 20 - 30% increases. The number of weaned rabbits (48/doe/year) refers to the average in French rabbitries and is increased to a larger extend than the other traits (KOEHL, 1997). However, this increase is mainly due to an improved management technique rather than to the increased zootechnical performances.

Table 1 : Comparison of the development of the performances in different species using specialised lines.

	1960	1980	1998
Layers (eggs/hen/year)	200	270	300
Broilers			
Age at 1.5 kg (weeks)	11-12	6	4-5
Feed efficiency	>3	1.9	1.5
Milk cows (l/cow/year)	4,000	6,000	8,500
Sows (piglets weaned/sow/year)	12-13	16-17	21-22
Rabbits			
Litter size (alive/litter)	8	8.5	9.5
Age at 2.5 kg (weeks)	12	11	10
Weaned/doe/year	35	40	48
Feed conversion (after weaning)	3.5	3.3	3.1

Data are based on the performances obtained at the Agricultural Research Centre Ghent, published in their yearly reports. Data with rabbits mentioned for 1998 refer to KOEHL (1997)

Table 2 : Comparison of the performances of different Spanish lines (FEKI *et al.*, 1996)

Line	V	R	C
Selection purpose	**Litter size**	**Growth rate**	**Global objective**
Weight at 63 days (g)	2116	2598	2251
Growth rate (g/d)*	37.9	48.0	39.2
Feed efficiency*	3.04	2.63	3.07

* covariated

Different possibilities exist to reduce the feed efficiency. The efficiency of using the feed to convert to meat depends largely of the genetic potential. Only quite recently (from the 1990's), have the use of specialised terminal sire lines been used, to increase daily weight gain and to improve the feed efficiency. The large potential of such lines have been demonstrated by BLASCO *et al.*, (1996) and ROCHAMBEAU *et al.* (1996). For example in Spain (FEKI *et al.*, 1996), a line is selected with an average daily weight gain of 48g and a feed efficiency of 2.63 (Table 2).

In the sire line of our Institute (MAERTENS, 1992), in which the only selection criteria are daily weight gain and feed efficiency, top rabbits show a daily weight gain around 60g and a feed efficiency less than 2.4 between 4 and 10 weeks of age. Both examples illustrate that the genetic possibilities of rabbits are not yet well utilized. Therefore the use of specialised lines (hybrids) will be of increasing interest in the future.

1.2. By nutrition

Feed efficiency is inversely linked with the dietary energy content as already been shown 25 years ago by LEBAS (1975). Rabbits try to adjust their feed intake in order to have the same daily DE-intake. However, if the diet is too diluted (<9.2 MJ DE/kg), rabbits can no

Table 3 : Distribution of the feed consumption in a closed rabbitry

Closed farm		In the fattening unit	
Category	**%**	**Week after weaning**	**%**
Does + young before weaning	28	0 - 2 weeks	22
Fattening	65	2 - 4 weeks	36
Young does + does in waiting cages	7	4 - 6 weeks	42

Table 4 : Effect of the dietary energy content on the fattening performances (ROMMERS and MAERTENS, 1996)

DE (Kcal/kg)	2 475	2 620	2 800
Weight at 35 days (g)	900	913	918
Weight at 70 days (g)	2 456	2 491	2 501
Daily weight gain (g)	44.8	45.1	45.3
Feed efficiency	3.15	3.05	2.88

longer fulfil their energy requirements because of their limited feed intake capacity (MAERTENS, 1992).

In a closed rabbitry, 2/3 of the feed is consumed by the fatteners and 25-30% in the maternity (Table 3). During the 6 weeks fattening period, 65% of the feed is consumed in the second half of the fattening period. These data refer to a rabbitry following a 42 reproduction rhythm and with a production level of 54 weaned young/doe/year. Weaning age is 30 days and rabbits are sold at the age of 72 days (2.4 kg).

Therefore, an adapted finishing feed (energy dense) can contribute a lot to improve the feed efficiency of the farm. The inverse relationship between the energy content and the feed conversion also exist for concentrated diets (Table 4). An increase with 325 kcal (13%) reduced the feed conversion with 0,37 or 9%.

Because of the fiber requirements, rabbit diets are not very concentrated in terms of available energy. However, rabbits digest fats, oils or fat-rich feedstuffs in a way comparable to other monogastric animals and lipids are an alternative to increase the dietary energy content of the fibrous rabbit diets. At low levels of inclusion, the digestibility of vegetable oils is nearly 100% (FERNANDEZ *et al.*, 1994). Several Spanish works have clearly shown that fat addition leads to comparable growth rates but favours feed efficiency due to the increased energy intake (for a review see MAERTENS, 1998). In does, fat enriched diets favour energy intake. This additional energy intake is primarily used for increased milk production (for a review see XICCATO, 1996 or FORTUN-LAMOTHE, 1997).

Attention has to be drawn to the fact that the dietary fatty acids manipulate to a large extend the body lipids (COBOS *et al.*, 1993; CAVANI *et al.*, 1996). As already mentioned, this topic will be treated in the lecture of XICCATO. Under practical feeding conditions, fat addition is limited because of technological problems. The durability of pellets drops significantly above 2-3% of fat addition (Table 5). However, fat addition and pellet quality is also highly dependent of several other factors as e.g. the pelleting facilities, the technology used, the choice of the feedstuffs and pellet binders (PAYNE *et al.*, 1994). Limits of fat addition or of the use of oil rich feedstuffs have to be considered in this view.

Recently, the amino acid (AA) requirements were better defined (TABOADA *et al.*, 1994; TABOADA *et al.*, 1996; DE BLAS *et al.*, 1998). Recommended levels of lysine, sulphur amino acids and threonine, based on their works, are given in Table 6. They have to be considered in relation to the energy density of the diet (10.4 - 10.6 MJ DE/kg). Dietary sulphur AA recommendations are especially high compared to the general accepted recommendations of LEBAS (1989) and later adapted versions (MAERTENS, 1996).

Their results suggest further that the amino acid requirements of weaned rabbits decrease with increasing age. During the two-week postweaning, significant responses were found up to higher levels of sulphur amino acids (TABOADA *et al.*, 1996). These results fit perfectly with the high sensitivity to low protein diets, in early postweaning stage, as observed in our trials (MAERTENS *et al.*, 1998). Therefore, the above

Table 5 : Effect of dietary fat addition on pellet quality (MAERTENS and DE GROOTE, 1987).

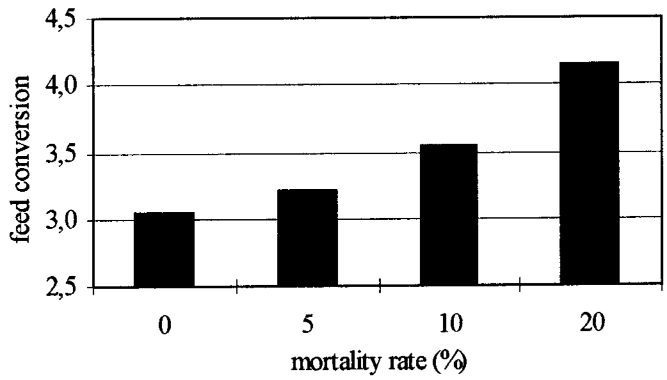
% added fat	0	2	4
Durability test (% of fines)	1.4	2.3	6.7
Pellet sieving test (% of meal)	0.6	1.0	3.3

Table 6 : Dietary amino acid content recommendations (g/kg) for growth and reproduction in commercial rabbit meat production (TABOADA *et al.*, 1994, 1996; DE BLAS *et al.*, 1997).

Amino Acid (AA)	Lysine	Sulphur AA	Threonine
Fatteners	7.6 *(6.0)*[1]	7.2 *(5.8)*	6.0 *(4.0)*
Reproduction	8.0 *(6.4)*	6.3 *(4.9)*	6.4 *(4.4)*

[1]Between brackets, recommendations are expressed as digestible values

Fig. 1: Effect of mortality rate during the fattening period on feed conversion



mentioned dietary AA recommendations are average values for the whole fattening period and probably underestimate the AA requirements of young rabbits (3-7 weeks) but overestimate them in the finishing period (8 -10 weeks of age). A phase feeding program (see also chapter 2) provides diets better adapted to the different ages resulting in a more efficient production. Because rabbit production is utilizing, more and more, a better organized reproduction system, large numbers of weanlings of the same age are housed together. Under field conditions, different diets can then be fed even when using an automatic feeding system.

Also interesting in the works of this Spanish team is the observation that the apparent faecal digestibility, of the crystalline AA, about 30 points higher was than the corresponding AA digestibility from raw materials. This indicates clearly the need of using digestible rather than crude units to express AA requirements and dietary recommendations. However, data concerning the digestibility of the AA content of raw materials are lacking. The caecotrophy phenomena in rabbits further complicates a correct evaluation as performed in pigs and poultry. Ileal AA digestibility has to be corrected in rabbits for microbial synthesis and will therefore not necessary provide more accurate information than faecal digestibility.

1.3. By reducing the mortality

The impact of the mortality rate on the feed conversion rate is extremely high. Not only all the feed consumed by these rabbits are lost, but also they reduce the efficiency of their mother. In figure 1, the effect of mortality on feed conversion is presented. These data were obtained in nutrition experiments at our Institute. Mortality refers to units of 4 cages (20 rabbits) in which 0, 1 (5%), 2 (10%) or 4 (20%) fatteners died.

In recent years, some dietary factors have been linked with the mortality rate in the fattening period. The sensitivity of young rabbits to high dietary levels of starch has been demonstrated in several experiments (LEBAS & MAITRE, 1989; BLAS *et al.*, 1994; PEETERS *et al.*, 1993; MAERTENS, 1995). Based on these works, low starch levels reduce the risk of digestive disorders in the first weeks following weaning.

Furthermore, the significant role of dietary lignin on the rate of passage and its protective effect against diarrhoea has been pointed out (GIDENNE & PEREZ, 1994; PEREZ *et al.*, 1994).

The mortality rate due to digestive disorders was closely related to the ADL level in their experiments :

$$\text{Mortality (\%)} = 15.8 - 1.08\ \text{ADL(\%)}$$
$$r = 0.99$$

Quite similar effects were observed by the same team of researchers with various cellulose (ADF-ADL) levels (GIDENNE & PEREZ, 1996; PEREZ *et al.*, 1996). The diet with a low cellulose level (9.3%) especially led to an increased transit time and significantly higher mortality rate. However, in this experiment cellulose was mainly replaced by starch while ADL level remains constant.

The significant role of starch and fibre fractions in preventing against enteric diseases was recently stressed by GIDENNE *et al.*, (1998). Diets with the same starch

Table 7 : Effect of lignin/cellulose ratio on the performances, transit time and sanitary situation (GIDENNE *et al.*, 1998).

Diets	LC8	LC4	LC2
Crude protein (%)	17.8	17.5	17.4
Starch (%)	21.5	22.0	22.6
Crude fibre (%)	10.7	11.4	12.6
ADF (%)	15.7	15.8	16.5
ADL (%)	7.0	4.8	2.5
ADL/cellulose ratio	0.80	0.42	0.18
Daily weight gain (g), weaning – 10 w	48.9 a	48.2 ab	46.4 b
Feed conversion rate	2.78 a	2.72 ab	2.68 b
Rate of passage (h)	16.4 a	21.2 b	20.8 b
Mortality (%)	13.6	10.6	7.6
Morbidity (%)	9.1 a	13.6 a	36.4 b
Sanitary risk (%)	22.7 a	24.2 a	43.9 b

and ADL level, but a very divergent lignin/cellulose ratio showed a clear response in rate of passage and in their risk of enteric problems (Table 7). At low ratio (0.2), a significant increased morbidity was observed but not a tendency to increased mortality.

It has to be stressed that the above-cited experiments are sometimes difficult to interpret because a quantitative increase of one component is always at the expense of another nutrient(s). Effects can not always be ascribed to a single nutrient. But the significant role of the carbohydrate fraction and the balance between starch and «fibre» became more and more clear in optimizing dietary safety. They clearly indicate that recommendations in terms of dietary safety can not be expressed by a single fibre fraction (e.g. crude fibre, ADF or ADL).

Table 8 : Influence of an experimental infection on the growth rate and mortality of young rabbits (PEETERS *et al.*, 1993).

Exp. Infection	Non-infected	Coli spiroforme	Coli 0132	C. spirof. + Coli 0132
Weight gain (g/d)	42.5	42.2	34.1	22.4
Mortality	1/20	1/20	2/20	7/20

Furthermore, recommendations are age dependent. Till 7-8 weeks of age, a maximum starch constrain has to be used (± 13.5%) in addition with sufficient lignin (ADL >5%) and cellulose (>15%). The cellulose recommendation is easily met if adequate levels of crude fibre (16%) or ADF (>20%) are used. In the finishing period, starch has no longer to be restricted while a dietary ADL level of 4.5% is sufficient in terms of dietary safety (PEREZ *et al.*, 1996).

Recently, results were published indicating that a high dietary buffering capacity leads to an increased ammonia and urea blood levels (BRIENS *et al.*, 1998). A tendency to decreased mortality was observed with a low buffering capacity especially when combined with a dietary acidifier. However, this observation has to be confirmed with a larger number of animals and under stricter experimental conditions.

Dietary safety fits perfectly with a future trend. A further banning by the EEC legislation of dietary additives can be expected. Therefore, disease control including dietary safety will be of increasing interest in the future. Nevertheless, the efficiency of alternative products (for antibiotics) is still regrettably doubtful.

However, when rabbits are contaminated with highly pathogenic agents mortality will occur even with a diet considered as safe. Recently the problems with enterocolitis are a perfect illustration (COUDERT *et al.*, 1997). Furthermore a synergistic effect of pathogenic agents, resulting in increased mortality, has been demonstrated quite independently of the diet used (Table 8). When rabbits where simultaneous orally

Table 9 : Objectives of future highly productive rabbits

Does :
- Litter size : 10 -11 young
- Weaned/litter: 9 - 10 and 7 litters/doe/year
- Milk production : 0 - 3 weeks: > 5 kg
- Feed intake : >150 g/kg$^{0.75}$ or >450 g/day or > 10% live weight

Fatteners :
- Daily weight gain : 50 g and a weight at 9 weeks of 2.4 kg
- Feed conversion ratio : < 3.0

Rabbitry : Overall feed conversion ratio : <3.25

Table 10 : Calculation of the feed conversion in a high performance reproduction unit

Feed consumption (kg)	per 100 doe-unit	Rabbit production (kg)	per 100 doe-unit
Doe + litter till weaning: 13.5k 7 litters/doe/year	9,450	Weaned young : 0.700 kg 56/doe/year	3,920
Other stock always present: young females: 20/100 does females in wait-cages : 15/100 pregnant females : 15/100 with an average feed intake : 160g/d or in total 50 x 160g/d x 365 days	2,920	Sold does or males: 70 of 3.0 kg	210
Total	**12.370**	**Total**	**4,130**

Feed conversion: 12,370/4,130 = **3.00**

Table 11 : N and P excretion (tons) of different sizes of rabbitries and their minimal taxation in Belgium (US $)

No of does	N	P	Taxes/year
300	2.5	1.4	-
1 000	8.2	4.8	850
10 000	82.1	47.7	13,000

If < 1.5 tons P_2O_5 and <3.0 tons N and enough land: no taxes
If between 1.5 and 15 tons P_2O_5 and 3 - 30 tons N : from 0.05 till 0.09 US $/kg
If > 15 tons P_2O_5 and > 30 tons N: 0.10 US $/kg

Table 12 : Calculation of the N and P excretion in a rabbitry

	N (kg)	P (kg)
Dietary input in the farm		
9.6 kg x 2.72%	0.261	
9.6 kg x 0.65%		0.0624
Output in sold rabbits		
2.4 kg x 2.90%	-0.070	
2.4 kg x 0.58%		-0.0140
Excretion per rabbit	0.191	0.0484 or 0.111 kg P_2O_5 (x 2.29)
Excretion per doe/year = x 43	8.21	4.77

infected with 2 moderate pathogenic agents (*C. spiroforme and E. Coli 0132*), effects on weight gain and mortality were much more pronounced than what could be expected from the single artificial infections.

1.4. Other factors linked with nutrition

When using high performance rabbits and adapted diets, we have indicated that a technical feed conversion (without mortality) less than 3 can be obtained during the fattening period (see Tables 2; 4 and 7).

However, to obtain an overall favourable feed conversion of the rabbitry, the feed consumption and production of weaned young is also important. An intensive use of high performance does, with short intervals between the litters, restricts the relative amount of feed consumed by the reproduction stock. Consequently an increasing number of weanlings/doe/year results in an improved feed efficiency. The future definition of high productive does is given in Table 9.

As an example, in Table 10 the feed conversion rate of a high performance reproduction unit is calculated. In this calculation, we have assumed that in a 100 doe unit always 50 non-productive adult rabbits are present (including young does). Their average intake level is estimated as 160g/day. The feed conversion rate of this high performance unit (56 fatteners/doe/year) is only 3.00.

During the last years, the overall feed conversion rate of rabbitries was around 3.8-3.9 in different European countries (RAFEL GUARRO, 1996). However, the above mentioned values for fatteners and reproducing does, demonstrate that an overall feed conversion rate of 3.0 is no longer fiction. Anyway, a further reduction from the actual average of 3.8 towards 3.25, is absolutely necessary to produce meat competitive with poultry and pork. Actually the most productive farms in France and Belgium can deliver rabbits with feed conversion rates of 3.25 kg feed/kg live weight.

2. Nutrition in view of reducing the mineral output

In Belgium (Flanders), animal producers have to pay per kg N and P produced on their farm. The taxation depends of the total farm production (rabbits and other livestock), the region, if you have enough land to use the manure as fertiliser and if you have a contract with an agriculture unit or if not. The general idea is that the polluter has to pay. In table 11 a simplified calculation of the taxation is given for 3 sizes of rabbit farms. However, if you have no land or no contract that the manure can be utilized as fertilizer, taxes are nearly twice as high. For this reason research to reduce the N and P excretion, originating from animal production has high priority.

For rabbit producers fix excretion data per doe are

Fig. 2: N-excretion of rabbits between 32 and 74d of age

Expressed as % of diet 1 (Maertens et al. 1997)

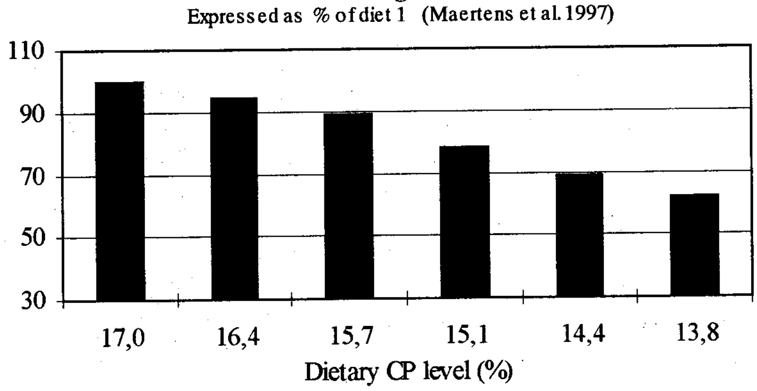


Table 13 : Performances and N-excretion of rabbits according to phase feeding

CP level of starter	18.3	16.3	16.3	15.6	15.6	14.9	14.9	P
CP level of finisher	18.3	15.4	14.7	14.7	14.0	14.0	13.3	
Weight at 71 days (g)	2401	2391	2410	2361	2323	2353	2293	0.014
Weight gain (g/d)	40.8	40.8	40.8	39.5	38.8	39.9	38.3	0.008
Feed efficiency	3.14	3.08	3.05	3.10	3.07	2.98	3.06	0.006
N-excretion	=100	73.8	71.1	63.2	62.9	58.4	55.0	0.001

used. The following production data were used to calculate this average excretion: 43 sold rabbits of 2.4 kg/doe/year and a feed conversion rate of 4.0. Diets contain on average 2.72% N (17% CP) and 0,65 P, while rabbits contain 2.90% N and 0.59 % P. With these data the following N and P balance can be drawn up (Table 12)

There exist a lot of nutritional possibilities to interfere on the mineral output of animals. First of all we have to avoid feeding animals in excess of their requirements. Unbalanced diets also lead to higher wastes to the environment. It is better to know the real requirements for each production phase, and how the feed can be adapted and formulated. Recently, experiments have been performed with N and P diluted diets in order to reduce the excretion.

2.1 N-excretion

Rabbits diets contain on average an excess of protein as has been demonstrated by MAERTENS *et al.* (1997). A dilution of the dietary protein content (CP) from 17.1 till 15.7% resulted in a decrease with 11% of the nitrogen excretion in their experiments. If the first limiting AA (lysine, sulphur AA and threonine) are above the requirements, the same zootechnical performances were obtained. A further dilution of the CP till 13.8% reduced daily weight gain with 9% but the N-excretion by 38% (Figure 2). This could be explained by the significant linear relationship between the protein intake and the N-excretion found in that experiment:

N-excretion (gDM/rabbit) = 0.14 CP intake (g/DM/rabbit) - 34.94
r =0.993 P<0.001

Below a level of 15.7% dietary CP, zootechnical performances were altered during the first weeks after weaning. Because of the significant interaction between diet and age of the rabbits, an age dependant response to the dietary protein (and AA) content was demonstrated (MAERTENS *et al.*, 1997). Young rabbits claim higher dietary protein (AA) levels than in their finishing stage.

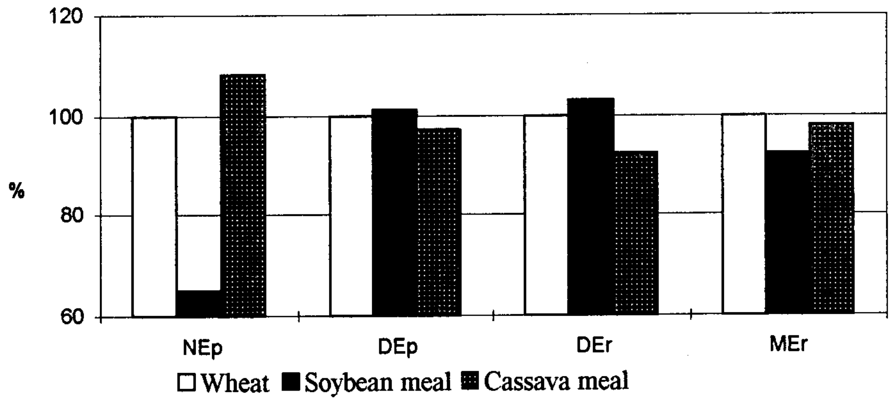
Based on these observations, different phase feeding systems were evaluated in order to reduce the N-excretion (MAERTENS & LUZI, 1997). After weaning, rabbits received one of the starter diets and changed to a finishing diet during the 3 last weeks of the fattening period (Table 13). Phase feeding combinations with the lowest CP content reduced weight gain by 2.3 till 6.1% but the observed decrease in N-excretion was between 26.8 and 45.0%. These results illustrate clearly that a very large reduction of the N-excretion can be obtained if the diet corresponds with the requirements at a given age. Further research is still necessary to match better the dietary composition with the real requirements.

The impact of quite small differences in protein/energy (P/E) ratio (11.5 vs 12.5) was recently stressed (MAERTENS *et al.*, 1998). Nitrogen output on diets with low P/E ratio was significantly reduced with 8.5% while comparable performances were obtained during the finishing period. In agreement with XICCATO (1998), the carcass composition and meat quality characteristics were not influenced in the used range of P/E ratios. However, the effect of the energy source (fat vs starch) was much more important. Practical levels of inclusion of fat (2.5%) or fullfat soybeans (10%) changed significantly the carcass composition, the final pH and the drip losses (MAERTENS *et al.*, 1998). Dietary fat addition promoted the production of fatter carcasses in agreement with the literature (XICCATO, 1998) and thereby stressed that minimal N-excretion using low protein diets holds the risk of undesired fat deposition.

2.2 P-excretion

Phosphorus requirements of rabbits are low and the amount supplied by the dietary raw materials exceeds the needs of both fatteners and does (LEBAS & JOUGLAR, 1990). Recently LEBAS *et al.* (1998) confirmed that a dietary P content of 4.8 g/kg is enough for maximal growth performance and to assure the bone strength. Although these observations seem promising in reducing the P excretion, a large reduction is not achievable under practical conditions. To obtain a

Fig. 3. Comparison of some energy systems in rabbits and



dietary P level below 5g/kg, several raw materials rich in P (grains, grain by-products...) can not be used. Consequently, reducing the dietary P-level results in more expensive diets.

3. Energy evaluation systems

Actually, in a lot of countries, the DE system is still followed in rabbit diet formulation. However, DE overestimates the energy value of protein concentrates (Fig. 3). These ingredients have to be evaluated on the basis of their amino acids instead as an energy source. The DE system favours further the production of protein rich diets and consequently it is a bad system in view of the above treated N excretion policy. For these reasons, already in 1990, The Netherlands and Belgium changed to the ME system (MAERTENS *et al.*, 1990). This system makes a more correct choice possible in obtaining least cost diets and can thereby lead to cheaper diets. The ME values were corrected to zero N retention.

In Fig. 3, the DE and ME values of cassava meal (carbohydrate rich), wheat and soybean meal are compared with the NEp and DEp values for pigs as proposed by NOBLET *et al.* (1994). Values are expressed as % of wheat in the different energy systems. Two main conclusions can be drawn: (i) ME favours grains and carbohydrate feedstuffs (ii) ME values used for rabbits tend to go in the direction of the NE values for pigs. Although imperfect, ME leads to a more correct mutual comparison and choice between feedstuffs. For example the DE value of soybean meal exceeds wheat while this is inverse in the ME system. When using least-cost diet formulation, the computer will chose for protein rich feedstuffs instead for starch rich feed feedstuffs as energy source (depending of the price situation). Consequently, the DE concept holds the risk to lead to protein rich diets. As already mentioned such diets favour the environmental pollution. Therefore, in the most recent feedstuff table for rabbits (PEREZ *et al.*, 1998), a method is given to calculate the ME values of feedstuffs from their DE content. Although in the future a NE system has to be developed, actually the ME system is the most valuable system in rabbit diet formulation.

CONCLUSIONS

a) Efforts to reduce the feeding costs will be of primarily importance to maintain an economical rabbit meat production. Rabbits still have a large potential to improve their feed efficiency. The combination of high performance rabbits, an adequate management, a control of the disease problems and adapted diets can reduce future overall feed conversion rates to 3.25.

b) In areas with a high density of animal production, constraints of diet formulation relating to minimal mineral excretion are important. Good quality dietary proteins, balanced in their amino acid levels and perfectly matching with the requirements are the most important keys to reduce the N-excretion in rabbits. Phase-feeding of such diets can reduce the output with 30-40% without deteriorating effects on the zootechnical performances.

c) Significant progress has been made in the knowledge of the «fibre» requirements of young rabbits. A lignin (ADL>5%), starch (<13.5%) and cellulose constrain (>15%) has to be used in diet formulation instead of a single recommendation for crude fibre or ADF. In finishing diets, dietary safety can be obtained when sufficient ADL(>4.5%) and crude fibre (>14.5%) or ADF (>18%) are available.

d) Dietary safety, reduced N-excretion, AA requirements and reduced feeding costs fits perfectly with the trend to use multi phase-feeding.

e) Finally, it has been stressed that further efforts are necessary to develop a more correct protein and energy evaluation system in rabbits.

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