Proceedings 4th World Rabbit Congress, 10-14 October 1988, Budapest Hungary, Vol. 3, 1-29

RECENT DEVELOPMENTS AND FUTURE GOALS IN RESEARCH ON NUTRITION OF INTENSIVELY REARED RABBITS

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In the last four years, after the IIIrd World Rabbit Congress held in Rome (April 1984), researches in the different fields of nutrition and feeding of intensively reared rabbits accomplished substantial and important progress.

The most important results of the research carried out in the countries most involved in intensive rabbit production have been published in some congresses and meetings. Among them, we can mention in chronological order:

- The meeting of "Gruppo Nazionale del C.N.R. - Allevamento delle piccole specie", held in Rome (Italy), Nov. 14-15, 1985.
  During this meeting, 23 papers on rabbit production were presented by Italian researchers. Eight of these papers concerned nutrition and feeding and, in particular, the following subjects: digestibility of concentrate diets, prediction and utilization of digestible energy in growing rabbits, utilization and nutritive value of alternative feeds or by-products.
- The "4th World Congress of animal feeding", held in Madrid (Spain), June 28th - July 4th, 1986.
  During this congress, results concerning protein and energy requirements of growing and reproducing rabbits, obtained from calorimetry experiments were presented.
- The "4^{émes} Journées de la recherche cunicole en France", held in Paris (France), Dec. 10th-11th, 1986.
  Twelve of the papers presented concerned feeding and nutrition and

included studies on caecotrophy, digestibility and digestive transit, quality of fibre, etc.

- The "1st North American Rabbit Congress", held in Portland, OR, U.S.A., Oct. 10th-13th, 1987.

Ten papers were presented in the nutrition and physiology section of this congress. The most interesting of those regarded vitamine A toxicity, non-protein nitrogen utilization and the microbiology of the rabbit intestine.

In this paper, it is practically impossible to review and/or discuss all the above-mentioned subjects.

Fortunately, a very well documented and comprehensive book on rabbit feeding and nutrition was recently published by Cheek (1987). This book summarizes the most recent advances of research in this field and it will be very useful to people concerned with rabbit rearing, including animal nutritionists.

For this reason, only a few aspects of rabbit nutrition will be treated in this paper. Among them, energy metabolism and requirements for growth and reproduction will be discussed. Moreover, mention will be made of the recent research on the protein to energy ratio, in order to give a suggestion regarding the standard requirements to be applied in formulating complete diets for rabbits.

Furthermore, the problem of the digestible energy prediction of rabbit diets will be considered, on the basis of chemical composition or dry matter digestibility.

Another topical subject, not yet completely clarified, will concern the digestive utilization of the so-called "fibre", namely, the vegetable cell wall constituents.

The energy metabolism of growing rabbits

The energy metabolism of growing rabbits has been recently studied using the comparative slaughter technique (indirect calorimetry). The results of 5 comparative slaughter experiments, involving 180 growing N.Z. White male rabbits, were used to study the effect of the DE intake on daily gain composition and on energy retained as protein and fat (Parigi-Bini and Xiccato, 1985).

The equations obtained from these experiments are reported in figure 1.

These regressions show that the daily empty body gain (EBG) increases as the DE intake increases, and that the chemical composition of EBG (and its energy value) is strongly influenced by the DE intake.

When the DE intake is equal to body weight maintenance (EBG = 0), a loss of body fat can be observed. When DE intake approaches the maximum value (about 250 kcal DE/kg net weight$^{.75}$), protein deposition is higher than that of fat in terms of weight, but the energy retained as fat is equal to energy retained as protein. In fact, for the growing rabbit, the calorific value of retained protein and fat is equal to 5.58 and 8.5 kcal/g, respectively, as determined by the bomb calorimeter (Parigi-Bini and Dalle Rive, 1978).

Assuming the above indicated energetic values for retained protein and fat, the quadratic regression equations and the corresponding curves of figure 2 were determined, demonstrating that energy retention (ER) is a function of DE intake.

From these equations, it appears that the energy equilibrium (ER = 0) is reached when DE intake is 113 kcal/kg net weight$^{.75}$.

In experiments involving 330 Spanish Giant rabbits, de Blas et al. (1985) obtained a higher value (132 kcal DE/kg metabolic weight) for maintenance of energy equilibrium. This difference may be due to the different breeds used (Spanish Giant vs N.Z. White) or, mainly, to the fact that only animals in positive energy balance were utilized for the calculations.

Other estimates of the DE requirement for maintenance and estimates of energy efficiency for protein and fat deposition are given by the equations reported in table 1 (de Blas et al., 1985; Parigi-Bini and Xiccato, 1985). These equations are quite similar and indicate an efficiency of DE for protein and fat deposition of 38-44% and 64-70%, respectively. Satisfactory consistency is shown also between the equations derived from the regression of digestible protein intake on protein retention (table 1). These equations indicate maintenance requirements for protein (RP = 0) of 3.7-3.8 g of digestible protein per kg of metabolic weight and an efficiency of digestible protein for protein retention higher than 90%.

In this regard, however, it is important to remember that the equations reported in table 1 have been obtained using the causal variable (i.e., DE or DCP intake) as a dependent variable. The estimations obtained using this procedure can be severely biased, unless the correlation between the two variables is very high (Gill, 1987).

The energy metabolism of rabbit does

There is little information in the scientific literature on energy metabolism and, in general, on nutritive requirements of intensively-reared does.

Only recently Partridge et al. (1986) published the results of calorimetry experiments obtained from does fed with highly concentrated diets in each of 4 physiological reproductive states: non pregnant, pregnant, lactating or concurrently pregnant and lactating. The most important results of this research are shown in table 2.

According to these equations, the dietary DE appears to be utilized very efficiently by reproducing does: 63.7% by non pregnant and pregnant does and more than 80% by lactating and concurrently pregnant and lactating does.

The very high overall efficiency of DE utilization in lactating does may be due, according to the authors, to body fat mobilization for milk synthesis, particularly in early and mid-lactation (in these phases, in fact, the energy excreted with milk cannot be fully compensated by DE intake, as voluntary intake is still rather low).

From the equations in table 2 the DE requirement for maintenance of energy equilibrium (RE = 0) can be estimated: 78, 85, 123 and 114 kcal/kg metabolic body weight/day, for non pregnant, pregnant, lactating and concurrently pregnant and lactating does, respectively.

In the case of lactating does, the energy contained in milk must be added, if the energetic equilibrium of the doe is to be maintened.

The milk energy output can be estimated on the basis of DE intake (DEI), using the following equation (Partridge et al., 1986):

$$\text{Milk E (kcal)} = 0.266 \text{ DEI (kcal)} + 150$$

or by multiplying the milk production (i.e., measured by weighing the does immediately before and after suckling) by the calorific value of rabbit milk (about 2 kcal/g).

As regards the energy balance during pregnancy and during pregnancy concurrent with lactation, the estimate is complicated by the transfer and partition of energy retained in the maternal body (as protein and fat) to the growing foeta.

The partition of dietary energy between the body of the doe and the pregnant uterus has been investigated by the comparative slaughter technique (Parigi-Bini et al., 1986). The results showed that in the first period of pregnancy (0-21 days) the energy retained in the doe's body was much higher than that retained in the pregnant uterus (80% and 20% of RE, respectively) and was equally represented by protein and fat (table 3). During the last period of pregnancy (21-30 days) an energy loss from the doe's body and a high energy gain in the pregnant uterus were observed (table 3). This gain was only partially explained by the dietary energy intake.

Data concerning various blood plasma metabolites (table 4), measured in the same experiment, confirm the intense modification of energy metabolism in late pregnancy. A clear demonstration of this modification is the redoubled level of glucagon. This pancreatic hormone antagonizes some actions of insulin and the serum insuline to glucagon ratio is thought to be important in the control of liver metabolism and in the catabolic utilization of body reserves (Brockman, 1986).

Glucagon may stimulate ketogenesis (Brockman, 1986) and a decreased glycemia and increased ketone bodies level in rabbit does was also observed in late pregnancy by others (Jean - Blain and Durix, 1985).

Therefore, it is evident that the last period of pregnancy is characterized by a transfer of energy (particularly as protein) from the doe's body to the pregnant uterus.

Similar results were reported for other animal species (i.e., by Noblet and Close, 1980, for sows and by Rattray et al., 1980, for ewes). showing that in late pregnancy the maternal tissues are catabolized to meet the energetic demand of the developing foeta.

This means that the rabbit doe, especially when submitted to intensive remating programs, is subjected to periods of severe energy deficit (late pregnancy, early lactation and/or concurrent pregnancy and lactation).

Consequently, in practical conditions, the maintenance of the energy equilibrium in the different phases of the reproductive cycle, seems to be merely a theoretical aim: the diet must be therefore studied in order to maintain an overall balance for the entire reproductive life, while assuring at the same time a good performance.

The energy and protein requirements for growth

Figure 3, adapted from Partridge (1986), shows the response in terms of daily growth, dry matter and energy intake to increasing concentrations of dietary digestible energy (DE). In these experiments, the digestible crude protein (DCP) to DE ratio was held constant at 55 g DCP/Mcal DE; the protein contained the major aminoacids in satisfactory equilibrium.

This typical growth-response curve shows that the maximum average daily growth is achieved when the concentration of DE in the diet is equal to 2.6-2.7 Mcal/kg DM, corresponding to an ingestion of 240 Kcal DE and 13 g DCP per kg of metabolic body weight.

The above-reported digestible protein intake and ratio to DE appears to be in excess if compared to that reported by others.

Fraga et al. (1983) and de Blas et al. (1985) identified an optimum digestible protein to energy ratio at about 43 g DCP/Mcal DE or 61 g CP/Mcal DE, assuming an average digestibility coefficient for protein of 70%. Therefore, a diet containing the recommended level of

Proceedings 4th World Rabbit Congress, 10-14 October 1988, Budapest Hungary, Vol. 3, 1-29

2.5 Mcal DE/kg as fed (Lebas, 1984) should contain 10.8% DCP or 15.4% CP.

The results shown in figure 4 were obtained in a recent metabolism experiment (Parigi-Bini et al., 1988). Conventional diets (based on barley - wheat bran - dehydrated lucerne and on soybean - sunflower proteins) were used, with added synthetic methionine and/or lysine to cover the accepted requirement of these amino acids (Lebas, 1984).

The results confirm that an intake of about 240 Kcal DE/kg body weight$^{.75}$ or little more is required for a maximum daily growth, with a protein to energy ratio equal to 45 g DCP/Mcal DE.

The energy and protein requirements for reproduction

In the last few years, the studies on protein and energy requirements of rabbits during pregnancy and lactation have made some progress.

Partridge (1986) reviewed this subject and evidenced a relation between milk production and protein and energy intake, as follows:

$$MP = 17.61 + .985\ CPI + 126.7\ DEI \pm .45$$

where: MP = milk production (g/day)
CPI = crude protein intake (g/day)
DEI = digestible energy intake (Mcal/day)

The crude protein to digestible energy (CP:DE) ratio derived from the standard requirements (180 g CP in a diet containing 2.6 Mcal DE/kg) (Lebas, 1984), is about 69 g CP/Mcal DE, or 48 g DCP/Mcal DE assuming a digestibility coefficient for protein of 70%.

Other authors, who utilized practical diets characterized by lower energy concentrations, indicated a similar ratio.

Sanchez et al. (1985), in a long term experiment involving a high number of does, obtained the best results in terms of fertility, pre-weaning and post-weaning performance, with a diet containing 50 g DCP/Mcal DE or 70 g CP/Mcal DE.

Similar results were reported by Mendez et al. (1986), who stressed that a protein to energy ratio lower than 48 g DCP/Mcal DE did not give a good reproductive performance, especially when associated with an intensive rebreeding program.

Raharjo et al. (1986), utilizing diets with relatively low energy concentrations (without cereal grains), confirmed the above indicated value.

In conclusion, a protein to energy ratio equal to 48-50 g DCP/Mcal DE (corresponding to 68-70 g CP/Mcal DE) seems to be fully adequate for the most frequent commercial and practical conditions. Only in particular situations (i.e. highly concentrated diets fed to does submitted to intensive reproductive programs), the protein to energy ratio can be higher, as indicated by Partridge et al. (1986).

Finally, as far as the protein to energy ratio for growth and reproduction-lactation is concerned, it is important to emphasize that the amino acid balance of dietary protein is of the utmost importance. In fact, the requirement of the animals is for amino acids, rather than for protein. Therefore, the concept of the digestible protein to digestible energy ratio must be extended to include the essential amino acid to digestible energy ratio.

The practice of increasing the protein dietary level to reach the level of a required essential amino acid value can have some negative consequences. As shown by Morisse et al. (1985), an excess of dietary protein increases the ammonia nitrogen level in the caecum, causing a pH increase, proliferation of pathogenic bacteria (i.e., Clostridia) and, consequently, enteritis problems.

The identification of the correct amino acid to digestible energy ratio may be very useful in formulating concentrated diets for rabbits, but unfortunately the information available in this field is still scarce. However, on the basis of the published requirements, (Lebas, 1984), the requirements of essential amino acids (in g/Mcal DE) for growing and lactating rabbits are reported in table 5.

Proceedings 4th World Rabbit Congress, 10-14 October 1988, Budapest Hungary, Vol. 3, 1-29

The prediction of the energy content in diets for rabbits

The knowledge of the energy content (or nutritive value) of feedstuffs for rabbits is obviously important, both from a scientific and practical point of view.

Several researchers have analysed this problem, both in the past and recently, and a round table has been organized in this congress as well to discuss the different methods used to estimate the nutritive value of diets for rabbits.

Fekete (1987) has recently stressed that digestible energy (DE) is the most useful and utilized unit to represent the nutritive value of feed: the estimate of the DE of feedstuffs and of complete diets is easier, more repeatable, less expensive and time-consuming than metabolizable or net energy determination, and, at the same time, DE is higly correlated with the real productive energy of feed.

The methods suggested by various authors to estimate the DE content of complete diets for rabbits can be divided into two groups (table 6):

- methods based on the chemical composition of feed;
- methods based on the digestibility of nutrients.

The former, which require only the determination of some chemical constituents, are quick and cheap but not very precise. The latter methods give very exact and reliable results, but require the execution of in vivo digestibility trials and are thus more expensive and time consuming.

From a practical point of view, it is obvious that the methods based on the analytical determination of one or few chemical constituents are to be preferred, despite the inevitable error of estimate. In particular, the methods based on ADF determination seem to be more precise (De Blas et al., 1984; Battaglini and Grandi, 1985), even though for the complete diets containing the most usual components (cereal meal and bran, dehydrated lucerne meal, soybean meal, etc.), the simple determination of "Weende" fibre gives a sufficiently reliable estimate (Parigi-Bini and Dalle Rive, 1977; Fekete and Gippert, 1985).

Proceedings 4th World Rabbit Congress, 10-14 October 1988, Budapest Hungary, Vol. 3, 1-29

Fibre digestibility and utilization

In comparison to other animals (including the omnivore adult swine) the rabbit digests fibre less efficiently (table 7).

However, it is well known that a relatively high quantity of fibrous materials is needed in diets for rabbits, if good health and productivity are to be achieved and maintained.

The role of fibre in rabbit nutrition has been recently reviewed by Cheeke et al. (1986), who stressed the beneficial effects of a correct dietary fibre level for a normal growth, gut motility, retention time of ingesta, prevention of enteritis and enterotoxemia. According to these authors, a low fibre diet, coupled with a high level of readily-fermentable sugars (i.e. starch) determines the so-called "carbohydrate overload".

According to the authors this condition is the main cause of enteritis, pathogen prolif-ration and enterotoxemia, particularly when accompanied by stress (i.e. sudden changes in environmental temperature).

With regard to th subject, not all the authors agree on the theory of "carbohydrat overload". Morisse et al. (1985) showed that "high fibre - low starch" diets, lowering the volatile fatty acid production and acidic conditions in the caecum,contrast the normal microflora and promote the proliferation of Clostridia spp.

More details on these contrasting theories are summarized in a letter exchange between Cheeke and Morisse (1986), where the two distinguished scientists discuss their opinions. Both agree, however, on the need of more research in this field and conclude on the necessity to balance the starch and the cell wall constituents of the diet, namely to identify a correct starch to fibre ratio.

At the moment, the information given by the scientific literature on this matter is very scarce and the question is raised if we are in the position to identify this ratio with the necessary precision.

Recently de Blas et al. (1986) published a paper on fibre and starch levels in fattening rabbit diets. These authors used diets containing several levels of starch (from 12.7% to 30% of d.m.). When the starch content increased, the crude protein level also increased (from 14.6% to 21.3% d.m.) and the fibre level decreased (ADF, from 32.7% to 12.6% of d.m.), in order to maintain a fairly constant protein to digestible energy ratio. The growing rabbits fed with the "30% starch - 12.6% ADF" diet showed a high diarrhea incidence and mortality, probably in relation to a low rate of passage of digesta and an impaired gut motility. The best results in terms of daily gain, feed efficiency and mortality were obtained from the diets containing 21-23% starch and 15-20% ADF in d.m..

In a recent digestibility experiment (Parigi-Bini et al., 1988), two diets containing the same levels of CP and ADF but different levels of starch were tested. As expected, the average daily gain was not significantly different, and the dry matter intake was slightly higher with the lower starch level diet.

The most interesting results concerned the effect of the dietary starch level on the digestibility of the different cell wall constituents, as shown in figure 5.

When the starch level was relatively high, the apparent digestibility of hemicelluloses (and consequently of NDF) significantly decreased, while the digestibility of CF, ADF and cellulose was practically unchanged.

The digestiblity of diets containing very low levels of starch (only 2.5% of d.m.) and very high levels of cell wall constituents (NDF, 47-52% d.m.; ADF, 32-40% d.m.; lignin, 7-16% d.m.), was measured by Gidenne (1987). In these dietary conditions, the digestibility of cell walls was very high: 31-39% for NDF, 43-50% for hemicelluloses, 33-37% for cellulose. High digestibility values were also obtained for NDF by others (Falcao e Cunha and Lebas, 1986), who utilized diets containing the same levels of crude protein, hemicelluloses and cellulose and increasing levels of lignin. In another experiment, the digestibility of energy and organic matter was lower when the diets contained the highest starch levels (Lebas and Frank, 1986).

The above-mentioned results are all consistent and support the conclusion that when the dietary starch level is low, the rabbit is able to adapt its digestive capacity to diet quality, increasing the digestibility of cell wall constituents and particularly that of hemicelluloses.

In this condition, the intestinal microflora probably shifts to a more intense and active population of cellulolytic and hemicellulolytic bacteria in response to "low-starch" diets.

In conclusion, the digestibility of fibre and of fibrous components appears to be influenced by several factors. One of the most important seems to be the above-discussed dietary starch level, but other factors are probably involved: among them, the cellulose to hemicelluloses ratio (ADF:NDF) and the degree of lignification and insoluble ash content of ADF are to be considered. Experimental findings on this subject are lacking and partially conflicting. In the future, research efforts should be intensified in order to clarify these aspects.

Further work is also needed on ligno-cellulose chemistry to better understand the complex carbohydrate utilization by the rabbit and its intestinal microflora for different dietary conditions and physiological states.

Progress in accurate measurements of dietary fibrous constituents and of their digestibility is also needed, using the appropriate analytical procedures. The acid and neutral detergent methods of Goering and Van Soest (1970) are to be preferred, with the enzymic removal of starch (Mc Queen and Nicholson, 1979), (Asp et al., 1983), (Englyst and Cummings, 1984).

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Table 1 - Digestible energy and digestible protein utilization in growing rabbits.

Equation	Statistics	Authors
DE = 122.7 + 2.61 ERP + 1.55 ERF	r = .64**, (n = 330, Spanish Giant)	de Blas et al. (1985)
DE = 115.7 + 2.26 ERP + 1.43 ERF ± 8	r = .96**, (n = 180, N.Z. White)	Parigi-Bini and Xiccato (1985)
DCP = 3.8 + 1.116 RP	r = .57**	de Blas et al. (1985)
DCP = 3.7 + 1.054 RP ± .68	r = .84**	Parigi-Bini and Xiccato (1985)

Note: - DE = Digestible Energy (kcal)
- ERP = Energy retained as protein (kcal)
- ERF = Energy retained as fat (kcal)
- DCP = Digestible Crude Protein (g)
- RP = Retained Protein (g)
- Data from de Blas et al. (1985) are in g or kcal/kg body weight$^{.75}$/day
- Data from Parigi-Bini and Xiccato (1985) are in g or kcal/kg net weight$^{.75}$/day

Table 2 - Regression of energy retained (ER) on digestible energy intake (DEI) in rabbit does for the different phases of reproductive cycle (adapted from Partridge et al., 1986)

Non pregnant does,	ER = .637 DEI − 50 ± 14
Pregnant does,	ER = .637 DEI − 54 ± 23
Lactating does,	ER = .855 DEI − 105 ± 5
Concurrently pregnant and lactating does,	ER = .808 DEI − 92 ± 9

Note: all items are in kcal/kg body weight$^{.75}$/day

Table 3 - Partition of weight gain and energy retention, during the first pregnancy of N.Z. White does (Parigi-Bini et al., 1986)

Days of pregnancy:		0 - 21		21 - 30*	
		Doe's empty body	Pregnant uterus	Doe's empty body	Pregnant uterus
Does	No	9	9	6	6
Composition of weight gain:					
water	g	75.8	163.8	-55.6	364.9
protein	g	60.3	18.2	-21.9	54.3
fat	g	39.5	9.1	-8.3	24.0
ash	g	4.6	2.0	-4.7	10.2
Energy balance:					
Total DE intake, kcal		7,518	-	3,435	-
ER as protein, kcal		337	102	-123	303
ER as fat, kcal		336	77	- 71	204

(*) Difference between the pregnant does slaughtered at 30 days and those slaughtered at 21 days of pregnancy

Table 4 - Blood plasma metabolites level in non-pregnant and pregnant does (Parigi-Bini et al., 1987)

		Non pregnant	Pregnant	
			21 days	30 days
Does	No	10	9	7
- glucose	mg, % ml	111[a]	105[a]	89[b]
- cholesterol	"	49[a]	19[b]	18[b]
- triglycerides	"	57[a]	152[b]	44[a]
- insulin	U/l	6.4[a]	n.a.	7.3[a]
- glucagon	μU/l	59.5[a]	n.a.	129.7[b]
- progesterone	ng/ml	.2[a]	n.a.	3.6[b]
- oestradiol-17β	pg/ml	10.0[a]	n.a.	1.9[b]

n.a. = not analyzed

Row means bearing different superscripts are different ($P < .05$)

Table 5 - Protein and essential aminoacid to digestible energy ratio in practical diets for growth and lactation (adapted from Lebas, 1984)

		Growth	Lactation
Crude protein	g/Mcal DE	60-65	68-70
Digestible protein	"	43-45	48-50
Lysine	"	2.60	2.88
Methionine + cystine	"	2.40	2.31
Tryptophan	"	.68	.84
Threonine	"	2.12	2.69
Leucine	"	4.00	4.81
Isoleucine	"	2.28	2.29
Valine	"	2.68	3.27
Histidine	"	1.32	1.65
Arginine	"	3.60	3.08
Phenil. + tyrosine	"	4.60	5.38

Table 6 - Prediction of apparent digestible energy (DE) of concentrate diets for rabbits.

a) prediction based on the chemical composition

Equation n.		Authors
1 DE (%)	= 85.1 - 1.48 (CF,% d.m.) ± 3.3%	Parigi-Bini and Dalle Rive, 1977
2 DE (%)	= 84.8 - 1.16 (ADF,% d.m.)	de Blas et al., 1984
3 DE (%)	= 92.35 - 1.47 (ADF,% d.m.)	Battaglini and Grandi, 1985
4 DE (kcal/kg d.m.)	= 4253 - 32.6 (CF,% d.m.) - 114.4 (A,% d.m.)	Fekete and Gippert, 1986
5 DE (kcal/kg)	= 7.1 (CP,g/kg) + 12.0 (EE,g/kg) + 5.59 (NFE,g/kg) - 1801	Maertens and De Groote, 1987

b) - prediction based on the dry matter (DM) or nutrients digestibility

Equation n.		Authors
6 DE (kcal/kg)	= 5.28 (DCP,g/kg) + 9.51 (DEE,g/kg) + 4.2 (DCF + DNFE,g/kg) ± .3%	Schiemann et al., 1972
7 DE (%)	= 6.8 + .93 (DDM, %) - .18 (CF, % d.m.) ± .84%	Parigi-Bini and Dalle Rive, 1977
8 DE (%)	= 1.04 (DDM, %) - 2.61	Battaglini and Grandi, 1985

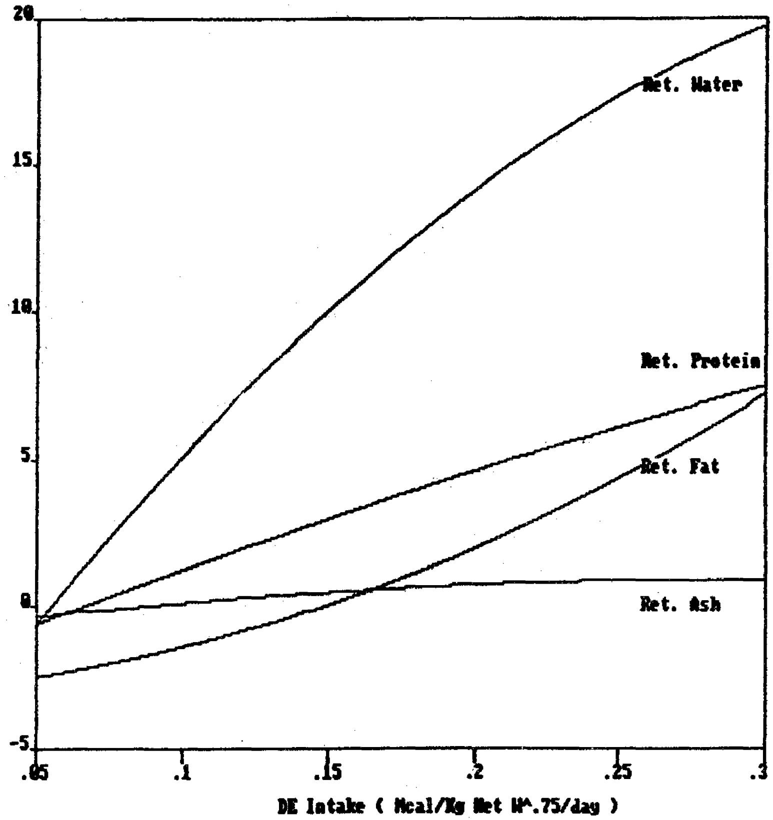
Note: - CF = Crude Fibre; ADF = Acid Detergent Fibre; A = Ash; CP = Crude Protein; EE = Ether Extract; NFE = Nitrogen Free Extractives; DCP, DEE, DCF, DNFE = Digestible nutrients, respectively; DDM = Digestible Dry Matter.
- Equations 1, 2, 3, 7 and 8 give an estimate of apparent digestibility of gross energy (GE) in %. The GE value can be estimated using the equation of Schiemann et al. (1972):
GE (kcal/kg) = 5.4 (CP, g/kg) + 9.60 (EE, g/kg) + 5.09 (CF, g/kg) + 4.17 (NFE, g/kg) ± .5%
or measured by bomb calorimeter.
- Equation 4 give directly the estimated DE content in kcal/kg d.m..
- Equations 5 and 6 give directly the estimated DE content in kcal/kg as fed.

Table 7 - Comparison of vegetable cell wall digestibility in some domestic animals and in the rabbit.

Species	Type of diet	% digestibility of: NDF	ADF	Hemicell.	Cellulose	Authors
Ruminant	hay/grain	56	-	68	52	Varel (1987)
Pony	lucerne	47	-	58	45	Varel (1987)
Pig	lucerne	35	-	43	40	Rerat et al. (1987)
Rabbit	lucerne pellets	-	13-18	-	-	Robinson et al. (1985)
Rabbit	laboratory diet	-	16	-	-	Stephens (1976)
Rabbit	concentrate diets	-	15-22	-	-	Grobner et al. (1985)
Rabbit	concentrate diets	16-23	15-17	18-34 (*)	20-24	Parigi-Bini et al. (1988)

(*) according to dietary starch percentage (see figure 5)

Figure 1: Regression of empty body gain composition on DE intake, in growing rabbits (Parigi-Bini and Xiccato, 1985)



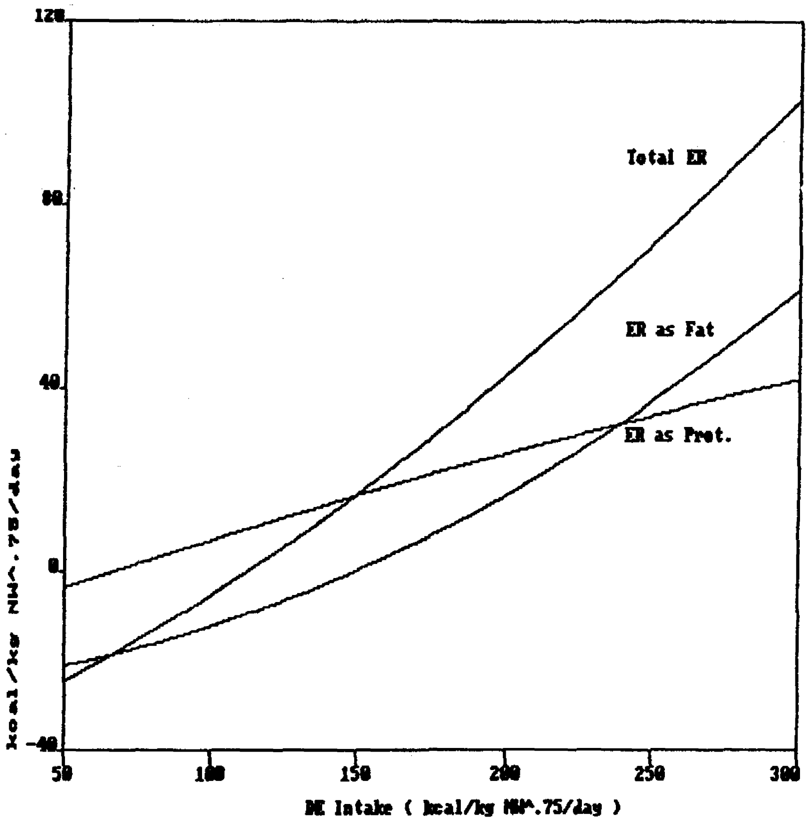
$$EBG = -14.007 + 202.907\ DEI - 128.335\ DEI^2 \pm 1.82 \qquad r = .93^{**}$$
$$RW = -7.253 + 140.503\ DEI - 168.319\ DEI^2 \pm 1.45 \qquad r = .83^{**}$$
$$RP = -2.684 + 41.873\ DEI - 26.766\ DEI^2 \pm .425 \qquad r = .91^{**}$$
$$RF = -3.064 + 7.075\ DEI + 90.540\ DEI^2 \pm .500 \qquad r = .94^{**}$$
$$RA = -1.006 + 13.443\ DEI - 23.738\ DEI^2 \pm .128 \qquad r = .67^{**}$$

where:

EBG (Empty Body Gain), RW (Retained Water), RP (Retained Protein), RF (Retained Fat), RA (Retained Ash) are in g/kg net weight$^{.75}$)/day

DEI (Digestible Energy Intake) is in Mcal/kg net weight$^{.75}$/day

Figure 2 - Regression of energy retention on DE intake, in growing rabbits (Parigi-Bini and Xiccato, 1985)



$$ER = -.041 + .294\ DEI + .619\ DEI^2 \pm .005 \qquad r = .96^{**}$$

$$ERP = -.015 + .234\ DEI - .151\ DEI^2 \pm .003 \qquad r = .91^{**}$$

$$ERF = -.026 + .060\ DEI + .770\ DEI^2 \pm .004 \qquad r = .94^{**}$$

<u>where</u>:

ER (Energy Retained), ERP (Energy Retained as Protein), ERF (Energy Retained as fat), DEI (Digestible Energy Intake) are in Mcal/kg net weight$^{.75}$/day

Figure 3 - Effect of different DE concentration on intake and growth (adapted from Partridge, 1986)

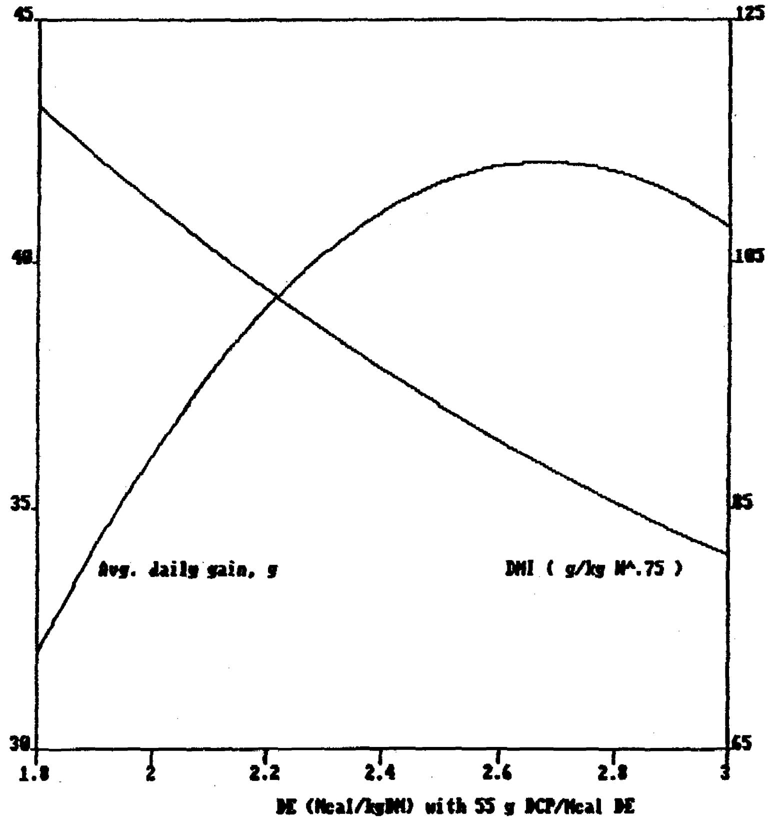


Figure 4 - Daily growth of rabbits fed with a diet containing 45 g DCP/Mcal DE (Parigi-Bini et al., 1988)

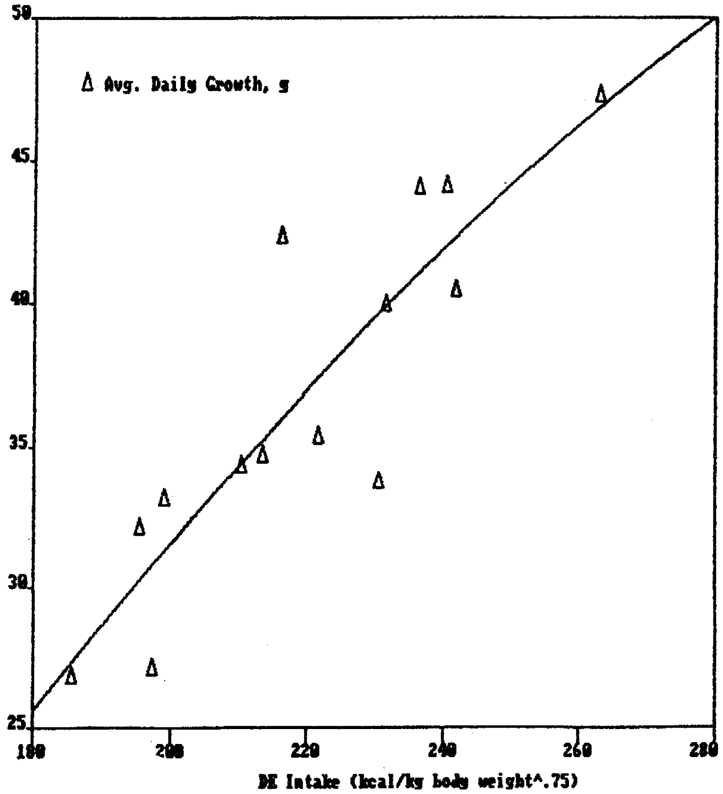
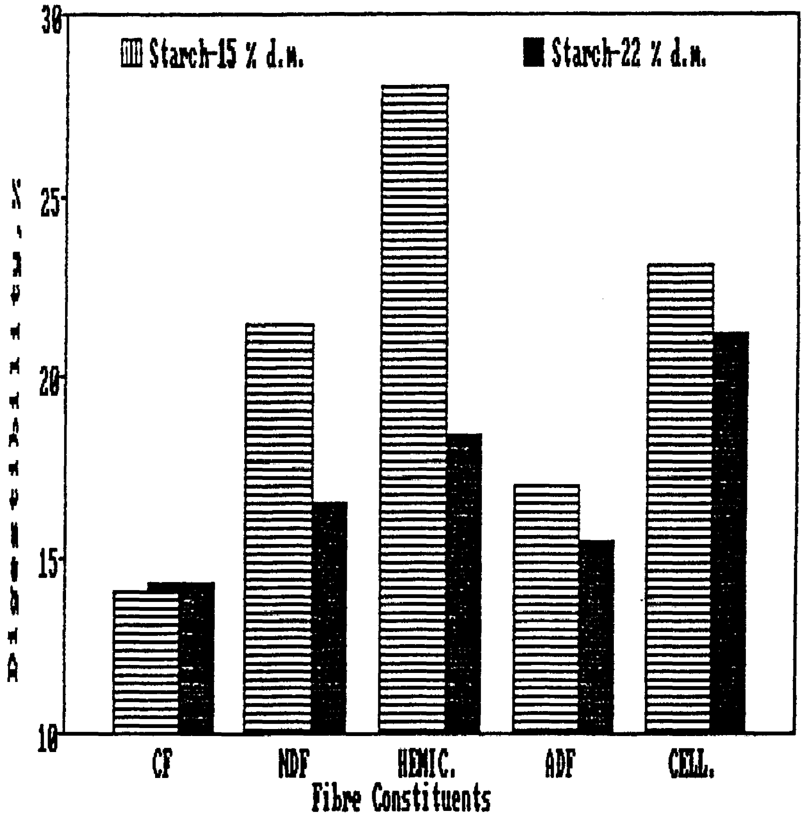


Figure 5 - Effect of dietary starch level on fibre digestibility
(Parigi-Bini et al., 1988)



Proceedings 4th World Rabbit Congress, 10-14 October 1988, Budapest Hungary, Vol. 3, 1-29

SUMMARY

RECENT DEVELOPMENTS AND FUTURE GOALS IN RESEARCH ON NUTRITION OF INTENSIVELY REARED RABBITS

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In the last four years, the research on nutrition of intensively reared rabbits achieved important progress. The author examines the following subjects:

energy metabolism - Results of calorimetry experiments are reported, in order to evaluate the most important aspects of energy metabolism. In the growing rabbit, growth rate, chemical composition and energetic value of body gain can be estimated as a function of digestible protein and energy intake. In the reproducing doe, the energy requirements for maintenance and for the different phases of reproductive cycle (pregnancy and/or lactation) have been determined.

protein to digestible energy ratio - On the basis of recent experiments, the protein to DE ratio for intensively reared rabbits are suggested: 43-45 g DCP/Mcal DE for growth and 48-50 DCP/Mcal DE for reproduction.

prediction of DE content of feeds. Differents methods of estimate are reported. The simple and quick methods based on ADF analysis seem to be preferred, in despite of the inevitable error of estimate.

fibre digestibility and utilization - Data concerning the digestive utilization of fibre constituents as influenced by dietary starch level are reported. The opportunity of more research efforts on this subject is emphasized.

RIASSUNTO

RECENTI SVILUPPI E PROSPETTIVE DELLA RICERCA SULLA NUTRIZIONE DEI CONIGLI IN ALLEVAMENTO INTENSIVO

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Negli ultimi quattro anni, la ricerca riguardante la nutrizione e l'alimentazione del coniglio in allevamento intensivo ha compiuto sensibili progressi. Rinviando alle più recenti pubblicazioni per maggiori e più completi dettagli, l'A. esamina i seguenti aspetti:
metabolismo energetico - Vengono riportati i risultati di ricerche di calorimetria che consentono di valutare, con sufficiente dettaglio, gli aspetti più importanti del metabolismo energetico. Per i conigli in accrescimento è possibile stimare la velocità di crescita, la composizione chimica ed il valore energetico dell'incremento ponderale in funzione della ingestione di energia e di proteina digeribile.
Per le coniglie fattrici, oltre ai fabbisogni di mantenimento, sono state precisate le esigenze energetiche per le varie fasi del ciclo riproduttivo (gravidanza e/o lattazione).
rapporto proteine/energia digeribile - Sulla base di recenti ecquisizioni sperimentali, vengono individuati i rapporti tra proteina ed energia ritenuti idonei per i conigli in allevamento intensivo: 43-45 g di proteina digeribile/Mcal ED per l'accrescimento e 48-50 g di proteina digeribile/Mcal ED per le coniglie fattrici. Vengono altresì indicati i rapporti tra aminoacidi ed energia digeribile, per l'accrescimento e per la riproduzione.
stima del contenuto di ED dei mangimi - Vengono riportati i metodi di stima proposti da varî Aa. Quelli basati sulla determinazione del contenuto in ADF sembrano più consigliabili, malgrado un inevitabile errore di stima, in quanto molto semplici e rapidi.
digeribilità e utilizzazione della fibra - Vengono riportati dati di utilizzazione digestiva delle varie frazioni fibrose, in funzione del contenuto di amido della dieta. Viene altresì sottolineata la necessità di ulteriori ricerche in questo settore.