REFLECTIONS ON RABBIT NUTRITION WITH A SPECIAL EMPHASIS ON FEED INGREDIENTS UTILIZATION

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ABSTRACT

In this invited communication the author proposes a list of nutritional recommendations for rabbits of different categories : growing from 18 to 42 days, from 42 to 80 days, for breeding does according to productivity (40-50 kits weaned per doe/year or more than 50) and for a single diet usable for all rabbits. Recommendations taking account the last published data, are divided in 2 groups. The first corresponds to nutrients which contribute mainly to feed efficiency : digestible energy, crude and digestible protein, amino acids, minerals, and fat-soluble vitamins. The second group corresponds to nutrients which contribute mainly to nutritive security and digestive health: different fibre components (lignins, cellulose, hemicelluloses) and their equilibrium, starch and water soluble vitamins. In a second part, were analysed 387 papers published during the last 30 years on raw material utilisation in rabbit feeding. In a total of 14 tables, the 542 corresponding experiments were summarised each by the identification of the raw material, by the highest level of incorporation used in the experiment, by the highest acceptable level, by the main ingredient(s) replaced by the raw material studied, and finally by the authors reference. Raw materials studied were those used in temperate as well as in tropical countries. The raw material were grouped according to the following categories : raw material used as single food (24 experiments), cereals and by-products (43 exp.), other carbohydrates source of energy (62 exp.), fats (27 exp.), full-fat oleaginous grains (10 exp.), oil cakes and meals (43 exp.), proteic seeds such peas or beans (42 exp.), miscellaneous sources of protein such yeast or leaf protein (18 exp.), animal products (21 exp.), non-protein nitrogen source such urea (9 exp.), forages (157 exp.), cereal straws, alkali treated or not (33 exp.), cover or parts of dried grains source of fibre such stalks, hulls or cobs (19 exp.) and industrial by-products usable as fibre source (51 exp.).

Key words : nutritional recommendations, raw materials, data basis

NUTRITIONAL RECOMMENDATIONS

Recent progresses in rabbit nutrition research have increased the number of criteria included in the nutritional recommendations, specially in the domain of fibrous components (GIDENNE, 2000; FORTUN-LAMOTHE and GIDENNE 2003). Thus it becomes very difficult to conceive an economical diet which respects exactly all recommendations. More, the basic reason of some recommendations is the highest performance possible in term of production or feed efficiency. For some others, the basic reason is the digestive flora nutrition and the digestive health of the rabbit.

In the first group are recommendations for energy, protein quality and quantity, fat-soluble vitamins or minerals. For these nutrients, the objective of the nutritionist is to conceive a diet which, after digestion, absorption and blood transport, can provide the rabbit cells for the vital elements at the lowest physiological price possible. This means that diet's digestibility must be as efficient as possible and that the nutrients proportions must be as balanced as possible in order the avoid deficiencies or nutrients excesses which would be eliminated at great cost through urine or faeces.

In the second group, are recommendations for starch, fibre quantity and quality (lignins, cellulose, hemicelluloses, pectins and their equilibrium) and for water soluble vitamins normally synthesized by the flora. For these nutrients, the objective of the nutritionist is to conceive a diet which provides balanced carbohydrate sources for the flora, and to provide water soluble vitamins in case of flora malfunctioning (first step of any digestive trouble). Recommendations for the best digestive functioning make necessary the inclusion in diets of components with low or very low digestibility such as cellulose and lignins. It is well known that these recommendations are conflicting with the highest possible diet's digestibility or feed efficiency, if the health situation of the rabbits is perfect.

Thus we have separate the new proposed recommendations for rabbits nutrition in 2 groups (table 1) : the first corresponds to recommendations for an optimum feed efficiency and the second corresponds to recommendations which must be scrupulously respected in case of endangered digestive situation in the rabbitry.

Data included in the table were determined mainly according to the most recent synthesis available in the literature (DE BLAS and VISEMAN, 1998; GIDENNE, 2000; FORTUN-LAMOTHE and GIDENNE 2003, LEBAS, 2003) and according to our own experience and literature knowledge. Despite the recent direct demonstration made by GUTIERREZ *et al*. (2003) of the noxious consequences of a high ileal flux of protein entering the caecum, no quantitative recommendation was made in relation with the optimum protein flux at the end of the small intestine. The reason is the absence of quantification of the optimum flux and the absence of characterisation of ieal digestibility of a sufficient number of feed ingredients. Such determination in the future would certainly represent an important step for the improvement of rabbits nutrition security. Recommendation for total sulphur amino-acid (TSSA) was made without proposition of a minimum level for methionine. Effectively a lot of years ago, COLIN (1978) has clearly demonstrated that methionine can replace cystine in the TSAA and vice versa within the widest possible range of variation. Since that time, as far as we know, nobody had experimentally demonstrated that a minimum of methionine (or of cystine) must be provided in rabbits diets.

Table 1 : Nutrients recommendation for rabbit feeding.

Type or period of production Without any other indication, unit = g/kg as fed (90% DM)		**GROWTH** 18 => 42 days	42 => 75-80 days	**REPRODUCTION** (1) Intensive	½ intensive	**Single feed** (2)
GROUPE 1 : Recommendations for the highest productivity						
Digestible Energy	(kcal / kg)	2400	2600	2700	2600	2400
	MJoules/ kg	9,5	10,5	11,0	10,5	9,5
Crude Protein		150-160	160-170	180-190	170-175	160
Digestible Protein		110-120	120-130	130-140	120-130	110-125
ratio Digest. Protein / Digestible Energy	(g / 1000 kcal)	45	48	53-54	51-53	48
	(g / 1 MJoule)	10,7	11,5	12,7-13,0	12,0-12,7	11,5-12,0
Lipids		20-25	25-40	40-50	30-40	20-30
Amino acids						
- lysine		7,5	8,0	8,5	8,2	8,0
- sulfur amino acids (methio.+cyst.)		5,5	6,0	6,2	6,0	6,0
- threonine		5,6	5,8	7,0	7,0	6,0
- tryptophan		1,2	1,4	1,5	1,5	1,4
- arginine		8,0	9,0	8,0	8,0	8,0
Minerals						
- calcium		7,0	8,0	12,0	12,0	11,0
- phosphorus		4,0	4,5	6,0	6,0	5,0
- sodium		2,2	2,2	2,5	2,5	2,2
- potassium		< 15	< 20	< 18	< 18	< 18
- chloride		2,8	2,8	3,5	3,5	3,0
- magnesium		3,0	3,0	4,0	3,0	3,0
- sulphur		2,5	2,5	2,5	2,5	2,5
- iron (ppm)		50	50	100	100	80
- copper (ppm)		6	6	10	10	10
- zinc (ppm)		25	25	50	50	40
- manganese (ppm)		8	8	12	12	10
Fat-soluble Vitamins						
- vitamin A (UI / kg)		6 000	6 000	10 000	10 000	10 000
- vitamin D (UI / kg)		1 000	1 000	1000 (<1500)	1000 (<1500)	1000 (<1500)
- vitamin E (mg / kg)		≥30	≥30	≥50	≥50	≥50
- vitamin K (mg / kg)		1	1	2	2	2
GROUPE 2 : Recommandation for the best health possible for rabbits						
Ligno-cellulose (ADF)		≥ 190	≥ 170	≥ 135	≥ 150	≥ 160
Lignins (ADL)		≥ 55	≥ 50	≥ 30	≥ 30	≥ 50
Cellulose (ADF – ADL)		≥ 130	≥ 110	≥ 90	≥ 90	≥ 110
ratio lignins / cellulose		≥ 0,40	≥ 0,40	≥ 0,35	≥ 0,40	≥ 0,40
NDF (Neutral Detergent Fiber)		≥ 320	≥ 310	≥ 300	≥ 315	≥ 310
Hemicelluloses (NDF – ADF)		≥ 120	≥ 100	≥ 85	≥ 90	≥ 100
ratio (hemicelluloses+pectins) / ADF		≤ 1,3	≤ 1,3	≤ 1,3	≤ 1,3	≤ 1,3
Starch		≤ 140	≤ 200	≤ 200	≤ 200	≤ 160
Water soluble Vitamins						
- vitamin C (ppm)		250	250	200	200	200
- vitamin B_1 (ppm)		2	2	2	2	2
- vitamin B_2 (ppm)		6	6	6	6	6
- nicotinamid (vitamin PP) (ppm)		50	50	40	40	40
- pantothenic acid (ppm		20	20	20	20	20
- vitamin B_6 (ppm)		2	2	2	2	2
- folic acid (ppm)		5	5	5	5	5
- vitamin B_{12} (ppm)		0,01	0,01	0,01	0,01	0,01
- choline (ppm)		200	200	100	100	100

(1) For does, ½ intensive production means a average yearly production of 40-50 weaned kits in the rabbitry, and an intensive production corresponds to a higher productivity (more than 50 kits /doe/year). (2) The single feed recommendation corresponds to a diet used for all rabbits in the rabbitry. It is a compromise between requirements of the different categories of rabbits.

For amino-acids in general, the correct recommendations would be done in term of digestible amino-acids as correctly proposed by the Madrid research staff (DE BLAS and MATEOS, 1998). But up to the moment no table for the feed's digestible amino-acids content is available for the rabbit. More, the correct recommendation would be done in amino acids digestible at the end of ileum because of the previously mentioned effect of excessive proteic-N entering the caecum. Thus the inclusion of recommendations for digestible amino acids remains of theoretical interest. For this reason they were not included in the tables of recommendations.

For the other components, composition of raw materials usable in a feed's formulation respecting the table 1 recommendations could be found for example in the recent tables of composition published by SAUVANT et al. (2002). This tables describe most of feed resources in use in Western European countries, for the gross composition including the fibre fractions, but also composition in amino acids, macro- and micro-minerals, vitamins, fatty acids, and nutritional value for the farm animals, rabbits included. When available, for rabbits are indicated the digestible and metabolizable energy content and digestibility coefficient of energy and nitrogen. An other important information source for raw materials, usable in most of the developing countries is AFRIS, the FAO data basis on Animal Feed Resources Information System. AFRIS is available on Internet with free access (AFRIS, 2004). For an impressive list of raw materials are given some explanations on the product (origin and possibilities of utilisation), data on gross composition, digestibility (mainly by ruminants), amino acids composition and a list of some references (with abstract available on line) on the use of this material, sometimes by rabbits. In addition this data basis is available in English but also in French, Spanish, Arabic and Chinese language.

FEED INGREDIENTS UTILISATION

Methodology for the estimation of the nutritive value of feed ingredients

All the analysis described in composition tables are useful to search the nutrients mentioned in recommendations. They are used by nutritionists with the help of a computer to know if a specific raw material is able or not to provide such or such nutrient mentioned in the recommendations, and how to mix different raw materials to obtain a balanced diet. But raw ingredient components are more complex than the description made through a list of nutrients, even if the list is very long. Some molecules present in a raw material may have consequences on the animal physiology, that of rabbits in particular. Some of these molecules can be tolerated if their final level in the complete diet is not too high *e.g.* case of mimosine content in diets with *Leucaena leucocephala* (SZYSZKA *et al.*, 1985), for other molecules, rabbits may prefer an intermediate concentration, *e.g.* for the saponin concentration in diets with lucerne (AUXILIA *et al.*, 1983). For these raw materials, the "key" molecules (mimosine or saponin) are known. Then a chemical determination can be done before utilisation and the result may be included in the computer for formulation. But for many raw materials, such components are not known. But that does not mean they don't exist and that they have no effect.

Up to now the only reliable method to know if a raw material can be used for rabbit nutrition is to ask rabbits themselves. The most common method consists to include graded levels of the studied raw material in rabbits ration, and to measure the performance. But the total of the ration remains always at 100% ; then if one ingredient is introduced at graded levels, one or some others ingredients must be withdrawn. For this reason many published experiments could be interpreted symmetrically from the reverse side as a progressive reduction of the incorporation level of an other raw material. Which one is responsible of the observed variation of the performance ? the increase of the first or the decrease of the second ?

In many cases, for a supposed easy future interpretation, the studied material is introduced in substitution to one unique ingredient or to the basal diet. In the later case if the basal diet (or control diet) is balanced according to rabbit's requirements, at the highest level of substitution the experimental diet is not balanced. Then, is the resulting performance a consequence of the presence of the studied ingredient or only a consequence of the ration imbalance ?

We consider that there is no perfect solution. Nevertheless, a reliable synthetic position may be established after a critical analysis of the different works published on the nutritive value of the studied raw material.

Revue of literature on raw material studies, methodological aspects

To make possible a reliable synthetic position, we have analysed a great number of works on raw material evaluation, published during the last 30 years (1973-2003). The data basis was obtained through a CAB International interrogation on Internet and through the analysis of all communications presented during the successive World Rabbit Congresses (1^{st} to 7^{th}) or during the successive French rabbit Days (1^{st} to 10^{th}). The final list contains 387 publications corresponding to 542 studies of diets with various levels of a raw material : most generally one control without the studied material and 1 to 5 levels of incorporation. This list is not exhaustive, but represent probably more than 90% of the literature available. The CAB International interrogation has given an abstract for each reference. Full text and abstract were available in the CD Rom of the World Rabbit Congresses (available at the WRSA office) or in the CD Rom of the French rabbit Days (available at the ITAVI office in Paris).

Most of studies were made with growing rabbits (91.7%). Breeding does were used for 5.4% of the experiments and 1.5% of the studies were made using angora wool production as the main criterion for evaluation or using various other physiological criteria.
In the experiments with growing rabbits we have given priority to the growth rate observed during the whole duration of the study, to establish the highest acceptable level of incorporation of the raw material. But in many cases the authors have also determined the feed efficiency, the digestibility of the experimental diets, the carcass characteristics, and sometime the meat quality, mortality rate or blood parameters. In the following tables (3 to 15), when the highest acceptable level of incorporation is identical to the highest level studied, it means that at this level the growth rate (more generally the performance) was not significantly different from that observed with the control diet, or was significantly better. When the highest acceptable level is an intermediate level it means that at this level the performance is higher or equivalent to that observed with the control, and that a higher level induced a significant

reduction of the performance. When the highest acceptable level is 0%, it means that at all incorporation levels the performance of the experimental rabbits was significantly lower than that of the control. Sometimes the reason was a real contre-performance, and the raw material must be discarded from rabbit nutrition. But in many other cases, the lower performance observed after introduction of the raw material was only the consequence of the imbalance created by this introduction. In this case, a careful analysis of the other studies made on the same raw material is necessary to establish a correct opinion. Nevertheless, one of the questions which remains frequently unanswered is the following: was the raw material studied in different publications effectively the same or not ?. Only a comparative analysis of the different publications made in great detail can give a beginning of answer. It's the occasion for each of us to exercise his or her critical sense.

Raw materials studied as only feed

Some raw materials were used as the only feed source in some experiences (table2). When some growth or adult live weight maintenance were observed (marked "OK") it means that the studied raw ingredient had no important toxic compound and nutrients are relatively balanced. The direct analysis of the publication reveals the

Table 2. Raw ingredients studied as only feed.

Ingredients	type of rabbit	Maintenance or growth	Authors
Arachis pintoi + *Pennisetum purpureum*	growing	OK	Nieves et al., 1996
arrowroot (*Maranta arundinacea*) forage	growing	OK	Erdman, 1986
bermuda grass fresh (*Cynodon dactylon*)	adult	**no**	Deshmukh et al., 1989
bermuda grass fresh (*Cynodon dactylon*)	adult	**no**	Deshmukh et al., 1993a
berseem fresh (*Trifolium alexandrinum*)	adult	OK	Deshmukh et al., 1989
berseem fresh (*Trifolium alexandrinum*)	adult	OK	Deshmukh et al., 1990
broom grass (*Thysanolaena maxima*) fresh or dried	growing	OK	Rohilla et al., 2000b
cabbage leaf wastes	growing	OK	Prawirodigdo et al., 1985
Grewia optiva leaves	adult	OK	Deshmukh et al., 1989
groundnut haulms	growing	OK	Ngodigha et al., 1994
guinea grass (*Panicum maximum*)	growing	**no**	Bamikole et al., 1999
lucerne (100%)	growth	OK	Perez et al., 1994
lucerne (96%)	growing or pregnant	OK	Pascual et al., 2002
lucerne (99.5%+NaCl)	growing	OK	Perez et al., 1998
maize whole grain soaked overnight	adult	**no**	Prasad et al., 1996
mulberry fresh leaves (*Morus alba*)	adult	OK	Deshmukh et al., 1989
mulberry fresh leaves (*Morus alba*)	adult	OK	Deshmukh et al., 1993b
oats (green, preflowering)	adult	OK	Deshmukh et al., 1989
rabbit faeces dried (98%+minerals) !!!!!!	growing	OK (!?)	Fekete et al., 1985
robinia (*Robinia pseudoacacia*) leaves	growing	OK	Singh et al., 1997a
robinia (*Robinia pseudoacacia*) leaves	growing	OK	Singh et al., 1999
Stylosanthes hamata cv. Verano	growing	**no**	Bamikole et al., 1999
sweet potato tops (dehydrated)	growing	OK	Abu et al., 1999
wheat bran (98.75%)	growing	OK	Robinson et al., 1986

real performance which is an indirect estimation of the nutritional balance of the raw material. When the growth or maintenance column is marked "no", it means that this raw material was nutritionally completely imbalanced or contained a toxic compound. To be as complete as possible, we have mentioned the work of FEKETE *et al*. (1985) where rabbit faeces were used as quasi only feed for rabbits (98% inducing a growth rate of 12 g/day), but in no way we will recommend the inclusion of faeces in the rabbit nutrition because of the corresponding uncontrolled sanitary risk.

Utilisation of cereals and cereal by products

To interpret correctly all experiences made on progressive introduction of cereals in rabbits rations (table 3) it is necessary to search the cereal in the "ingredient" column as well as in the "substitution" column. Most of the cereals and by-products can clearly be used up to 40-50%. The main limitations are those associated with diets nutritional balance, specially the starch maximum when rabbitry health is not optimum.

Table 3 : Experiments on the incorporation of cereals and cereal by-products in rabbit feeding.

Ingredient	Nb Levels	Highest level studied	Accep-table level	substituted mainly to	Evalua-tion on	Authors
barley (hydroponic, green, 10 days)	2	~40%	~40%	basal diet	growth	Kriaa *et al.*, 2001
barley grain	2	100% of maize	100% maize	maize	growth	Akram *et al.*, 1989
barley grain	2	100% of 3 cereals	100% of 3 cereals	barley, maize, triticale	growth	Lanza *et al.*, 1986
barley grain	2	100% cereals	100% cereals	barley, wheat triticale	growth	Sinatra *et al.*, 1987
barley grain	2	100% of cereals	0%	oats	growth	Struklec *et al.*, 1995
barley grain	2	46%	46%	3 cereals	growth	Seroux, 1984a
barley grain, flaked	2	42%	0%	barley	growth	Seroux, 1989b
barley grain, flaked	2	42%	42%	barley	growth	Seroux, 1982
barley radicle	3	10%	10%	barley	growth	Ibrahim *et al.*, 1999
barley roots (by-product malt industry)	2	8%	8%	-	growth	Bagliacca *et al.*, 1987
buckwheat (*Fagopyrum esculentum*)	5	60%	60%	maize & wheat mill run	growth	Tor-Agbidye *et al.*, 1990
hard wheat bran	2	56%	56%	barley & soybean m.	growth	Berchiche *et al.*, 2000
hard wheat middlings	2	23%	23%	barley & soybean m.	growth	Berchiche *et al.*, 2000
maize grain	2	100% of wheat	100% of wheat	wheat	growth	Cossu *et al.*, 2002
maize grain	2	100% of 3 cereals	100% of 3 cereals	barley, maize, triticale	growth	Lanza *et al.*, 1986
maize grain	2	100% cereals	0%	oats	growth	Struklec *et al.*, 1995
maize grain	2	39%	39%	3 cereals	growth	Seroux, 1984a
maize grain, flaked	2	38%	38%	maize	growth	Seroux, 1982

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Table3 : utilisation of cereals and cereal by-products (continuation)						
maize offals	2	34%	34%	maize	growth	Onifade *et al.*, 1993
maize offals	2	100% of maize	100% of maize	maize	growth	Uko *et al.*, 1999
maize starch	3	14%	0%	wheat straw	breeding	Lebas *et al.*, 1996
millet offals	2	100% of maize	100% of maize	maize	growth	Uko *et al.*, 1999
Milurex (byproduct of wheat starch production)	5	40%	20%	basal diet	growth	Perez *et al.*, 1997
oats grain	2	100% of maize	100% of maize	maize	growth	Akram *et al.*, 1989
oats grain	2	100% barley & sunfl. m.	100% barley & sunfl. m.	barley & sunflower meal	growth	Jensen *et al.*, 1989
rice (broken rice)	2	40%	20%	maize	growth	Oanh, 1983
rice bran	5	92.5%	60%	-	growth	Raharjo *et al.*, 1988
rice bran	2	40%	20%	maize	growth	Oanh, 1983
rice feed meal	2	40%	40%	maize	growth	Oanh, 1983
rice-polish	3	15%	15%	maize	growth	Bhatt, 2000
sorghum grain	5	56%	56%	maize	growth	Carregal *et al.*, 1980b
sorghum grain	4	20%	15%	barley & wheat	growth	Demchenko *et al.*, 1985
sorghum offals	2	100% of maize offals	100% of maize offals	maize offals	growth	Uko *et al.*, 1999
triticale grain	2	100% cereals	100% cereals	barley, wheat, triticale	growth	Sinatra *et al.*, 1987
triticale grain	2	100% of 3 cereals	100% of 3 cereals	barley, maize, triticale	growth	Lanza *et al.*, 1986
triticale grain	2	30%	30%	barley	growth	Bonanno *et al.*, 1990
wheat bran	3	~40%	~40%	maize	growth	Singh *et al.*, 1997b
wheat bran	3	20%	20%	lucerne	growth	Gippert *et al.*, 1988
wheat grain	2	~46%	~46%	maize	growth	Nizza *et al.*, 1997
wheat grain	2	100% cereals	100% cereals	barley, triticale, wheat	growth	Sinatra *et al.*, 1987
wheat grain	2	42%	42%	3 cereals	growth	Seroux, 1984a
wheat grain, flaked	2	41%	41%	wheat	growth	Seroux, 1982
wheat grain, flaked	2	41%	41%	wheat	growth	Seroux, 1989a

Carbohydrates source of energy, other than cereals

If in numerous rabbit's rations cereals are the main source of digestible energy, many other ingredients can provide also starch (*e.g.* cassava roots) or other highly digestible carbohydrates (*e.g.* beet or citrus pulp, molasses). Many of such raw materials are listed in the table 4, and most of them were introduced in substitution to cereals. A special attention should be made the technological quality of the raw material studied and to the exact origin of the product. For example citrus pulp is frequently proposed and used without botanical indication, but citrus pulp from lemon and from orange are not necessary equivalent. The same type of citrus pulp (orange) may also be positively evaluated in on experiment and negatively in a second (LETO *et al.*, 1984) probably in relation with the batch of citrus used.

Table 4. Experiments on the incorporation of carbohydrates sources of energy other than cereals, in rabbit feeding.

Ingredient	Nb Levels	Highest level studied	Accep-table level	substituted mainly to	Evalua-tion on	Authors
ajar seed kernel (*Lagestroemia flos-regina*)	4	27%	9%	cereals & wheat bran	growth	Saikia *et al.*, 2000
Amaranthus caudatus (residual pulp from leaf fractionation)	4	30%	10-20%	maize	growth	Omole *et al.*, 1979
amaranthus seed (*Amaranthus hypochondriacus*)	4	40%	40%	-	growth	Reddy *et al.*, 1993
Azadirachta indica = neem, seeds	4	30%	20%	-	growth	Fajinmi *et al.*, 1990
banana fresh fruits, green	2	32% DM	32% DM	basal biet	growth	Gidenne, 1985a
beet molasses stillage (condensed)	2	5%	5%	-	breeding	Cavani *et al.*, 1987
beet pulp (sugar beet pulp)	6	25%	25%	-	growth	El-Zeiny *et al.*, 1998
beet pulp (sugarbeet pulp)	2	15%	15%	lucerne	growth	Evans *et al.*, 1983
beet pulp (sugarbeet pulp)	3	30%	15%	barley	growth	Garcia *et al.*, 1992
beet pulp (sugarbeet pulp)	4	50%	15%	barley	growth	Garcia *et al.*, 1993
beet pulp (sugarbeet pulp)	4	30%	10%	-	growth	Jensen *et al.*, 1992
beet pulp (sugarbeet pulp)	3	15%	8%	maize	growth	Battaglini *et al.*, 1978a
beet pulp (sugarbeet pulp)	2	20%	20%	cereal grains	growth	Skrivanova *et al.*, 1996
beet pulp (sugarbeet pulp))	2	15%	15%	lucerne or barley	growth	Trocino *et al.*, 1999
beet pulp (sugarbeet pulp)	4	30%	30%	wheat grain& straw	growth	Franck *et al.*, 1980
beet pulp (sugarbeet pulp)	3	50%	50%	barley	growth	Cobos *et al.*, 1995
beet pulp (sugarbeet pulp))	3	100% of lucerne	0% of lucerne	lucerne	growth	El-Adawy *et al.*, 2000
beet pulp (dried) + 35%molasses	4	30%	15-20%	-	growth	Jensen *et al.*, 1992
beet pulp (molassed sugarbeet pulp)	4	20%	20%	-	growth	Colaghis *et al.*, 1983
beet root slices	3	25%	25%	lucerne	growth	Gippert *et al.*, 1988
buffalo gourd (*Cucurbita foetidisima*) dried root meal	4	30%	30%	sorghum	growth	Morales Zuñiga, 1980
buffalo gourd (*Cucurbita foetidisima*) dried root meal	4	30%	30%	sorghum	breeding	Morales Zuñiga, 1980
cane molasses concentrate	2	5%	5%	concentrate	growth	Cavani *et al.*, 1988b
cassava peel meal	2	31%	0%	maize	growth	Onifade *et al.*, 1993
cassava peel meal	4	45%	15%	maize	growth	Okeke *et al.*, 1986
cassava peel meal	2	100% of maize	100% of maize	maize	growth	Agunbiade *et al.*, 1999
cassava peel meal	3	40%	40%	maize	growth	Omole *et al.*, 1981a
cassava peel meal	4	100% of maize	50% of maize	maize	growth	Esonu *et al.*, 1993
cassava peel meal	2	100% of maize	100% of maize	maize	growth	Agunbiade *et al.*, 2001
cassava peel, ensiled meal	4	45%	30%	maize	growth	Okeke *et al.*, 1986
cassava root meal	2	25%	25%	basal diet	growth	Ratnakumar *et al.*, 1992
cassava root meal	4	50%	50%	barley	growth	Radwan *et al.*, 1989
cassava root meal	2	22%	22%	-	growth	El-Gendy, 1994

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Table 4 : Carbohydrates source of energy other than cereals (continuation)						
cassava root meal	2	100% of maize	100% of maize	maize	growth	Ikurior *et al.*, 1998
cassava root meal	2	20%	20%	barley	meat quality	Soliman, 1994
cassava root meal	4	45%	45%	-	breeding	Eshiett *et al.*, 1980
cassava root meal	4	45%	45%	-	growth	Eshiett *et al.*, 1980
cassava root meal (unpeeled)	2	31%	31%	maize	growth	Onifade *et al.*, 1993
cassava waste meal	5	100% of maize	100% of maize	maize	growth	Abu *et al.*, 1996
citrus (lemon) pulp	2	20%	0%	maize	growth	Leto *et al.*, 1984
citrus (lemon) pulp	2	20%	20%	barley	growth	Alicata *et al.*, 1985
citrus (orange) pulp	4	18%	18%	maize	growth	Leto *et al.*, 1984
citrus (orange) pulp	2	20%	0%	maize	growth	Leto *et al.*, 1984
citrus pulp	4	25%	25%	-	growth	Leon *et al.*, 1999
citrus pulp	6	75%	45%	basal diet	growth	Martinez Pascual *et al.*, 1980
fodder beet roots (fresh)	3	~20%	~20%	concentrate	growth	Bassuny *et al.*, 1999
garri sievate (residue of grated cassava fermented, dried and sieved for garri production)	3	30%	20%	maize	growth	Ngodigha *et al.*, 1995
molasse (sugar cane molasse)	3	10%	5-10%	basal diet	growth	Sanchez *et al.*, 1984
oak acorn (*Quercus coccifera*)	2	20%	20%	maize	growth	Nowar *et al.*, 1994
olive pulp	4	30%	30%	-	growth	Tortuero *et al.*, 1989
plantain peel (*Musa* cv) sun dried	4	100% of maize	66% of maize	maize	growth	Fanimo *et al.*, 1996
potatoes starch	3	14%	14%	wheat	growth	Pinheiro *et al.*, 2000
potatoes steamed, dried	3	30%	30%	basal diet	growth	Kuzniewicz *et al.*, 1979
potatoes steamed, dried	3	22%	22%	cereals & bran	growth	Wojsyk-Kuzniewicz *et al.*, 1981
radish (*Raphanus sativus*) seed raw or autoclaved	3	40%	0%	wheat & soybean m.	growth	Sanchez *et al.*, 1984
Samanea saman, whole pods, autoclaved	2	10%	10%	-	growth	Oduguwa *et al.*, 2000
sweet potato meal.	5	100% of maize	100% of maize	maize	growth	Agwunobi *et al.*, 1997
sweet potato root meal	6	50%	20%	sweet potato tops	growth	Abu *et al.*, 1999
tager-nut (*Cyperus rotundus* L.)	6	100% of maize	60% of maize	maize	growth	Bamgbose *et al.*, 1997
tall fescue seeds (*Festuca arundinacea*)	5	80%	80%	maize (?)	growth	Tor-Agbidye *et al.*, 1992
tannia cocoyam tuber meal (*Xanthosoma sagittifolium*)	5	100% of maize	100% of maize	maize	growth	Agwunobi *et al.*, 2000
vinasse (high in yeast cell walls)	3	8%	8%	molasse & beet pulp	growth	Maertens *et al.*, 1994

Fat use in rabbit nutrition

The different fats were frequently studied in addition to a basal diet or in substitution to one of the ingredient in order to increase the digestible energy of the diet (table 5). In many other studies one type of fat was introduced in substitution to an other source of fat. In later case the conclusion is that all the oils can be changed from one to the other. In some experiments the highest substitution level was very high : 8-9%

and even 16% (HEMID *et al*., 1995; BEYNEN, 1988), but with such levels it is impossible to obtain pellets of acceptable quality.

Table 5. : Experiments on fat incorporation in rabbit feeding.

Ingredient	Nb Levels	Highest level studied	Accep-table level	Substituted mainly to	Evalua-tion on	Authors
beef tallow	3	6%	6%	soya oil	growth	Fernandez *et al*., 1992
beef tallow	2	3%	3%	-	growth	Fernandez *et al*., 1996
beef tallow	3	8%	4%	-	growth	Raimondi *et al*., 1976
beef tallow	3	8%	4%	maize	growth	Falcão-e-Cunha *et al*., 1996b
beef tallow	2	8.5%	8%	barley	breeding	Fernandez-Carmona *et al*., 1996
calcium soap	3	6%	6%	-	growth	Fernandez Carmona *et al*., 1994
groundnut oil	2	5%	5%	maize oil	growth	Omole, 1979
groundnut oil	3	8%	4%	-	growth	Raimondi *et al*., 1976
maize oil	3	8%	8%	basal diet	growth	King, 1981
maize oil	4	16%	16%	maize starch	growth	Beynen, 1988
oleins	3	6%	3%	soya oil	growth	Fernandez *et al*., 1992
oleins	2	3%	3%	-	growth	Fernandez *et al*., 1996
palm oil	2	7%	7%	soya oil	growth	Kessler *et al*., 1993
palm oil	2	5%	5%	maize oil	growth	Omole, 1979
palm oil	4	9%	9%	basal diet	growth	Hemid *et al*., 1995
palm oil soapstock, acidulated	2	1%	1%	maize oil	growth	Abd-El-Rahim *et al*., 1994
palm oil soapstock, acidul.	2	1%	1%	basal diet	breeding	Tawfeek *et al*., 1994
poultry fat	4	9%	5%	basal diet	growth	Hemid *et al*., 1995
rapeseed oil	3	9%	9%	no added fat	breeding + growth	Christ, 1999
rapeseed oil	2	7%	7%	soya oil	growth	Kessler *et al*., 1993
soybean oil	2	3%	3%	-	growth	Fernandez *et al*., 1996
soybean oil	2	4.50%	4.50%	no added fat	breeding + growth	Christ, 1999
soybean oil	3	6%	6%	basal diet	growth	Meirelles *et al*., 1979
soybean oil	3	4%	4%	-	growth	Carregal *et al*., 1980a
sunflower oil	2	3%	3%	wheat straw	breeding	Lebas *et al*., 1996
sunflower oil	2	6%	6%	starch	growth	Falcão-e-Cunha *et al*., 2000
vegetable oils (mixed waste from edible oil refining)	2	1%	1%	maize oil	growth	Abd-El-Rahim *et al*., 1994

Full fat oleaginous grains

The increase of diet's lipid content – and generally of the digestible energy content - could be done with the incorporation of pure fats as studied in the previous section, but it is also possible with the use of oleaginous grains. In this case the raw material provides non only lipids but also protein. When the diets were balanced, all tested oleaginous grains were considered as usable at the highest tested level *i.e.* up to 30-40% (table 6). Nevertheless, a special mention must be done for the sunflower seeds. The lower performance observed with 30% of full-fat seeds is surprising because when seeds are separated in 2 parts, sunflower oil and sunflower meal, both parts can be used without restriction other than the diet's balance (tables 5 and 7). Thus we suggest that in the 2 experiments with sunflower seeds mentioned in table 6, some pollutant had reduced the acceptability of seeds (BALOGUN *et al.*, 1991;. MESINI, 1994). However some additional experiments with this raw material should be welcome.

Table 6. Experiments on oleaginous-seeds incorporation in rabbit feeding.

Ingredient	Nb Levels	Highest level studied	Accep-table level	substituted mainly to	Evalua-tion on	Authors
cotton seeds whole, extruded	2	43%	43%	soybean m.	growth	Johnston *et al.*, 1984
linseed, whole seed	2	8%	8%	concentrate	meat quality	Cavani *et al.*, 2003
linseed, extruded whole seed	2	39%	39%	soybean m.	growth	Johnston *et al.*, 1984a
rapeseed grain (00 cultivar)	2	10%	10%	cereals	growth	Seroux *et al.*, 1982
safflower seeds, extruded	2	34%	34%	soybean m.	growth	Johnston *et al.*, 1984a
soya lipids (oil + full-fat soya)	2	~7%	~7%	barley	breeding	Fernandez-Carmona *et al.*, 1996
soybean seeds (full-fat soya, extruded)	2	20%	20%	soybean m.	growth	Johnston *et al.*, 1984a
soybean seeds (full-fat soya, heat-treated)	3	6%	6%	soybean m.	growth	Cavani *et al.*, 1996
sunflower seeds (full-fat)	4	30%	20%	-	growth	Balogun *et al.*, 1991
sunflower seeds (whole with husks)	4	30%	<10%	maize & oil	growth	Mesini, 1994

Oil cakes and meals

When the oil is removed from oleaginous seeds, generally for human utilisation, the remaining part is protein rich and may be used for animal nutrition. For rabbits as for the other animals, the reference meal is the toasted soybean meal. Not less than 15 oil cakes were studied. Most of them can be introduced at 15-20% or more, and they can provide up to 60% of the diet's protein without problem.

Table 7. Experiments on oil cakes (meals) incorporation in rabbit feeding.

Ingredient	Nb Levels	Highest level studied	Accep-table level	Substituted mainly to	Evalua-tion on	Authors
bambara groundnut toasted meal (*Voandzeia subterranea*)	5	25%	25%	-	growth	Joseph *et al.*, 2000
cottonseed meal	2	24%	0%	poultry offals & wheat bran	growth	Fotso *et al.*, 2000
cottonseed meal	2	43%	<43%	soybean m.	breeding	Johnston *et al.*, 1985
cottonseed meal	2	20%	20%	soybean meal	semen quality	McNitt *et al.*, 1982

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Table 7. Oil cakes and meals (continuation N°1)						
cottonseed meal	2	10%	10%	groundnut cake	growth	Prasad *et al.*, 1998
cottonseed meal	2	60% of the total protein	60% of the total protein	groundnut cake	angora	Singh *et al.*, 1987
cottonseed meal (expeller extracted)	3	17%	17%	soybean meal	growth	McNitt *et al.*, 1982
cottonseed meal (pre-press solvent extracted)	3	16%	16%	soybean meal	growth	McNitt *et al.*, 1982
groundnut cake	2	~20%	~20%	sunflower meal	growth	Aduku *et al.*, 1988
groundnut cake	2	24%	0%	fish meal	growth	Omole *et al.*, 1982
hempseed oil cake (*Canabis sativa*)	3	30%	30%	sunflower meal	growth	Lebas *et al.*, 1988
linseed meal	2	11%	0%	soybean m.	growth	Gippert, 1980
linseed meal	2	60% of diets protein	60% of diets protein	groundnut cake	angora	Singh *et al.*, 1987
meadow foam meal (*Limnanthes alba*)	3	40%	40%	soybean m.	growth	Throckmorton *et al.*, 1981
mustard cake	2	23%	23%	groundnut cake	growth	Prasad *et al.*, 1998
mustard cake (urea/NH_3 treated or not)	3	100% of ground-nut meal	100% of ground-nut meal	groundnut cake	angora	Gowda *et al.*, 1997
mustard cake	2	60% of diets protein	60% of diets protein	groundnut cake	angora	Singh *et al.*, 1987
neem kernel meal (*Azadirachta indica*) (urea/NH_3 or NaOH treated)	3	100% of ground-nut meal	100% of ground-nut meal	groundnut cake	angora	Gowda *et al.*, 1997
neem kernel meal (*Azadirachta indica*) (urea/NH_3 or NaOH treated)	3	100% of ground-nut meal	100% of ground-nut meal	groundnut cake	growth	Gowda *et al.*, 2000
neem seed kernel meal (*Azadirachta indica*)	4	20%	10%	groundnut cake	growth	Vasanthakumar *et al.*, 1999
Nigela sativa meal	3	10%	0%	basal diet	growth	Nasr *et al.*, 1996
olive oil cake	3	23%	23%	soybean m.	growth	Ben Rayana *et al.*, 1994
olive oil cake	2	30%	30%	lucerne	growth	Chaabane *et al.*, 1997
olive oil cake, ± kernelled	2	30%	30%	sulla hay	growth	Leto *et al.*, 1981
palm kernel meal	2	~40%	~40%	sunflower meal	growth	Aduku *et al.*, 1988
rapeseed meal	2	12%	12%	soybean m.	growth	Gippert, 1980
rapeseed meal	2	20%	20%	soybean m.	breeding	Lebas *et al.*, 1982
rapeseed meal	5	20%	20%	soybean m.	growth	Scapinello *et al.*, 1996b
rapeseed meal	4	18%	18%	soybean m.	growth	Colin *et al.*, 1976
rapeseed meal (non toasted)	2	15%	15%	sunflower meal	breeding	Lebas, 1978
rapeseed meal (toasted)	2	15%	15%	sunflower meal	breeding	Lebas, 1978
rapeseed meal (Tower)	4	100% of soybean meal	100% of soybean meal	soybean meal	growth	Throckmorton *et al.*, 1980
rapeseed meal, dehulled	2	20%	20%	soybean m.	breeding	Lebas *et al.*, 1982
rapeseed oilmeal (low in erucic acid)	2	100% sunflower meal	100% sunflower meal	sunflower meal	growth	Lebas *et al.*, 1977
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Table 7. Oil cakes and meals (continuation N°2)						
rapeseed protein concentrate	2	7%	7%	silkworm chrysalid & soybean m.	growth	Liu *et al.*, 1987
safflower meal	2	60%	60%	lucerne	growth	Harris *et al.*, 1980
soya protein concentrate	2	~30% diets protein	~30% of diets proteins	soybean meal	growth	Gutierrez *et al.*, 2003
soybean meal	2	30%	30%	groundnut cake	growth	Prasad *et al.*, 1998
soybean meal	3	10%	10%	basal diet	growth	Nasr *et al.*, 1996
sunflower meal	4	24%	16%	groudnut cake	growth	Bhatt *et al.*, 1999
sunflower meal	2	15%	15%	soybean m.	growth	Battaglini *et al.*, 1977
sunflower meal	2	10%	10%	soybean m.	growth	Gippert, 1980
sunflower meal	2	~30% of diets proteins	~30% of diets proteins	soybean meal	growth	Gutierrez *et al.*, 2003
sunflower meal	5	21.6%	21.6%	-	growth	Ismail *et al.*, 1999

Proteic seed (peas, beans, …)

Leguminous seeds with medium to low lipid content (less than 10% in general) and some similar seeds may be also sources of protein for rabbits. Experiments of utilisation were conducted with not less than 18 types of proteic seeds (table 8). Some of the seeds can be used only if different components of the seed are removed by an adequate treatment (*e.g.* debittered *Lupinus mutabilis* - JOHNSTON *et al.*,1989). For some others, the presence of a noxious compound is the main factor limiting the incorporation in rabbit's ration (*e.g*. presence of mimosine in the *Leucaena leucocephala* seeds – AWOSANIA *et al*., 1996). For some other seeds such *Lathyrus cicera* the antinutritional factors which reduces feed intake and growth rate were not

Table 8. Experiments on proteic seeds (beans, peas, …) incorporation in rabbit feeding.

Ingredient	Nb Levels	Highest level studied	Accep-table level	substituted mainly to	Evalua-tion on	Authors
African locust-bean (*Parkia filicoidea*) (raw, autoclaved or water extracted)	4	27%	27% water extracted	oil cakes & maize	growth	Balogun *et al.*, 1983
beans (*Phaseolus vulgaris*) raw or autoclaved pinto beans	2	40%	0%	lucerne & soybean m.	growth	Sanchez *et al.*, 1983
bitter lupin seeds (*Lupinus mutabilis*) debittered seeds	2	100% soybean m.	100% soybean m.	soybean meal	growth	Johnston *et al.*, 1989
bitter lupin seeds (*Lupinus mutabilis*) debittered	2	29%	29%	soybean meal	growth	Johnston *et al.*, 1988
bitter lupin seeds (Lupinus mutabilis) raw or toasted	2	29%	0%	soybean meal	growth	Johnston *et al.*, 1988
bitter lupin seeds (*Lupinus mutabilis*) raw or toasted	2	100% soybean meal	0% soybean meal	soybean meal	growth	Johnston *et al.*, 1989

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Table 8. Proteic seeds (continuation)						
chickpeas (*Cicer arietinum*)	2	20%	< 20%	soybean m. & barley	growth	Alicata *et al.*, 1991
chickpeas (*Cicer arietinum*)	3	20%	20%	basal diet	growth	Alicata *et al.*, 1992
chickpeas (*Cicer arietinum*)	3	20%	20%	soybean m.	growth	Alicata *et al.*, 1993
chickpeas (*Cicer arietinum*)	3	20%	20%	wheat & soybean m.	growth	Lebas *et al.*, 1988
chickpeas (*Cicer arietinum*) = Bengal gram	2	100% barley protein	100% barley protein	barley	growth	Sastry *et al.*, 1982
horse bean (*Vicia faba*) seeds	4	37%	37%	soybean m.	growth	Berchiche *et al.*, 1988
horse bean (*Vicia faba*) seeds	4	37%	26.50%	soybean m.	growth	Berchiche *et al.*, 1995
horse bean (*Vicia faba*) seeds	2	30%	30%	soybean m. & maize	growth	Berchiche *et al.*, 1999
horse bean (*Vicia faba*) seeds	3	20%	20%	soybean m.	growth	Colin *et al.*, 1976
horse bean (*Vicia faba*) seeds	2	10%	10%	soybean m.	growth	Maitre *et al.*, 1990
horse bean (*Vicia faba*) seeds	4	30%	30%	soybean m.	growth	Seroux, 1984b
jack bean (*Canavalia ensiformis*) cooked seeds	3	20%	20%	-	growth	Esonu *et al.*, 1996
jack bean (*Canavalia ensiformis*) raw seeds	3	20%	10%	-	growth	Esonu *et al.*, 1996
jack bean (*Canavalia ensiformis*) raw seeds	3	28%	28%	-	growth	El-Rahim, 1996
jack bean (*Canavalia ensiformis*) autoclaved seeds	2	28%	28%	-	growth	El-Rahim, 1996
Jack bean (*Canavalia ensiformis*) boiled seeds	4	30%	10-20%	oil cakes	growth	Bamikole *et al.*, 2000a
Job's tears (*Coix lachryma*) corticated grain	3	30%	30%	-	growth	Gupta *et al.*, 1995
Latyrus cicera seeds	4	40%	10%	soybean m. & oat	growth	Falcão-e-Cunha *et al.*, 1996a
Leucaena leucocephala seeds, roasted	4	30%	10%	-	growth	Awosanya *et al.*, 1996
mung beans (*Phaseolus aureus* = *Vigna radiata*)	5	32%	24%	soybean m.	growth	Amber, 2000
pea (*Pisum sativum* variety Frijaune)	3	18%	18%	soybean m.	growth	Castellini *et al.*, 1991
pea (*Pisum sativum*)	3	22%	22%	soybean m. & maize	growth	Colin *et al.*, 1976
pea (*Pisum sativum*)	2	100% soybean meal	100% soybean meal	soybean meal	growth	Johnston *et al.*, 1989
pea (*Pisum sativum*)	2	30%	30%	soybean m.	growth	Seroux, 1984b
pea (*Pisum sativum*) spring pea	2	21%	21%	wheat & soybean m.	breeding	Seroux, 1988
pea (*Pisum sativum*) toasted	2	100% soybean meal	100% soybean meal	soybean meal	growth	Johnston *et al.*, 1989
pigeon pea (*Cajanus cajan*)	2	20%	0%	-	growth	Nieves *et al.*, 1995
Prosopis chilensis algaroba fruit dried	3	29%	29%	bran & oil cake	growth	Caro *et al.*, 1991
quinoa grain (*Chenopodium quinoa*)	4	30%	30%	maize & fish meal	growth	Crizon Navarrete *et al.*, 1991
Samanea saman, whole pods	2	10%	10%	-	growth	Oduguwa *et al.*, 2000
sweet lupin (*Lupinus albus*)	3	16%	8%	-	growth	Battaglini *et al.*, 1991
sweet lupin (*Lupinus albus*)	2	10%	10%	soybean m.	growth	Maitre *et al.*, 1990
sweet lupin (*Lupinus albus*)	4	21.5%	21.5%	soybean m.	growth	Sarhan, 1999
sweet lupin (*Lupinus albus*)	4	21%	21%	soybean m.	growth	Seroux, 1984b
Vicia sativa = vetch, seeds	4	30%	10%	-	growth	Yalcin *et al.*, 2003
Vigna unguiculata cowpea	2	50%	50%	wheat bran	growth	Aduku *et al.*, 1986

identified (FALCÃO-E-CUNHA *et al.*, 1996). The consequence is that up to now, the only solution is to discard this protein source from rabbit nutrition.

Yeasts, mycelium, leaf protein and other protein concentrates

The only raw material of this heterogeneous group, that cannot be used in rabbit nutrition is the raw guar meal (residue after extraction of the guar gum) even when it's introduction represents only 25% of the soybean protein (Prasad *et al.*, 1998).

Table 9. : Experiments on incorporation of yeast, mycelium, leaf protein and other protein concentrates, in rabbit feeding.

Ingredient	Nb Levels	Highest level studied	Accep-table level	substituted mainly to	Evalua-tion on	Authors
alga *Scenedesmus acutus*	2	12%	<12%	soybean meal	growth	Battaglini *et al.*, 1979
amaranth (unthreshed mature grain seedhead)	4	30%	10%	oil cakes	growth	Bamikole *et al.*, 2000b
Aspergillus niger (dried mycelium)	4	~10%	~10%	fodder yeast	growth	Atabekyan *et al.*, 1976
beet (fodder beet) leaf protein concentrate	3	50% of soybean meal	50% of soybean meal	soybean meal	growth	El-Baki *et al.*, 1992
berseem leaf protein concentrate (*Trifolium alexandrinum*)	3	100% soya protein c.	50% soya protein c.	soya protein concentrate	growth	El-Adawy *et al.*, 1999
brewer's yeast	2	6%	6%	casein/soya	plasma cholesterol	Abreu *et al.*, 1994
cassava leaf protein concentrate	3	50% of soybean meal	50% of soybean meal	soybean meal	growth	El-Baki *et al.*, 1992
guar meal (*Cyamopsis tetragonoloba*)	2	22.5%	22.5%	groundnut cake	growth	Prasad *et al.*, 1998
guar meal (*Cyamopsis tetragonoloba*)	5	100% of soybean meal	0%	soybean meal	growth	Schurg *et al.*, 1986
mushroom (*Pleurotus pulmonarius*) substrate waste	4	30%	30%	lucerne & oil cakes	growth	Muzic *et al.*, 1994
water haycinth leaf protein concentrate (*Eichhornia crassipes*)	3	100% soya protein c.	50% soya protein c.	soya protein concentrate	growth	El-Adawy *et al.*, 1999
yeast (*Saccharomyces* sp) dried by rotation roller	6	20%	15%	soybean meal	growth	Scapinello *et al.*, 1999
yeast (*Saccharomyces* sp) dried by rotation roller	5	5-20%	0%	same yeast spray-dried	growth	Scapinello *et al.*, 1999
yeast (*Saccharomyces* sp) spray-dried	6	20%	15%	soybean meal	growth	Scapinello *et al.*, 1999
yeast (*Saccharomyces* sp.), spray-dried	5	100% of soybean meal	100% of soybean meal	soybean meal	growth	Scapinello *et al.*, 1996a
yeast (*Saccharomyces* sp.), spray-dried	5	20%	20%	soybean meal	growth	Scapinello *et al.*, 1997
yeast (*Sacchomyces cerevisiae*)	5	100% of soybean meal	75% of soybean meal	soybean meal	growth	Carregal *et al.*, 1990
yeast *Candida utilis*	2	4%	4%	*Saccharom. cerevisiae*	growth	Battaglini, 1979

For the other protein concentrates, the main limiting factor seems to be the protein quality when no correction of the amino acids balance was made at the occasion of the substitution.

Animal products

Most of animal products experimented in rabbit nutrition were tested as source of protein. The only noticeable exception is the whey, fresh or dried, which is a source or energy (lactose). All the tested products seem to be usable, the hydrolysed leather or feather residues included.

Table 10. : Experiments on animal products incorporation in rabbit feeding.

Ingredient	Nb Levels	Highest level studied	Accep-table level	substituted mainly to	Evalua-tion on	Authors
blood meal	2	10%	10%	fish meal	growth	Sahu *et al*., 1990
cattle hide scrap (hydrolysed meal)	5	100% of soybean meal	50% of soybean meal	soybean meal	growth	Furlan *et al*., 1997
earthworms meal from *Eisenia foetida* and *Lumbricus rubellus*	2	~12%	~12%	soybean m.	growth	Orozco Almanza *et al*., 1988
extruded hatchery waste	5	6%	6%	fish meal	growth	Handa *et al*., 1996
feather meal, enzymatically digested	2	30%	30%	soybean m.	growth	Fekete *et al*., 1986
fish meal	2	16%	16%	poultry offals	growth	Fotso *et al*., 2000
krill meal	3	6%	6%	animal protein	growth	Niedzwiadek *et al*., 1981
leather hydrolysates	2	4%	4%	meat meal	growth	Verita *et al*., 1977
meat meal	2	10%	10%	fish meal	growth	Sahu *et al*., 1990
milk (dried skimmed)	2	5%	5%	fodder yeast	growth	Halga, 1974
milk (dried skimmed)	2	16%	16%	no milk	plasma choleste rol	Aggarwal *et al*., 1991
milk (dried skimmed)	2	15%	15%	-	pre-weaning	Blas *et al*., 1990
poultry viscera meal	3	8%	8%	fish meal	growth	Ahlawat *et al*., 2001
rumen liquor sediment (dried)	4	20%	15%	-	growth	El-Adawy, 1997
rumen liquor sediment (dried)	3	20%	10%		breeding	El-Adawy, 1997
silkworm chrysalis meal (*Bombix mori*)	6	100% of soybean meal	100% of soybean meal	soybean meal	growth	Carregal *et al*., 1987
whey (dried)	4	20%	20%	-	growth	Coppings *et al*., 1990
whey (dried)	2	5%	0%	-	growth	Masoero *et al*., 1980
whey (dried) ± viable cells	3	5%	5%	barley	growth	Masoero *et al*., 1982
whey (fresh liquid sweet whey)	4	60%DM	40%DM	basal diet	growth	Colina *et al*., 1989
whey (hydrolysed condensed)	3	6.40%	6.40%	barley	growth	Masoero *et al*., 1982

Urea and other non protein sources of nitrogen

Because rabbit's caecal flora can use urea to synthesise true proteins (SALSE *et al.*, 1977), many experiments were conducted to try to replace in rabbit feeding true proteins by industrial non proteic compounds. When the protein level of the basal diet was very low (12% or less) a real utilisation of urea or biuret was generally demonstrated (table 11). But when the basal diet has 13-14% of true protein or more, the non-proteic source was valueless. In this case, the only positive result is that it demonstrates that rabbits can tolerate up to 2% urea in their ration without trouble.

Table 11. Experiments on the incorporation of industrial non-protein nitrogen sources in rabbit feeding.

Ingredient	Nb Levels	Highest level studied	Accep-table level	Substituted mainly to	Evaluation on	Authors
biuret	2	1.6	1.6%	-	N retention	Gioffre *et al.*, 1988b
oxycellurea	2	5.3	0%	-	N retention	Gioffre *et al.*, 1988b
urea	2	1%	1%	soybean m.	growth	Abou-Ashour *et al.*, 1983
urea	2	1.5	0%	-	N retention	Gioffre *et al.*, 1988b
urea	3	2%	1%	fish meal	breeding	Niedzwiadek *et al.*, 1975
urea	3	2%	1%	fish meal	breeding	Niedzwiadek *et al.*, 1976
urea	4	0.75%	0.50%	ground nut cake	growth	Okeke, 1983
urea	2	1.5%	1.5%	groundnut cake	growth	Singh *et al.*, 1990
urea	4	3%	0%	addition	growth	Zhou *et al.*, 2002

Forage studied for rabbit nutrition

In the forage group we have included about 80 raw materials. These feed ingredients have in common a chemical composition relatively close to nutritional recommendations. They also correspond to the whole or a part of the vegetative apparatus of plants harvested when growing. Most of them can be used in rabbit nutrition, even those with antinutrional factors such *Leucaena leucocephala* (20 experiments in the table 12) For this specific forage we have also include the study of SZYSZKA et al. (1985) which have worked with extracted mimosine to determine the acceptable level of this toxic amino acid.

Table 12. Experiments on forages incorporation in rabbit feeding.

Ingredient	Nb Levels	Highest level studied	Accep-table level	substituted mainly to	Evalua-tion on	Authors
Acacia albida pods	5	20%	20%	-	growth	Igwebuike *et al.*, 1999
Acacia saligna	4	60%	40%	concentrate	growth	Abdel-Samee *et al.*, 1992
Acacia saligna, dried leaves	3	30%	30%	basal diet	growth	Eleraky *et al.*, 1996
Acacia saligna, dried leaves	4	30%	30%	clover hay (berseem)	growth	El-Gendy, 1999a

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Table 12. Forages (continuation N° 1)						
amaranth meal (vegetative parts)	5	60%	15%	lucerne	growth	Alfaro *et al.*, 1987
Amaranthus hypochondriachus sun dried		~40%	0%	lucerne	growth	Harris *et al.*, 1981a
Arachis glabrata perennial groundnut plant	2	100% of lucerne	100% of lucerne	lucerne	growth	Gomez-de-Varela *et al.*, 1983
Arachis pintoi pinto peanut, dried	4	30%	10%	basal diet	growth	Huang *et al.*, 1998
Arachis pintoi, dried	2	15%	15%	-	growth	Nieves *et al.*, 1998
Arachis pintoi, fresh green	5	40%	30%	-	growth	Nieves *et al.*, 1996
artichoke leaves, dried	3	10%	10%	lucerne	growth	Bonomi *et al.*, 1999
azolla (sun dried)	4	36%	24%	clover hay	growth	Abou-Zeid *et al.*, 2001
Azolla filiculoides (sun dried)	4	36%	12%	basal diet	growth	Abdella *et al.*, 1998
Azolla filiculoides dried meal	3	100% of soybean meal	50% of soybean meal	soybean meal	growth	Gualtieri *et al.*, 1988
Azolla pinnata (sun dried)	4	60%	20%	lucerne	growth	Wittouck *et al.*, 1992
banana leaves (fresh green)	4	60% DM	40% DM	basal diet	growth	Rohilla *et al.*, 2000a
barley whole plant, dried	3	35%	35%	meadow hay	growth	Corino *et al.*, 1982
barley whole plant, dried	3	28%	28%	cereal meal	growth	Auxilia *et al.*, 1977
barley whole plant, dried	3	35%	35%	hay (meadow ?)	growth	Polidori *et al.*, 1984
Bauhinia variegata tree leaves (fresh)	2	to appetite	~15% DM	basal diet	angora	Negi *et al.*, 1985
bermuda grass (*Cynodon dactylon*)	4	~20%	0%	lucerne	growth	Champe *et al.*, 1983
bermuda grass (*Cynodon dactylon*)	2	100% of lucerne	100% of lucerne	lucerne	growth	Daniels *et al.*, 1985
berseem hay (*Trifolium alexandrinum*)	3	100% of lucerne	100% of lucerne	lucerne	growth	El-Adawy *et al.*, 2000
berseem silage (*Trifolium alexandrinum*)	2	100% of fresh berseem	100% of fresh berseem	fresh berseem	growth	El-Ayouty *et al.*, 2000
birdsfoot trefoil (*Lotus corniculatus*)	5	32%	32%	lucerne	growth	Grandi *et al.*, 1988
Boehmeria nivea hay (ramie hay)	3	50%	25%	-	growth	Mendes *et al.*, 1980
Bromus catharticus hay (first cut)	4	24%	24%	lucerne	growth	Grandi, 1993
broom grass (*Thysanolaena maxima*)	3	100%	40%	concentrate	growth	Rohilla *et al.*, 2000b
cabagge (fresh)	3	25%	15%	maize	growth	Fomunyam, 1984
cabbage (fresh)	2	24%	24%	mixed cereals	growth	Fedeli Avanzi *et al.*, 1976
cabbage residues (fresh)	4	~75%	~75%	basal diet	growth	Shqueir *et al.*, 1985
Cajanus cajan hay	2	100% of *Cynodon dactylon*	100% of *Cynodon dactylon*	*Cynodon dactylon* hay	growth	Moura *et al.*, 1992
Cajanus cajan hay (guandu hay)	5	37%	28%	lucerne	growth	Crespi *et al.*, 1992a
carrot leaves	2	3%	3%	stylosanthes	growth	Omole *et al.*, 1976a
carrot roots (fresh)	2	45%	0%	mixed cereals	growth	Fedeli Avanzi *et al.*, 1976
carrot tops (sun dried)	3	35%	20%	berseem hay	growth	A-Eleraky, 1996
carrot tops (sun dried)	4	60%	60%	-	growth	El-Kerdawy *et al.*, 1992
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Table 12. Forages (continuatioN° 2)						
carrot tops (sun dried)	3	75% of soybean meal protein	75% of soybean meal protein	soybean meal	growth	Magouze *et al.*, 1998
cassava leaves and stems hay	4	30%	10-20%	-	growth	Scapinello *et al.*, 2000
cassava leaves and stems meal	4	50%	50%	clover hay	growth	Toson *et al.*, 1999
cassava leaves *Manihot esculenta*	2	40%	0%	lucerne	growth	Harris *et al.*, 1981b
cassava leaves meal (dried)	2	42%	42%	poultry offals & wheat bran	growth	Fotso *et al.*, 2000
cassava leaves meal dried	3	40%	40%	copra meal	growth	Ravindran *et al.*, 1986
Cassia tora (tropical legume forage)	2	100% of lucerne	100% of lucerne	lucerne	growth	Cheeke *et al.*, 1983
Cistus ladanifer flour	2	24%	24%	lucerne	growth	Zamora Lozano *et al.*, 1984
Clitoria ternata (tropical legume forage)	2	100% of lucerne	100% of lucerne	lucerne	growth	Cheeke *et al.*, 1983
clover hay	4	60%	20%	-	growth	Marai *et al.*, 1979
coconut (spent part after preparation of coconut milk)	4	30%	0%	-	growth	Eekeren *et al.*, 1991
Commelina benghalensis (stems and leaves)	2	40%	40%	basal diet	growth	Mtenga *et al.*, 1994
Crotalaria ochroleuca, air dried	4	45%	15-30%	sunflower meal	growth	Laswai *et al.*, 2000
Desmodium distortum	2	40%	40%	lucerne	growth	Harris *et al.*, 1981b
Desmodium distortum (tropical legume forage)	2	100% of lucerne	100% of lucerne	lucerne	growth	Cheeke *et al.*, 1983
fodder beet leaves (fresh)	3	~40%	~40%	concentrate	growth	Bassuny *et al.*, 1999
Gliricidia leaf meal	4	15%	5%	-	breeding	Herbert, 1998
Gliricidia maculata leaves, dried	2	27%	27%	berseem meal	growth	Rao *et al.*, 1986
Gliricidia maculata leaves, fresh (=*G. sepium*)	2	~10% DM	10%	concentrate	growth	Onwudike, 1995
Grevia oppositifolia leaves	2	100% barley protein	0%	barley	growth	Sastry *et al.*, 1982
Grewia optiva tree leaves (fresh)	2	to appetite	~15% DM	basal diet	angora	Negi *et al.*, 1985
groundnut haulms	2	50%	20%	wheat bran	growth	Aduku *et al.*, 1986
groundnut haulms	5	100%	50%	basal diet	growth	Ngodigha *et al.*, 1994
groundnut hay	2	27%	27%	berseem meal	growth	Rao *et al.*, 1986
guinea grass (*Panicum maximum*) hay	2	100%	~10%	concentrate	growth	Bamikole *et al.*, 1999
hedge lucerne (*Desmanthus virgatus*)	2	27%	27%	berseem meal	growth	Rao *et al.*, 1986
Hibiscus rosa-sinensis leaves	2	18%	0%	basal diet	growth	Gidenne, 1985b
horse bean leaves, sun dried (*Vicia faba*)	3	75% of soybean meal protein	75% of soybean meal protein	soybean meal	growth	Magouze *et al.*, 1998
Kentucky bluegrass (*Poa pratensis*)	2	~40%	~40%	lucerne	growth	Harris *et al.*, 1981a
kudzu (*Pueraria* spp.)	2	100% of lucerne	0% of lucerne	lucerne	growth	Gomez-de-Varela *et al.*, 1983

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Table 12. Forages (continuation N°3)						
kudzu (*Pueraria thunbergiana*) vine	4	50%	25%	ryegrass hay	growth	Randhir *et al.*, 1994
lettuce (dried at 25-35°C)	4	30%	30%	basal diet	growth	Goby *et al.*, 2001
lettuce (dried at 25-35°C)	3	20%	20%	beet pulp	growth	Goby *et al.*, 2003
Leucaena leucocephala hay	6	23%	23%	lucerne	growth	Scapinello *et al.*, 2000
Leucaena leucocephala hay cultivar «Cunningham»	6	22%	22%	lucerne	growth	Scapinello *et al.*, 2000
Leucaena leucocephala leaf meal	4	60%	0%	-	growth	Tangendjaja *et al.*, 1990
Leucaena leucocephala leaf meal with mimosin converted into DHP	3	60%	0%	untreated *Leuc*. leaves	growth	Tangendjaja *et al.*, 1990
Leucaena leucocephala leaves (treated : heated, silage, sundried)	5	20%	20% heated	-	growth	Awosanya *et al.*, 2000
Leucaena leucocephala leaves dried	5	20%	15%	-	growth	El-Galil *et al.*, 2001
Leucaena leucocephala whole plant	2	20%	0%	-	growth	Nieves *et al.*, 1995
Leucaena leucocephala leaves dried	3	30%	30%	basal diet	growth	Mtenga *et al.*, 1994
Leucaena leucocephala leaves dried	2	20% or 40%	0%	basal diet	growth	Mtenga *et al.*, 1994
Leucaena leucocephala leaves dried	4	30%	30%	hard wheat bran	growth	Parigi-Bini *et al.*, 1984
Leucaena leucocephala leaves dried	3	50%	25%	basal diet	growth	Gupta *et al.*, 1996a
Leucaena leucocephala leaves dried	5	20%	15%	lucerne	growth	Ghazalah *et al.*, 1998
Leucaena leucocephala leaves dried and treated with 1.2% $FeCl_3$	3	50%	50%	basal diet	growth	Gupta *et al.*, 1996a
Leucaena leucocephala leaves fresh	2	15%	15%	-	growth	Nieves *et al.*, 1998
Leucaena leucocephala leaves fresh	4	24%	24%	wheat bran	growth	Muir *et al.*, 1992
Leucaena leucocephala leaves fresh	2	~10% DM	0%	concentrate	growth	Onwudike, 1995
Leucaena leucocephala leaves fresh	3	50%	<30%	mash concentrate	growth	Onwuka *et al.*, 1992
Leucaena leucocephala leaves fresh	4	60% DM	40% DM	basal diet	growth	Rohilla *et al.*, 1999
Leucaena leucocephala leaves fresh	2	24%	0%	other forages	breeding	Muir *et al.*, 1995
Leucaena leucocephala, mimosine extracted from seeds of …	4	0.39%	0.26%	basal diet	growth	Szyszka *et al.*, 1985
Leunae cornuta stems and leaves (wild lettuce)	2	40%	40%	basal diet	growth	Mtenga *et al.*, 1994
Lolium perenne (ray grass)	3	14%	14%	lucerne	growth	Grandi, 1983
lucerne dried	3	40%	40%	-	growth	Reddy, 1987
lucerne dried	2	96%	96%	basal diet	pregnancies	Pascual *et al.*, 2002
lucerne dried	2	50%	50%	basal diet	growth	Payne *et al.*, 1983
lucerne dried	5	40%	40%	-	growth	Cheeke *et al.*, 1980
lucerne hay	3	96%	92%	barley & soybean m.	breeding at 30°C	Fernandez-Carmona *et al.*, 2000

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Table 12. Forages (continuation N°4)						
lucerne hay	3	96%	0%	barley & soybean m.	breeding at ~22°C	Pascual *et al.*, 2000
lucerne with high saponins concentration, dried	4	35%	best with 0,6% saponin in diet	lucerne low concentra. of saponin	growth	Auxilia *et al.*, 1983
lucerne, dehydrated after ensiling	3	50%	0%	lucerne	growth	Perez *et al.*, 1990
lupin (*Lupinus albus*) as green forage	3	40%	20%	basal diet	growth	El-Gendy, 1999b
Macroptilium lathyroides (tropical legume forage)	2	100% of lucerne	100% of lucerne	lucerne	growth	Cheeke *et al.*, 1983
maize silage (whole plant)	2	100% of fresh berseem	100% of fresh berseem	fresh berseem	growth	El-Ayouty *et al.*, 2000
maize whole plant, dried	3	28%	28%	cereal meal	growth	Auxilia *et al.*, 1977
maize whole plant ,dried	3	40%	40%	maize	growth	Auxilia *et al.*, 1979
maize whole plant, dried	3	40%	40%	maize	growth	Auxilia *et al.*, 1980
maize whole plant, dried	3	40%	40%	-	growth	Masoero *et al.*, 1979
maize whole plant, dried	2	35%	35%	hay	growth	Polidori *et al.*, 1982
maize whole plant, dried	3	35%	35%	hay (meadow ?)	growth	Polidori *et al.*, 1984
maize whole plant, dried	4	70%	70%	wheat grain & straw	growth	Seroux *et al.*, 1980
Morus alba mulberry fresh leaves	3	40%	40%	concentrate	growth	Rohilla *et al.*, 2000c
Morus alba mulberry fresh leaves	3	50%	50%	basal diet	growth	Meena *et al.*, 1999
Neonotonia wightii hay (perennial soya)	5	38%	38%	lucerne	growth	Crespi *et al.*, 1992b
oat plant meal	3	50%	25%	basal diet	growth	Bhatt *et al.*, 2001
oats + vetch forage, ensiled	21	100% fresh forage	100% fresh forage	same fresh green forage	growth	Kennou *et al.*, 1990
orchard grass (*Dactylis glomerata*) seed screening	4	45%	45%	lucerne	growth	El-Sayaad *et al.*, 1992
palm frond leaves (oil palmtree)	4	100%	<<50%	basal diet	growth	Dahlan *et al.*, 1994
poplar leaves (*Populus tremuloides*)	5	40%	40%	lucerne	growth	Ayers *et al.*, 1992b
Potamogeton natans L. var. fluitans	2	8%	8%	lucerne, bran & barley	growth	Grandi, 1978
Psophocarpus tetragonolobus	2	40%	0%	lucerne	growth	Harris *et al.*, 1981b
Psophocarpus tetragonolobus hay	4	22%	22%	lucerne	growth	Grandi *et al.*, 1985
rape (fresh)	2	21%	21%	mixed cereals	growth	Fedeli Avanzi *et al.*, 1976
Robinia pseudoacacia , black locust leaves meal	2	40%	0%	lucerne	growth	Harris *et al.*, 1984
Robinia pseudoacacia leaves	2	40%	0%	lucerne	growth	Cheeke *et al.*, 1984
Robinia pseudoacacia leaves	2	100%	100%	Concentr.+ *Pennisetum*	growth	Singh *et al.*, 1999
Robinia pseudoacacia leaves (partially sun dried)	3	~33% DM	~ 17% DM	basal diet	growth	Sanjiv *et al.*, 2000
Robinia pseudoacacia leaves (dried)	4	75%	75%	basal diet	growth	Bhatt *et al.*, 2000
ryegrass	2	50%	50%	basal diet	growth	Payne *et al.*, 1983
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Table 12. Forages (continuation N°5)						
ryegrass straw (NH_3 treated)	2	20%	20%	rygrass straw	growth	Aderibigbe *et al.*, 1992
Schleichera oleosa leaf meal	3	10%	10%	basal diet	growth	Sreemannarayana *et al.*, 2001
seaweed (*Ulva fasciata*) dried	4	15%	15%	concentrate	growth	Raju *et al.*, 1995
seaweed *(Ulva fasciata)* dried	4	15%	5%	basal diet	growth	Sreemannarayana *et al.*, 1995
Sesbania aegyptica (dried leaves)	5	20%	15%	lucerne	growth	Ghazalah *et al.*, 1998
star grass (*Cynodon plectostachyus*)	2	~40%	0%	basal diet	growth	Ramchurn *et al.*, 2000
Stylosanthes	2	40%	0%	lucerne	growth	Harris *et al.*, 1981b
Stylosanthes hamata cv. Verano hay	2	100%	50%	concentrate	growth	Bamikole *et al.*, 1999
sulla (*Hedysarum coronarium*)	2	35%	35%	lucerne	growth	Cucchiara, 1989
sunflower leaves	2	40%	0%	lucerne	growth	Harris *et al.*, 1981a
sunhemp (*Crotalaria juncea*) dried	2	27%	27%	berseem meal	growth	Rao *et al.*, 1986
sweet potato tops	6	100%	80%	sweet potato roots	growth	Abu *et al.*, 1999
tall fescue hay	3	50%	0%	basal diet	growth	Bhatt *et al.*, 2001
Trifolium pratense red clover hay	4	30%	30%	lucerne	growth	Grandi *et al.*, 1988
Vicia sativa, common vetch sun dried	2	60%	60%	lucerne hay	breeding	Lopez *et al.*, 1996
Vigna umbellata (ricebeans) green	3	~25%	~50%	basal diet	growth	Gupta *et al.*, 1996b
Vigna unguiculata cowpea testa, dried	5	80%	60%	poultry mash	growth	Sese *et al.*, 1999
Vigna unguiculata owpea leaves, sun dried	3	75% of soya protein	0% of soya protein	soybean meal	growth	Magouze *et al.*, 1998
water haycinth (*Eichhornia crassipes*)	3	100% of lucerne	0% of lucerne	lucerne	growth	El-Adawy *et al.*, 2000
water hyacinth (*Eichhornia crassipes*)	2	10%	10%	lucerne	growth	Grandi, 1981a
water hyacinth (*Eichhornia crassipes*)	4	12%	12%	-	growth	Grandi *et al.*, 1983a
water hyacinth *(Eichhornia crassipes*)	3	30%	30%	lucerne	growth	Moreland *et al.*, 1991
water hyacinth (*Eichhornia crassipes*)	3	30%	30%	lucerne	breeding	Moreland *et al.*, 1991
water hyacinth (*Eichhornia crassipes*) prebloom stage	4	30%	10-20%	barley	growth	Zeweil *et al.*, 1993
water hyacinth (*Eichhornia crassipes*) dried	4	30%	30%	-	growth	Biobaku *et al.*, 1991
water hyacinth (*Eichhornia crassipes*) dried leaves	3	30%	30%	basal diet	growth	Eleraky *et al.*, 1996
water lettuce (*Pistia stratiotes*) dried	4	30%	30%	-	growth	Biobaku *et al.*, 1991
wheat whole plant (dried)	3	28%	28%	cereal	growth	Auxilia *et al.*, 1977

Cereal straws (alkali treated or not)

Straws have generally a poor nutritive value for rabbits, but this type of raw material may be an excellent source of fibre. Alkali treatment which makes soluble one part of lignins may sometime improve the nutritive value, but it also modify the "fiber" ability of treated straw to provide fibre component necessary for digestive health control (table1 part 2). The normal incorporation level can be increase up to 15-20% with satisfactory results. With higher level it is clearly impossible to formulate a balanced diets.

Table 13. Experiments on straw (alkali treated or not) incorporation in rabbit feeding.

Ingredient	Nb Levels	Highest level studied	Accep-table level	substituted mainly to	Evalua-tion on	Authors
barley straw	4	45%	15%	basal diet	growth	Radwan *et al.*, 1983
barley straw	2	10%	10%	lucerne	growth	Ben Rayana *et al.*, 1995
barley straw (NaOH or NH_3 treated)	4	45%	0%	untreated straw	growth	Partridge *et al.*, 1984
barley straw (NaOH treated)	4	18%	18%	lucerne	growth	Gioffre *et al.*, 1988a
barley straw (NaOH treated)	4	45%	15%	basal diet	growth	Radwan *et al.*, 1983
barley straw (NH_3 treated)	4	45%	15%	basal diet	growth	Radwan *et al.*, 1983
rice straw (5% NaOH treated)	3	25%	15%	lucerne	growth	Sfairopoulos *et al.*, 1987
rice straw (NaOH treated or not)	5	30%	30%	lucerne hay	growth	Masoero *et al.*, 1984
rice straw fermented with *Trichoderma* sp. & A*zotobacter chroococcum*	3	25%	25%	wheat bran	growth	Huang *et al.*, 1990
wheat straw	2	10%	10%	grass meal	growth	Bielanski *et al.*, 1996a
wheat straw	2	10%	10%	grass meal	breeding	Bielanski *et al.*, 1996b
wheat straw	3	19%	19%	lucerne	growth	Franck *et al.*, 1978
wheat straw	4	20%	13%	lucerne	growth	Gippert *et al.*, 1988
wheat straw	2	10%	10%	hay	growth	King, 1983
wheat straw	2	10%	10%	lucerne	growth	Lebas *et al.*, 1978
wheat straw	3	20%	20%	basal diet	growth	Lebas *et al.*, 2001
wheat straw	3	15%	15%	-	growth	Parigi-Bini *et al.*, 1994
wheat straw	4	30%	0%	meadow hay	growth	Pomytko *et al.*, 1975
wheat straw	2	50%	0%	basal diet	growth	Payne *et al.*, 1983
wheat straw (NaOH treated)	5	25%	20%	lucerne	growth	Jensen, 1984
wheat straw (NaOH 4-8% treated)	2	25%	25%	straw	digest.	Abd-Ellah, 1995
wheat straw (NaOH or NH_3 treated)	2	12%	12%	grass meal	growth	Bielanski *et al.*, 1996a
wheat straw (NaOH or NH_3 treated)	2	12%	12%	grass meal	breeding	Bielanski *et al.*, 1996b
wheat straw (NaOH or NH_3 treated)	2	12%	12%	-	growth	Guermandi, 1999
wheat straw (NaOH treated or not)	5	30%	30%	lucerne hay	growth	Masoero *et al.*, 1984
wheat straw (NaOH treated)	3	20%	20%	untreated straw	growth	Lebas *et al.*, 1978
wheat straw (NaOH treated)	2	10%	10%	untreated straw	growth	Lebas *et al.*, 1979
wheat straw (NaOH treated)	4	30%	30%	-	breeding	Lindeman *et al.*, 1982

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Table 13. Straws (continuation)						
wheat straw (NaOH treated)	2	50%	50%	untreated straw	growth	Payne *et al.*, 1984
wheat straw (NH_3 treated)	2	50%	0%	untreated straw	growth	Payne *et al.*, 1984
wheat straw (treated 2% NaOH)	4	30%	30%	lucerne	growth	Mercier *et al.*, 1980
wheat straw (untreated)	4	30%	30%	lucerne	growth	Mercier *et al.*, 1980
wheat straw ± treated	4	20%	20%	-	growth	Chiofalo *et al.*, 1984

Hulls, husks, corn and stalks

Parallel to that of straw, the utilisation of the cover of some dried grains may provide fibres of different qualities. Most of these products may be used widely in rabbit nutrition (table 14) and the acceptable incorporation level may be increased up to 15-20% as it is for straws. Nevertheless for formulation it must be taken in account that fibrous cell walls composition vary widely from one source to the other (SAUVANT *et al.,* 2002), and that a mixture of various fibre sources is frequently the only solution to meet the qualitative recommendations during rabbits diet formulation.

Table 14. Experiments on hulls, husks, cobs, stalks, … incorporation in rabbit feeding.

Ingredient	Nb Levels	Highest level studied	Accep-table level	substituted mainly to	Evalua-tion on	Authors
almond hulls	4	60%	40%	lucerne	growth	Aderibigbe *et al.*, 1990
beans straw (*Phaseolus vulgaris* ?)	2	10%	10%	lucerne	growth	Gippert *et al.*, 1988
cocoa-pod husks	3	30%	30%	-	growth	Ridzwan *et al.*, 1993
cocoa-pod husks	3	25%	25%	-	growth	Ridzwan *et al.*, 1995
maize cobs	3	20%	10%	Berseem hay	growth	A-Eleraky, 1996
maize cobs	4	42%	14%	-	growth	Marai *et al.*, 1979
maize cobs [corn cobs]	3	20%	10%	lucerne	growth	Gippert *et al.*, 1988
maize stalk	4	30%	20%	clover hay	growth	Tag-El-Din *et al.*, 1999
maize stalk [corn stalk]	4	20%	20%	lucerne	growth	Gippert *et al.*, 1988
peanut hulls	3	18%	12%	berseem hay	growth	El-Gamal, 2003
peanut skins	3	39%	0%	berseem hay	growth	El-Gamal, 2003
rapeseed hulls	4	40%	40%	lucerne	growth	Lebas *et al.*, 1981
rapeseed hulls	2	20%	0%	wheat & straw	breding	Lebas *et al.*, 1982
rice hulls	6	30%	10%	-	growth	Raharjo *et al.*, 1990
soybean hulls	2	10%	10%	lucerne	growth	Evans *et al.*, 1983
soybean hulls	3	20%	20%	-	growth	Martina, 1983
sunflower hulls	4	20%	15%	lucerne	growth	Gippert *et al.*, 1988
sunflower hulls	3	20%	20%	-	growth	Martina, 1983
sunflower husks	6	25%	18%	basal diet	growth	Gippert *et al.*, 1984

Industrial by products used mainly as fibre source

The treatment of vegetable products for human consumption (tomatoes for juices or sauces, grapes for wine, …) or for industry (wood for sawing or paper production,…)

produces a lot of fibrous by-products which can be used in rabbit nutrition. Even if some of them have no interest as feed source (*e.g.* date pits – ABOU-ELA et al., 1999), most of the others can be used at 15-20% and sometimes up to 30% (table 15). Nevertheless according to our experience on the practical utilisation of products of this group, their main problem is not the proportion of such or such nutrient, but the risk of mycotoxins presence (LEBAS *et al.*, 1998). Effectively these products are generally damp when produced and they are rarely processed quickly enough to avoid mouldy developments. For this reason before to try to use one product of this category in rabbit feeding, the first precaution is to study its industrial process of production and storage and to evaluate the risk of mycotoxins presence.

Table 15. Experiments on industrial by-products used mainly as source of fibre in rabbit feeding.

Ingredient	Nb Levels	Highest level studied	Accep-table level	substituted mainly to	Evalua-tion on	Authors
alder bark (*Alnus*)	2	25%	need of balanced diets	lucerne	growth	Ayers *et al.*, 1992a
alder sawdust (*Alnus*)	2	25%	need of balanced diets	lucerne	growth	Ayers *et al.*, 1992a
apple pomace (dried)	3	20%	20%	lucerne	growth	Gippert *et al.*, 1988
apple pomace (dried)	4	30%	11%	-	growth	Sawal *et al.*, 1995
apple pomace (dried)	5	50%	30%	-	growth	Schurg *et al.*, 1980
artichoke bracts, dried	3	30%	15%	lucerne	growth	Bonanno *et al.*, 1994
artichoke bracts, dried	3	20%	20%	-	growth	El-Sayaad *et al.*, 1995
barley screenings	2	20%	20%	lucerne	growth	Evans *et al.*, 1983
brewer's grains, dried	4	45%	15%	-	growth	Omole *et al.*, 1976b
brewer's grains, dried	2	30%	30%	soybean m. & maize	growth	Berchiche *et al.*, 1999
brewer's grains, dried	2	30%	30%	basal diet	growth	Maertens *et al.*, 1997
date pits	5	20%	0%	-	growth	Aboul-Ela *et al.*, 1999
eggplant (*Solanum melongena*) waste from the freezing industry	3	6.50%	3.50%	lucerne	growth	Grandi *et al.*, 1983c
grape pomace	2	30%	30%	beet pulp	growth	Harris *et al.*, 1980
grape pomace	4	30%	30%	lucerne	growth	Motta Ferreira *et al.*, 1996
grape pomace	6	40%	40%	lucerne	growth	Parigi-Bini *et al.*, 1980
grape pomace	2	10%	10%	-	growth	Schurg *et al.*, 1980
grape seed meal (defatted)	2	15%	15%	basal diet	growth	Garcia *et al.*, 1999
grape seed meal (dehulled)	3	20%	20%	lucerne	growth	Cavani *et al.*, 1988a
grape seed meal (whole)	2	15%	15%	lucerne	growth	Alicata *et al.*, 1988a
marrow (*Cucurbita pepo*) industrial waste	3	10%	10%	soybean meal & wheat bran	growth	Grandi, 1981b
malt	2	8%	8%	-	growth	Bagliacca *et al.*, 1987
oak sawdust (*Quercus*)	2	25%	need of balanced diets	lucerne	growth	Ayers *et al.*, 1992a
orchard grass (*Dactylis glomerata*) seed screening	4	45%	45%	lucerne	growth	El-Sayaad *et al.*, 1992
palm oil mill effluent (dried)	4	10%	10%	maize offals	growth	Abu *et al.*, 1993

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Table 15 : Industrial by-products, source of fibre (continuation)						
paper (ground paper)	2	10%	10%	hay	growth	King, 1983
paper (ground salvaged paper)	3	20%	20%	lucerne	growth	Lebas, 1976
pear pomace	2	10%	10%	-	growth	Schurg *et al.*, 1980
peas (*Pisum sativum*) waste from the pea processing industry	3	10%	10%	lucerne	growth	Grandi *et al.*, 1983d
Robinia pseudoacacia bark	2	25%	need of balanced diets	lucerne	growth	Ayers *et al.*, 1992a
rumen content, dried	5	20%	12%	maize	growth	Olumeyan *et al.*, 1996
rumen content, sun-dried	4	25%	15%	hay	growth	Abd-El-Rahman *et al.*, 1989
sawdust	4	25,5%	8,5%	-	growth	Marai *et al.*, 1979
sawdust	4	20%	15%	-	growth	Radwan, 1994
sawdust	4	10%	10%	-	growth	Fayek *et al.*, 1989
sawdust (4%NaOH treated)	-	-	15%	-	growth	Omole *et al.*, 1981b
sawdust (urea-treated)	4	10%	10%	-	growth	Fayek *et al.*, 1989
sweet pepper (*Capsicum annuum*) discarded stalk, receptacle and central core	3	8%	8%	lucerne	growth	Grandi *et al.*, 1983b
tea marc	4	18%	18%	-	growth	Eekeren *et al.*, 1991
tobacco fibrous residues after removal of protein fractions	3	24%	24%	lucerne	growth	Costantini *et al.*, 1988
tomato pomace (dried)	4	40%	10%	-	growth	Caro *et al.*, 1993
tomato pomace (dried)	3	50%	50%	concentrate	angora	Caro *et al.*, 1995
tomato pomace (dried)	3	10%	10%	maize	growth	El-Razik, 1996
tomato pomace (dried)	4	30%	20%	lucerne	growth	Gippert *et al.*, 1988
tomato pomace (dried)	3	20%	13%	-	growth	Sawal *et al.*, 1996
tomato processing residues	3	20%	20%	wheat bran & lucerne	growth	Rojas *et al.*, 1989
tomato skins without seeds	2	10%	<<10%	oats	growth	Battaglini *et al.*, 1978b
tomato skins and seeds	2	10%	10%	oats	growth	Battaglini *et al.*, 1978b
tomato skins and seeds	2	20%	20%	lucerne	growth	Alicata *et al.*, 1988b
tomato skins and seeds	2	20%	20%	lucerne	breeding	Alicata *et al.*, 1996
vine residues (dried)	3	10%	5%	-	growth	Martina, 1983

CONCLUSION

This invited report has been for the author the occasion to propose a practical updated table of nutrients recommendations for rabbits feeding, as complete as possible. The long list of ingredients studied for rabbit feeding must be considered mainly as an annotated list of references on the subject. It may be risky to use the highest acceptable levels mentioned in tables 3 to 15 for a specific raw material without reading of original papers. In addition, if some raw material were extensively studied and don't need more experiments (wheat or barley straw for example), for many others new experiments would be welcome.

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