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Feeding strategy for small and medium scale rabbit units

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Abstract

Feeding strategy of rabbit breeders depends first of all of the type and source of feeds available for the unit. For units situated in a urban context, with no or only a very small surface cultivable for rabbits, the main source of feeds can be only raw or manufactured materials (complete feeds) purchased from the local market. Fresh material obtained from a small garden or as kitchen waste could have only a marginal contribution in rabbits feeding, if the number of rabbits simultaneously present in the unit exceed 4-5 individuals. If available locally, the use of complete pelleted feeds is the easiest and most frequently the cheapest solution. If not available, a simple solution is the use of dry forages purchased from the market (*i.e.* hay in most of the situations) distributed ad libitum plus cereal grains distributed in limited quantities, and fresh water. According to climate and conditions of cultivation, with 1000 m² of crop cultivated exclusively for rabbits, one may expect to produce 15 to 60 slaughter rabbits per year. For units located in the countryside, if the breeder can cultivate a sufficient area, he can feed his rabbits almost exclusively with the production of his field : forage, cereals, etc... and some crop by-products. It's necessary to purchase only minerals, (salt, calcium for the does and probably phosphorus), and cages design must be adapted to healthy distribution of grains (feeders) and forages (rack). But the breeder must pay attention to the relative income he can obtain from the same field, if it is cultivated for rabbits feeding or cultivated for a production directly marketable. He must also compare the economical result of rabbit feeding with purchased complete feeds, if locally available.
The nutritional balance of grains and fodder obtained from the crops must be at the centre of the cultivation planning. The strategy should be adapted to the type of rabbits in consideration. After weaning, growing rabbits are relatively easy to feed : they grow for the quantity and quality of the provided feeds: low feed quantity and/or unbalanced diet = low growth rate; on the other hand if feed quality is good and quantity sufficient, growth rate is higher . The only important point is to provide enough fiber. On the contrary breeding does and more specially lactating ones must receive balanced diets in the proper quantity. If this objective is not obtained, the doe produces milk by drawing nutrients from her poor reserves. The milk quantity is too low for the young, the doe's health declines quickly and its reproduction stops. Forages, green or dry, provide the required level of fiber, one part of the digestible energy and of digestible proteins. Grains provide energy and an appreciable quantity of proteins, largely greater for legume grains than for the cereals grains. It must be pointed out that in cereals and in grass in general the proportion of lysine in the proteins is too small to cover rabbits requirement, but the sulphur amino acids (SSA) content is generally sufficient. On the contrary in legumes grains and forages, the lysine content of proteins is sufficient but the SAA content may be too low. Some data on suitability of more than 200 different forages, grains and crops by-products are given in the text particularly as source of proteins and minerals. These data were mainly extracted from the Feedipedia online encyclopedic database. The final remark is that rabbit feeding every day with green fodder is time consuming and in many cases working time is the limiting factor of this technique. Utilization of dried stored forages (hay) provides a greater flexibility in the daily feeding practice.

Keywords : rabbit - feeding - feed resources - growth - reproduction

Introduction

For rabbits as for any type of animal raised by farmers, feeding strategy would be based on feeding behavior et nutritional requirements whatever the dimension of the production unit. Once these initial points known, for small and medium scale unit feeding strategy of rabbit breeders depends first of all of the type and source of feeds available for the unit. For units situated in a urban context (about 41% of the total population in Asia, Anonymous 2013), with no or only a very small surface cultivable for rabbits, the main source of feeds can be only raw or manufactured materials (complete feeds) purchased from the local market. For units situated in the countryside, the situation would be more open with the same possibilities than in urban areas and in addition the possibility of utilization of raw materials produced on the farm for rabbits or collected around it.

These different points would be shortly developed in this paper

Rabbit requirements and feeding behaviors

Requirements
For small and medium scale rabbit units it is reasonable to consider only one type of recommendation for all types of rabbit, corresponding in the nutritional tables to a mixed or single feed (Lebas 2004, de Blas and Mateos, 2010). The main nutritional recommendations are summarized in the table 1. More detailed recommendations, specially the ratios between the different fibrous fractions are available in the international literature (Gidenne *et al.,* 2010)

Table 1 : Main nutritional recommendations for a balanced feed for all types of rabbits (without other indication nutrients in percentage of the diet, supposed to contain 89% of dry matter).

Nutrients	%	Nutrients	%
Digestible energy (MJoules/kg)	10.0	Starch	< 16.0
Crude protein	16.0	Lipids	2.50
Digestible protein	11.5	Vitamin A (IU/kg)	10 000
Lysine	0.80	Vitamin D (IU/kg)	< 1500
Methionine + Cystine	0.60	Vitamin E mg/kg	> 50
Threonine	0.65	Calcium	1.10
Crude fiber	15.0	Total Phosphorus	0.50
NDF	31.0	Sodium	0.22
ADF	17.0	Potassium mini	0.60
ADL	5.5	Potassium max	< 1.80

For a possible modulation of these recommendations according to the physiological situation, crude protein level could be increased up to 18% for lactating does, and calcium could be reduced down to 0.8% for growing rabbits. An other important point is that nutritional requirements expressed as composition of a complete diet are the same whatever the genotype of rabbits.

Feeding behaviors
A detailed description of rabbit feeding behavior could be found in the publications of Gidenne and Lebas (2006) or Gidenne *et al*. (2010).

Different points must be underlined and taken account in the daily practice of rabbit feeding

- Total digestive transit is relatively short (16-24 hours) when compared to other herbivorous animal (about 60 hours for a cow or 30 hours for a guinea pig).
- Contrary to the ruminants, an increase of the diet's fibrous content induces a acceleration of the speed of transit time in the rabbit. Correspondingly rabbit has a high capacity to adapt its feed intake to the fiber level of its ration : daily feed intake increases with the diet's fibrousness as demonstrated in the figure 1. This is mainly the consequence of the regulation of the energy daily intake : fiber digestibility is lower than the average digestibility value of the diet. Thus, an increase of the fiber content induces a decrease of the digestible energy content. In order to obtain enough energy, the rabbit offset the lowest energy concentration by an increase of the daily intake of the more diluted ration.

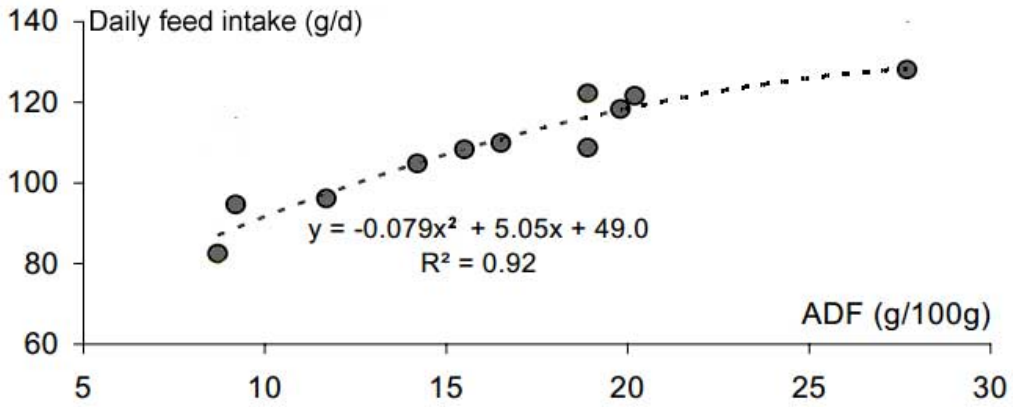

Figure 1: Average feed intake of growing rabbits between 4 and 11 weeks of age in relation with the complete feed's ADF content (Gidenne & Lebas, 2006)

- The instantaneous capacity of ingestion is limited by the stomach small capacity : a content of about 15-18 g of dry matter for a stay of 1 to 2 hours and an average daily intake of 110-120 g (for a growing rabbit of 2kg).
- When it is fed *ad libitum* a pelleted complete diet, the rabbit makes about 35-40 meals per day (3-5 g each), mainly during the dark part of the 24 hours. If the feed is distributed in limited quantity, the ingestion begins immediately after the distribution, but the rabbit makes the same number of meals per day just more close to each other.
- With pellets feeding, the rabbit spends about 10% of the 24 hours cycle to feed (Mirabito *et al*, 2005). If the feed is presented as meal instead of pellets this duration is multiplied by 1,5 to 2 and a great part of this time is devoted to scratch in the feeders to search more interesting fractions or particles. If the daily ration contents an important part of forages, this time could be multiplied by 3 or 4.
- Two or 3 rabbits are able to eat simultaneously in the same feeder without competition problems because once the feed is taken in the feeder (5-10 seconds) each rabbit removes his head from the feeder to chew during 0.5 to 1 minute and then after introduces again the head in the feeder for 5-10 seconds
- When ambient temperature increases above 28-30°C the feed intake is reduced. This drawback could be partially, but only partially, offset by increasing the lipid concentration of the feed or by increasing the protein /energy ratio of the diet. Conversely, if the ambient temperature is below 10°C, the rabbit increases its food intake to compensate for the energy cost of thermoregulation. It can even endure a temperature of minus 15 to 20 ° C below zero in the condition of having a water source (roots, unfrozen water, ...).
- When a concentrate (low fiber diet compound diet) and a dry fibrous material are proposed as free choice to rabbits, they prefer the concentrate. The fibrous material is consumed in only small quantities and the growth rate may be reduced (Lebas *et al*, 1997).

The consequence is also an immediate increase of the sanitary risk for rabbits with digestive disorders by lack of fiber (Gidenne, 2003). If the fibrous material is presented fresh (green) the balance between concentrate and forage is more difficult to predict, and the recommendation is to propose the more palatable in restricted quantity.

- The maximum intake capacity of a rabbit per day is about 5 to 9% of it's live weight expressed as dry matter. For example dry matter intake of a rabbit doe varies from 3.5% of her live weight when she is empty and dry, up to 8-9% of the live weight at the peak of lactation. With the high speed growth selected lines, the dry matter intake may represent up to 10% of the live weight at peak of growth (when 35-40 days old)
- The need of water is about twice that of the dry matter intake, with an increase of the proportion when temperature is above 28-30°C. It means that if rabbits receive a daily ration with a minimum average content of 70-75% of humidity, water distribution is not "necessary" even if it is strongly recommended. In any other cases the distribution of clean water is absolutely necessary.

Available sources to feed rabbits

The sources of raw material usable for rabbit feeding are very numerous but according to the country or the urban environment, only some raw materials are effectively available for practical rabbits feeding. To help in the choice of the most suitable ones, a list was established out of the encyclopedic data basis "Feedipedia". This data basis is freely available on Internet at the URL www.feedipedia.org. It is still under construction by the French animal nutrionists (AFZ, INRA, CIRAD) with the help of FAO, but a lot of information is already available. In fact it has replaced officially the old FAO "Afris" data basis since the end of 2012.
The chemical composition is available in the Feedipedia data basis, but unfortunately the amino acid composition is lacking for many forages. More frequently the digestible energy for rabbits and the crude protein digestibility are also lacking.

To offset this lack of information it's possible to use the equations recently proposed by Lebas (2013) for the estimation of digestible energy and protein digestibly of raw materials for rabbits using the classical parameters of the chemical analysis, summarized for example in the Feedipedia encyclopedic database.

$$DE\text{-}Rab = 15.627 + 0.000982\ CP^2 + 0.0040\ EE^2 - 0.0114\ MM^2 - 0.169\ ADF \pm 1.250\ MJ/kg\ DM\ (R^2 = 0.912)$$

$$Protein\text{-}Digestibility = 64.734 + 0.646\ CP + 2.170\ CF + 0.414\ NDF - 2.894\ ADF \pm 9.338\ \%\ (R^2 = 0.825)$$

DE in MJoules /kg DM ; DM = Dry matter ; CP = %crude protein in DM; EE = % ether extract (lipids) in DM; MM =% minerals (ash) in DM; ADF = % acid detergent fibre in DM ; CF = % crude fibre in DM; NDF = % Neutral detergent fibre in DM.

Rabbits are more or less able to correctly regulate their daily feed intake according to the diet's digestible energy concentration. If a feed ration respects the nutritional recommendations summarized in the table 1 even without consideration of the digestible energy, the corresponding diet is necessarily within the range of digestible energy ingestion regulation. Thus the next most important parameters to estimate the nutritive value of a feedstuff to be introduced in a balance diet are :

- the proteins level and these proteins amino-acids balance
- the quantity and type of fiber (highly or poorly digestible according mainly to the lignin level)
- and the ability to provide calcium and phosphorus.

For the rabbit, a raw material could be an interesting source of protein, of amino acids, of fiber or of minerals if the content exceed recommendations reminded in the table 1. For this reason in the table 2 to 9, the nutrients content of each material is presented as percentage of rabbits

requirements. This type of information makes easy to determined the interest of a given raw material for such or such nutriment as well as its inadequacy for some others.
A little bit more than two hundred raw materials usable for rabbit feeding are presented in the following tables with their aptitude to cover rabbits nutritional requirements.

Table 2 : Cereal, their by-products and other poaceae seeds : ability to cover rabbits nutritional requirements (for an "all rabbits" diets)

	Nutrients						
	Protein / DM	Lysine / Prot	Met+Cys / Prot	Calcium / DM	Phosph. / DM	NDF / DM	ADL / DM
Rabbit's requirements % DM, or %CP	18.0	5,0	3,7	1,2	0,55	35,0	5,5
Feeds	Percentage coverage of rabbits requirements						
Cereals and other poaceae seeds							
Barley grain	66	74	105	7	71	62	20
Finger millet *Eleusine corcana* grain	49	60	111	41	62	68	38
Fonio *Digitaria exilis* grain	47	52	189	8	38	22	5
Foxtail millet *Setaria italica*, grain	66	48	151	23	60	na	na
Job's tears *Coix lacrima-jobi* seeds	61	38	157	1	na	na	na
Kodo millet *Paspalum scrobiculatum* grain	67	72	81	48	58	na	na
Maize grain	52	62	119	4	55	35	11
Oats grain	61	86	127	9	65	102	45
Pearl millet *Pennisetum glaucum* grain	69	56	97	3	60	49	18
Quinoa *Chenopodium quinoa* grain	84	106	95	9	75	na	na
Rice brown grain	58	72	108	4	47	9	36
Rice grain as Broken rice	58	82	92	4	58	45	15
Sorghum S*orghum bicolor* grain	60	44	97	3	60	31	20
Tritical grain	65	70	108	6	71	42	20
Wheat grain	70	58	103	6	65	40	20
Cereal by-products							
Brewers' grain	145	62	100	20	105	163	100
Corn distillers	163	60	108	13	144	98	80
Maize bran (maize offals)	67	90	119	40	62	104	40
Oat hulls	29	80	89	16	33	217	129
Pearl millet *Pennisetum glaucum* bran	76	38	na	7	105	94	38
Rice bran (not defatted)	71	88	97	6	251	98	124
Sorghum bran (sorghum offal)	65	82	119	7	89	123	91
Sorghum brewers' grain	144	76	119	64	147	114	91
Wheat bran	96	80	97	12	202	129	69
Wheat distillers	207	50	97	20	155	92	82

All cereal are poor in proteins and lysine, covering on average only 62 and 65% of requirement respectively, with the noticeable exception of quinoa grains rich in lysine. On the contrary their proteins are relatively rich in sulfur amino acids (116% of requirements on average). For other studied nutrients, cereals provide a small to very small proportion of requirements. Thus cereals are mainly sources of energy and secondarily of sulfur amino acids.

Some cereals by-products on the contrary could provide an appreciable proportion of proteins rich in sulfur amino acids but again with a low proportion of lysine. They could provide a high proportion of phosphorus requirements, with the exception of maize and sorghum bran and oats hulls, But for all of them as for the cereals grains, the content of calcium is very low. Cereal by-products represent an interesting source of fiber (123% of NDF requirement) but with a lignin content a little bit too low for rabbits (84% of requirements for ADL).

Table 3 : Legume gains or seeds, and by-products : ability to cover rabbits nutritional requirements (for an "all rabbits" diets) (na = no available analysis)

	Nutrients						
	Protein / DM	Lysine / Prot	Met+Cys / Prot	Calcium / DM	Phosph. / DM	NDF / DM	ADL / DM
Rabbit's requirements % DM, or %CP	18.0	5,0	3,7	1,2	0,55	35,0	5,5
Feeds	Percentage coverage of rabbits requirements						
Legume grains & seeds							
African locust bean *Parkia filicoidea* seeds	177	134	68	18	31	81	na
African yam bean *Sphenostylis stenocarpis* seeds	130	172	97	5	60	139	109
Babul *Acacia nilotica* seeds	113	114	89	66	62	106	76
Black gram *Vigna mungo* seeds	132	140	68	18	89	53	5
Butterfly pea *Clitoria ternatea* seeds	236	122	95	6	104	na	na
Cajan pea *Cajanus cajan* seeds	129	130	76	32	58	44	na
Chickling vetch *Lathyrus sativus*, seeds	135	194	49	54	55	51	9
Chickpea *Cicer arietinum* seeds	123	136	54	14	76	31	4
Common beans *Phaseolus vulgaris* seeds	138	136	54	21	89	46	4
Common vetch *Vicia sativa* seeds	158	116	49	52	87	45	16
Cowpea *Vigna unguiculata* seeds	138	132	70	9	75	40	18
Elephant's ear *Enterolobium cyclocarpum* seeds	121	136	81	57	51	na	na
Faba bean *Vicia faba* seeds	161	126	54	13	102	45	18
Guar *Cyamopsis tetragonoloba* seeds	156	80	54	29	36	na	na
Jack bean *Canavalia ensiformis* seeds	162	116	49	15	87	98	29
Jack beans *Canavalia ensiformis* seeds	162	116	49	15	87	98	29
Lablab bean *Lablab purpureus* seeds	149	118	46	17	78	89	20
Lentil *Lens culinaris* seeds	149	130	57	9	82	37	29
Lima beans *Phaseolus lunatus* seeds	136	120	68	33	100	38	27
Lupin white *Lupinus albus* seeds	214	98	65	32	78	61	18
Mung bean *Vigna radiata* seeds	141	122	54	18	84	40	22
Peas *Pisum sativum seeds*	133	144	65	10	82	41	7
Sword bean *Canavalia gladiata* seeds	172	110	65	16	95	na	na
Tamarind *Tamarindus indica* seeds	86	130	81	25	31	146	120
Umbrella throrn *Acacia tortilis* seeds	164	92	na	47	133	86	35
Velvet beans *Mucuna pruirens* seeds	154	84	68	16	89	55	16
Legume seeds by-products: pods, husks, ...							
Babul *Acacia nilotica* dry pods	65	80	78	52	31	77	104
Camel thorn *Acacia erioloba* dry pods	73	88	57	55	24	127	82
Carob pods (without seeds)	28	76	59	41	16	95	309
Chilean mesquite *Prosopis chilensis* pods	58	66	na	24	27	108	127
Common bean *Phaseaolus vulgaris* crop resi.	84	80	62	134	44	109	75
Elephant's ear *Enterolobium cyclocarpum* pods	92	128	68	74	98	103	195
Groundnut *Arachis hypogaea* hulls	38	92	62	20	13	198	427
Groundnut *Arachis hypogaea* tops	62	90	57	92	27	148	185
Guar *Cyamopsis tetragonoloba* meal	233	82	62	58	116	59	5
Mesquite *Prosopis juliflora* dry pods	106	80	59	38	27	132	104
Paperback thorn *Acacia sieberiana* dry pods	68	54	41	37	33	102	105
Soybean *Glycine max* hulls	73	126	78	46	29	183	44
Umbrella thorn *Acacia tortilis* dry pods	89	94	na	82	58	98	93

All studied legume seed are interesting sources of proteins (148% of rabbits requirements on average) with the only exception of tamarind seeds. Most of them are also sources of lysine (125% of requirements on average) but they provide only few sulfur amino acids (65% of

requirements on average). Their contribution to calcium, phosphorus and fiber balance are also poor.
Most of the legume seed by-product are poor sources of protein with the noticeable exception of the guar meal (germ +husk obtain after mechanical separation of the guar seed endosperm). The proteins are also poor in lysine (in opposition with the seeds proteins) and sulfur amino acid, only the elephants ears pods are rich in lysine. The contribution of legume by-products to Ca and P is poor with again the exception of the elephants ears pods, rich in calcium, and the guar meal rich in phosphorus.

Table 4 : Grass forages : ability to cover rabbits nutritional requirements (for an "all rabbits" diets) (na = no available analysis)

	Nutrients						
	Protein / DM	Lysine / Prot	Met+Cys / Prot	Calcium / DM	Phosph. / DM	NDF / DM	ADL / DM
Rabbit's requirements % DM, or %CP	18.0	5,0	3,7	1,2	0,55	35,0	5,5
Feeds	Percentage coverage of rabbits requirements						
Grass forages							
Barley forage fresh	62	132	95	42	27	150	44
Bread grass *Brachiaria brizantha fresh*	58	120	103	38	40	191	102
Coastal bermuda grass *Cynodon dactylon* hay	57	65	81	35	35	186	76
Cocksfot *Dactylis glomerata fresh*	91	126	97	34	51	171	82
Cocksfot *Dactylis glomerata* hay	73	76	62	33	49	182	82
Columbus grass *Sorghum x Almum* fresh	56	70	32	38	75	197	95
Gamba grass *Andropogon gayanus* fresh	43	106	78	32	29	205	109
Guinea grass *Panicum maximum fresh*	62	112	95	41	44	207	111
Jaragua *Hyparrhenia rufa* fresh	39	142	100	32	31	207	113
Kikuyu *Pennisetum clandestinum* fresh	84	64	54	26	67	187	78
Napier grass *Pennisetum purpureum* fresh	54	62	43	30	53	204	104
Pangola grass *Digitaria eriantha* fresh	45	68	59	42	47	204	107
Ryegrass *Lolium sp* hay	83	65	85	54	58	142	95
Sugarcane tops *Saccharum officinarum* fresh	26	92	14	23	22	199	82
Timothy *Phleum pratense* hay	51	68	51	28	38	187	80

The first remark about table 4 is the relatively small number of grasses included in this list while it's well known that a greater number of grasses could be used in rabbit feeding (Lebas, 2004). But because most chemical analysis are made at the occasion of studies with ruminants, the amino acids composition of proteins is most generally not determined and then not available for rabbit nutrition. For ruminants, because of the important transformations of nitrogenous compounds in the rumen, the amino acids composition is of poor interest to estimate the nutritive value of a forage, but this not the case for rabbits.

This drawback remains nevertheless relatively small since most of grasses can contribute only partially to the protein content of rabbit ration (59% of requirements on average). The lysine content of these proteins may vary widely and cover from 62 to 126% of lysine needs. Contrary to the grass seeds and grains, the sulfur amino acids content of forage grasses proteins, is below the rabbits requirements for almost all of these raw materials. If the contribution for calcium and phosphorus remains poor around 40% of requirements, the contribution on total fiber is really substantial : 188% of NDF requirements on average, but that of lignin is more variable and represent on average only 91% of requirements (from 44 to 113%).

Table 5 : Legume forages : ability to cover rabbits nutritional requirements (for an "all rabbits" diets) (na = no available analysis)

	Nutrients						
	Protein / DM	Lysine / Prot	Met+Cys / Prot	Calcium / DM	Phosph. / DM	NDF / DM	ADL / DM
Rabbit's requirements % DM, or %CP	18.0	5,0	3,7	1,2	0,55	35,0	5,5
Feeds	Percentage coverage of rabbits requirements						
Legume forages							
Alfalfa *Medicago sativa* fresh	114	112	78	162	45	112	138
Alfalfa *Medicago sativa* hay	101	86	68	140	47	128	138
Berseem *Trifolium alexendrinum* fresh	111	86	68	161	49	127	93
Berseem *Trifolium alexendrinum* hay	87	112	78	183	47	141	96
Butterfly pea *Clitoria terneata* aerial part	118	88	97	106	53	167	165
Caribean stylo *Stylosanthes hamata* fresh	87	94	73	120	31	147	165
Centro *Centrosema pubescens* aerial part	105	70	70	79	47	158	155
Common vetch *Vicia sativa* aerial part fresh	128	106	54	100	80	105	111
Common vetch *Vicia sativa* hay	109	144	78	121	53	110	118
Cowpea *Vigna unguiculata* aerial part fresh	101	66	62	110	44	119	80
Green leaves Desmodium *intortum* fresh	83	74	68	85	56	155	191
Kudzu *Peraria montana* aerial part fresh	84	88	78	103	44	154	142
Lablab bean *Lablab purpureus* aerial part	101	112	54	98	53	127	142
Lebbek *Albizia lebbek* leaves fresh	90	88	76	161	31	143	180
Leucaena leucocephala fresh aerial part	129	110	97	89	38	117	196
Lima bean *Phaseolus lunatus* vines	108	72	57	100	55	109	135
Mung bean *Vigna radiata* aerial part	95	82	54	206	62	114	127
Pea forage *Pisum sativum* aerial part	98	132	68	155	71	89	87
Perrenial soybean *Neotonia wightii* fresh	95	96	57	124	45	145	144
Perrenial soybean *Neotonia wightii* hay	78	80	76	83	56	175	231
Persian clover *Trifolium resupinatum* fresh	120	104	54	183	71	81	49
Persian clover *Trifolium resupinatum* hay	78	84	49	124	33	123	120
Puero *Pueraria phaseolides* aerial part fresh	107	64	78	82	49	123	135
Red clover *Trifolium pratense* fresh	106	132	89	120	62	103	64
Red clover *Trifolium pratense* hay	102	86	57	113	164	102	102
Sainfoin *Onobrychis viciifolia* fresh	94	104	70	118	84	101	171
Sainfoin *Onobrychis viciifolia* hay	84	104	70	114	56	136	164
Sesban *Sesbania sesban* aerial part fresh	136	106	46	133	60	77	82
Sirato *Macroptilium atropurpureum* fresh	90	92	59	87	31	145	133
Soybean forage *Glycine max* fresh	76	70	70	128	51		82
Soybean forage *Glycine max* hay	87	70	70	72	45	169	175
Stylo *Stylosanthes guianensis* fresh	78	86	57	115	42	113	155
Stylo *Stylosanthes guianensis* hay	51	70	78	81	29	156	218
Trifolium subterraneum hay	84	88	41	95	42	132	138
Tamarind *Tamarindus indica* leaves	66	118	59	156	38	157	427
White clover *Trifolium repens* fresh	137	90	108	84	60	80	69

On average the legume forages or fabaceae forages according to the last denomination, provide a proportion of protein in dry matter corresponding to the rabbits requirements (98% on average), but variations from one forage to the other are very wide : covering from 51% of proteins requirement with low quality stylosanthes hay, up to 136-137% with fresh white clover or with Sesbania fresh leaves. Some reasons of such variation are the classical variations with vegetative stage and type of plant but also with conditions of harvesting . The small leaves are very rich in proteins (up to 28-30%/DM) but they are also easily lost during

the harvesting and drying process. See for example the higher protein contribution of fresh sainfoin or berseem , compared to the hay protein contribution of these 2 forages (table 5)
Because of their relatively high level of protein, legume forages present some potential interest for pig or even laying hens nutrition, *i.e.* other monogastric animals. For this reason a higher proportion of these forages was analyzed for the amino acids content. In the proteins, the lysine content is relatively close to rabbits requirement (94% on average) but with variations between 70% for example in the aerial part of soybean plant or *Centrosema* forage, up to 132% in the aerial part of common pea (*Pisum sativum*). It must be underlined that it is not possible to establish a simple relation between the lysine content of the seeds and that of the forage of the same plant. Some legume forages could be a good source of calcium but for some other the content is too poor for rabbit feeding. Nevertheless on average the legume forages content represents 127% of rabbits requirements. For phosphorus the contribution is only 53% on average. Systematically the NDF content cover largely rabbits requirements (127% on average) and frequently, but not systematically that of lignin : 142% on average with variations from 69% up to 230%.

Table 6 : Other forages and water plants : ability to cover rabbits nutritional requirements (for an "all rabbits" diets) (na = no available analysis)

	Nutrients						
	Protein / DM	Lysine / Prot	Met+Cys / Prot	Calcium / DM	Phosph. / DM	NDF / DM	ADL / DM
Rabbit's requirements % DM, or %CP	18.0	5,0	3,7	1,2	0,55	35,0	5,5
Feeds	Percentage coverage of rabbits requirements						
Other forage plants : leaves and forages							
Abelmoschus esculentus Okra fresh leaves	132	116	89	240	69	na	na
Acanthus mollis aerial part fresh	118	82	na	80	64	na	na
Amaranthus sp aerial part fresh	111	109	70	150	98	99	na
Beta vulgaris Beet fresh leaves	93	116	49	92	67	na	na
Cassava *Manihot esculenta* foliage dryied	142	96	59	174	58	121	145
Cassava *Manihot esculenta* foliage fresh	138	118	89	99	67	121	171
Celery *Apium graveolens* fresh leaves	119	70	49	225	309	68	na
Chromolaena odorata Queens weed, fresh	184	118	92	66	67	na	na
Helianthus annuus Sunflower fresh forage	72	108	81	146	56	113	176
Ipomoea batatas Sweet potato, dry forage	73	96	132	103	56	115	205
Ipomoea batatas Sweet potato, fresh forage	92	72	124	79	53	122	151
Jerusalem artichoke *Helianthus tuberosus* aerial part fresh	85	108	81	157	60	116	209
Margosa *Azadirachta indica* fresh leaves	92	200	227	167	45	123	335
Moringa oleifera Moringa fresh leaves	116	104	78	220	47	81	127
Morus alba White mulberry; fresh leaves	108	120	86	228	82	91	91
Morus nigra Black mulberry; fresh leaves	98	84	81	180	24	na	na
Symphytum x uplandicum Russian comfrey fresh	103	72	na	156	89	53	na
Taro *Colocasia esculenta* aerial part fresh	128	99	78	75	56	101	116
Trichanthera *Trichanthera gigantea* fresh	106	80	68	417	75	114	151
Water plants							
Azolla filiculoides whole plant	99	100	81	49	22	na	na
Azolla pinnata whole plant, sun dried	92	76	65	119	56	137	na
Duck weed (average common, inflated, great and rootless duckweed) dried	154	84	81	253	71	107	na
Water hyacinth *Eichornia crassipes* whole	102	94	43	79	115	164	156
Water spinach *Ipomoea aquatica* leaves	119	85	64	58	102	86	182

Most of the leaves and forages of the studied other plants (non grass nor legume) could be considered as interesting sources of proteins. Only sunflower forage and sweet potato dried

vines have a too low level (72-73% of requirements). Some of them are interesting source of lysine and even of sulfur amino acids such as sweet potato green forage and *Azadirachta indica* fresh leaves. Most of them are important sources of calcium but not of phosphorus. The NDF content is most frequently close to the rabbits requirement, and the lignin level, when determined, is generally higher.
The dry matter of the water plants contains an appreciable proportion of proteins, but these are deficient in sulfur amino acids, particularly water hyacinth and water spinach. Mineral content of these plants depends largely of the composition of the water on which they are grown, thus the values of the table 6 are only indications.

Table 7 : Roots, tuber, fruits and by-products : ability to cover rabbits nutritional requirements (for an "all rabbits" diets) (na = no available analysis)

	Nutrients						
	Protein / DM	Lysine / Prot	Met+Cys / Prot	Calcium / DM	Phosph. / DM	NDF / DM	ADL / DM
Rabbit's requirements % DM, or %CP	18.0	5,0	3,7	1,2	0,55	35,0	5,5
Feeds	Percentage coverage of rabbits requirements						
Other forage plants : roots, fruits...							
Beet root , fodder type, fresh roots	37	124	76	23	36	38	18
Breadfruit *Artocarpus artilis* dried fruit meal	22	69	48	8	29	na	na
Carrot *Dacus carota* fresh roots	51	104	68	32	53	34	18
Cassava *Manihot esculenta* dry sliced roots	16	78	86	14	20	23	31
Desert date *Balanites aegyptiacus* fresh fruits	62	54	95	13	73	na	na
Jerusalem artichoke *Helianthus tuberosus* tuber fresh	41	90	62	15	58	26	104
Phoenix dactylifera Date palm fruit	21	54	84	33	49	69	142
Phoenix dactylifera Date palm, depitted fruit	27	24	68	62	15	na	na
Potato *Solanum tuberosum* tuber raw	60	98	51	6	40	20	24
Taro *Colocasia esculenta* fresh tuber	31	89	94	32	80	na	na
Other plants by-products							
Ananas comosus Pineapple, dry canning by-product	25	40	22	41	24	119	71
Beet molasses	79	28	22	9	5	1	0
Beet pulp dehydrated	52	124	76	129	18	137	44
Brewer's yeast	270	126	65	25	240	25	15
Cabbage leaves (wastes) , fresh	98	70	59	38	69	36	31
Cassava *Manihot exculenta* dry peels	27	46	35	14	38	66	222
Citrus pulp dried	39	72	59	142	18	60	49
Cocoa hulls	99	102	70	31	80	133	316
Cocoa husks	43	100	49	48	62	158	244
Coffe pulp dehydrated	63	68	16	27	24	140	165
Grape marc dehydrated	78	82	103	71	56	183	629
Grape pulp dehydrated	76	108	105	82	47	184	605
Soybean hulls	73	126	78	46	29	183	44
Sugarcane molasses	31	2	41	77	13	2	1
Sunflower hulls	39	102	130	37	24	213	404
Tomato pomace, dehydrated	116	160	116	38	64	159	458

Roots, tuber or fruits are poor providers of proteins, and these proteins are in addition relatively poor in lysine and in sulfur amino acids. Only the relatively high proportion of lysine in the proteins in fodder beet, carrots and potato deserves some attention. These types of feeds are also deficient in calcium, phosphorus and fiber.
For the by-products of this heterogeneous group of feeds, the contribution to rabbits requirements varies widely from one product to the other. It could nevertheless be underlined

that it is in this by-product group, that are feed ingredients with the highest lignin level, even if the ADL method don't always separates correctly the true lignin and tannins.

Table 8 : Oil seeds and meals : ability to cover rabbits nutritional requirements (for an "all rabbits" diets) (na = no available analysis; EE = ether extract % in DM)

	Nutrients						
	Protein / DM	Lysine / Prot	Met+Cys / Prot	Calcium / DM	Phosph. / DM	NDF / DM	ADL / DM
Rabbit's requirements % DM, or %CP	18.0	5,0	3,7	1,2	0,55	35,0	5,5
Feeds	Percentage coverage of rabbits requirements						
Oil seeds							
Cashew *Aanacardium occidentale* nut kernel (45.4% EE)	122	80	68	13	60	na	na
Cotton seeds (19,7% EE)	121	80	84	13	107	139	193
Soya beans (toasted, ,,,) (21,3% EE)	220	124	78	28	111	39	22
Linseeds (36,6%EE)	132	70	111	25	115	72	95
Rape seeds (00) (46,1%EE)	116	124	122	41	135	60	116
Sunflower seeds (47,9%EE)	92	78	108	21	107	85	115
Oil Meals & Cakes							
Attalea speciosa Babassu oil meal, decorticated (1,8%EE)	104	110	224	10	153	110	202
Canola meal (4,0%EE)	217	112	122	62	211	77	144
Cocoa oil meal (2,0%EE)	157	80	76	18	135	126	336
Coconut copra oil meal expeller (9,8% EE)	124	52	68	10	105	156	122
Coconut copra oil meal solvent (2,8% EE)	131	62	78	6	118	161	145
Cottonseed meal (3,1%EE)	262	80	84	18	248	77	111
Crambe abyssinica oil meal (1,5%EE)	244	96	114	75	193	85	138
Groundnut cake decorticated (10,1%EE)	272	70	51	10	118	40	44
Groundnut meal (2,0%EE)	304	64	54	14	113	69	91
Hempseed meal (11,3%EE)	179	52	109	23	160	137	240
Linseed meal, expeller (10,2%EE)	190	78	100	36	164	69	113
Maize germ meal (5,9%EE)	84	76	105	4	131	103	29
Mustard oil meal (9,%EE)	194	88	105	4	202	na	na
Palm kernel meal expeller (9,2%EE)	93	58	81	23	109	209	244
Palm kernel meal solvent (2,8%EE)	104	64	84	23	120	209	233
Papaver somniferum oil meal (10,3%EE)	200	84	132	253	255	97	227
Papaver somniferum oil meal (1,2%EE)	206	74	86	217	182	125	255
Rapeseed meal (00) (2,8%EE)	213	110	119	72	231	90	178
Safflower meal (9,4%EE)	138	112	127	23	122		
Sesame meal (11,1%EE)	247	50	132	165	231	61	31
Sheanut cake *Vitellaria paradoxa* oil meal (4,5%EE)	78	80	92	25	44	103	395
Soybean meal high protein (1,8%EE)	297	126	81	30	138	31	9
Soybean meal low protein (2,0%EE)	288	122	78	33	125	39	15
Sunflower meal dehulled (1,8%EE)	209	70	108	38	236	111	156
Sunflower meal non dehulled (2,3%EE)	174	72	108	36	202	133	204

With few exceptions, oil seed and the corresponding meals or cakes are potential important sources of proteins. Only sunflower seeds, maize germ oil meal, and sheanut cake have a proteins content lower than the rabbits requirement. According to botanical source these proteins are rich in lysine or sulfur amino acids , rarely in both together as it is the case for rapeseed meal, canola meal or safflower meal. On the other hand, some meals or cakes frequently used such as groundnut meal or palm kernel meal are simultaneously deficient in lysine and sulfur amino acids. With few exceptions, the calcium content of this group of products is lower than requirements (44% on average) but rich in phosphorus (151% on average). The NDF content (40 to 209% of requirements) and that of lignin (9-395% of

needs) vary so widely from one product to the other, that the calculation of an average is totally meaningless.

Table 9 : Animal products and mineral sources : ability to cover rabbits nutritional requirements (for an "all rabbits" diets) (na = no available analysis)

	Nutrients						
	Protein / DM	Lysine / Prot	Met+Cys / Prot	Calcium / DM	Phosph. / DM	NDF / DM	ADL / DM
Rabbit's requirements % DM, or %CP	18.0	5,0	3,7	1,2	0,55	35,0	5,5
Feeds	Percentage coverage of rabbits requirements						
Animal products							
Blood meal	523	174	62	11	40	0	0
Feather meal (hydrolyzed)	476	42	135	106	149	159	100
Fish meal 60-68% protein as fed	392	150	95	362	507	0	0
Fish meal low protein	269	140	103	661	724	0	0
Hatchery by-product	127	84	89	1592	56	0	0
Meat & bone meal high fat (12,1%EE)	305	100	65	842	885	0	0
Meat & bone meal low fat (5,3%EE)	344	100	70	787	833	0	0
Silkworm pupae meal	350	140	122	32	109	14	2
Whey, sweet, dehydrated, skimmed	69	152	89	43	116	0	0
Mineral sources							
Bone meal calcinated	0	0	0	2525	2545	0	0
Bone meal steamed	44	270	95	2708	2727	0	0
Dicalcium phosphate hydrated	0	0	0	2083	3273	0	0
Eggshells	31	30	86	3058	29	0	0
Limestone	0	0	0	3208	4	0	0
Oystershells	0	0	0	3167	9	0	0

Most of the animal products are good sources of proteins. Fish meal and blood meal are interesting sources of lysine and the silkworm pupae meal also. Feather meal and silkworm pupae meal are good sources of sulfur amino acids, but attention must be paid to the correct hydrolysis of feather meal, otherwise the proteins digestibility, and consequently that of all amino acids, are quite nil. The animal products are generally interesting sources of calcium and phosphorus and, despite some chemical results, completely devoid of fiber.

Among the classical sources of calcium and phosphorus only bone meals and dicalcium phosphate are sources of phosphorus. Egg shells, oyster shells and limestone provide exclusively calcium.

Practical feeding

Use of pellets and complete feeds

If complete pelleted (or even non-pelleted) feeds are used for rabbits as exclusive source of nutrients, whatever the dimension of the rabbit unit, the best solution is to follow recommendations proposed by the feed manufacturer and to distribute *ad libitum* clean water in addition to the pellets. This is why this solution is not more broadly described herein. The only additional remark is that if the commercial so called complete feed has a too low level of fiber, it is advisable to distribute in addition some very palatable fibrous forages (grasses in general) to provide the fiber lacking in the pellets. The quantity may represent 10-20% of the daily dry matter intake, and the farmers must remember that almost always rabbits prefer the feeds in that order : green forages > pelleted complete feeds > dried forages > non-pelleted complete feeds.

Small units and direct use of raw materials

In small units of production, if raw materials are at the basis of rabbits nutrition, the breeder, if possible with the help of the technician of an extension service, must search in his environment (crops, market, uncultivated areas) which raw materials are available or possible to produce in the farm. Then he determine the ability of each to cover rabbits nutritional requirements. To obtain a more or less balanced diet it is necessary to be able to propose to rabbits at minimum one raw material rich (more than 100% of requirement) for each of the main nutrients listed in the tables 2 to 9. According to climate and conditions of cultivation, with 1000 m² of crop cultivated exclusively for rabbits, one may expect to produce 15 to 60 slaughter rabbits per year. This idea of productivity may be useful to determine to real possibilities of rabbits feeding with home made products, or with raw or manufactured material purchased on the market

It is not advised to mix roughly non processed raw material because of the great ability of rabbits to select some parts of a mixture, to eat only the most palatable ones and then destroy the nutritional balance proposed by the breeder. In addition, when a rabbit seeks the most palatable parts, he scratches inside of the feeder and can waste up to 40-50% of the distributed mixture. One of the best ways is to distribute the dry concentrates such as cereals or cakes separately, in limited quantity in the morning. This makes possible a visual control of the real intake. The quantity distributed must be completely eaten within 6-7 hours. In many conditions, the concentrated raw materials may be economically replaced by complete rabbit feeds if possible pelleted. In this situation it is advisable that the pellets don't represent more than 40-50% of the daily dry matter ration, the other part being constituted by various forages. It must be pointed out that in no case rabbit pellets + cereals can constitute a balanced diet, specially for reproduction.

At the end of the afternoon, green forages can be distributed, in racks but never on the floor of the cage, in such quantity that, in the next morning, only very few or none of the distributed quantity remains in the rack. This remaining part should be discarded. Dry forages (hay) could be distributed *ad libitum* but in a different part of the rack if they are used simultaneously with greens.

In most regions, forages, the main source of the fiber for rabbits, are not necessarily available in the green form all the year round with optimum nutritive value. Consequently, the production and storage of dried forages is strongly encouraged for small breeders. The green forages can be harvest in small quantities, day after day, during the rainy season and/or at the beginning of the dry season, and dried in the immediate vicinity of the farmer's house. This sun drying can be done on large tarpaulins, on cemented or rocky areas, or on the roof terrace of the farmer's house (Figure 2). The advantage of drying in the vicinity of the house, is the possibility for the farmer or his family to temporarily and quickly put the forage during drying process, out of the rain in a shed or an annex to the house for a few hours, waiting for the return of the sun.

Figure 2 : Sun drying of berseem on an house terrace in Afghanistan

Almost all forages, tree leaves or foliages can be sun dried. In the above chapters it was mentioned that during the drying process, one part of the nutrients could be lost, mainly the small leaves rich in proteins. But it is clearly preferable to have a forage with a little bit lower quality than not having one at all. Moreover the farmer could harvest cultivated forages, weed forages or spontaneously grown forages or tree leaves, at the optimum of their nutritive value, while for the green forages the nutritive value declines gradually and irremediably as the plant matures.

Medium scale units and direct use of raw materials

All recommendations done for small units are suitable for medium one. Only the drying process of forages needs a better organization and specific means because quantities are greater.

Medium scale production units can produce their own complete feed, alone or in association with some (3-4) nearby other medium rabbit units.

The only equipment strictly necessary are a forage grinder and a balance This small equipment is available for example from different Chinese or Indian companies for a reasonable amount of money (Figure 3).

Figure 3 : Small forage grinding machine at work in Benin, with a diesel engine, loaded by hand

Figure 4 : Small pelleting machine at work in China, with an electric engine (protected inside the box below the pelleting device), loaded by hand.

This type of forage grinder with a large "entry" is perfectly able to grind dried forages, cereals and any type of dry by-product. In extreme cases it is even able to grind half-dried products (used without grid), the obtained wet meal being easier to dry completely than the raw product. The interest of grinding is to obtain an homogenous coarse meal (not a powder) whatever the processed raw material. The adequate quantity of the meal obtain from each raw material used in a dietary formula are weighted and then mixed together and with additives (minerals in powder, premix, pure amino acids if necessary, ...) A correct mixture can be obtained by hand with a shovel on a cemented area, or with a mechanical mixing device. The later is not a necessary equipment if the quantities to be mixed at one time are not too important. If the mixed raw meal obtain is not too dusty, the mixture can be distributed in this form to rabbits. Nevertheless it is strongly advised to pelletize this meal. Efficient pelleting machines are available on the international market at low cost (figure 4). The small pelleting machine can be loaded by hand and the obtained pellets can be refrigerated by simple repartition in thin layer on a cemented area. If the hot pellets are refrigerated on a tarpaulin, it

is easier to pick them up from the ground than if they were directly placed on the cemented area. If the farmer must choose between a mixer and a pelleting machine because of the price of the whole equipment, he has clearly to choose the pelleting machine.
As mentioned for the small units, the home made pellets can be used alone or as a complement of green or dried forage. The farmer can easily produce different types of feed adapted for example to reproducing does, to just weaned or fattening rabbits, etc. Because the whole equipment is not very bulky it can be placed "fixed" on a trailer and transported in the vicinity to be used by 3 or 4 other breeders successively. It may be easier to carry the complete processing equipment, than to carry to a single working location the raw materials produced by the different farmers. If the option of making pelleted diets at home is not chosen a commercial diet can used without problem in the conditions described for small units.

Conclusions

In small or medium units, rabbit feeding must be the object of a great attention by the breeder as it is the case for larger units. Because rabbit is an herbivorous but also a monogastric animal it is able to valorize raw forages and concentrates. But like for pigs and poultry and in opposite with ruminants, a great attention must be given to the quality of the proteins distributed to rabbits, *i.e.* to the composition in amino acids of these proteins.
To provide daily the fiber necessary for the rabbit's digestive health, green forage or dried forages can be used. But it is clear that dried forages provide a greater flexibility in the everyday feeding than green ones. In small or medium units, rabbit feeding must be the object of a great attention by the breeder as it is the case for larger units. For medium-sized units, making feed pellets with locally available raw materials, can be an economical solution, because only few cheap machines are really necessary.

Cited references

Anonymous, 2013. Population urbaine en 2008 et 2010 in Statistiques mondiales . website http://www.statistiques-mondiales.com consultation 31 July 2013

De Blas C., Mateos G.G., 2010. Chapter 12 - Feed formulation De Blas C. and Wisemann J., Nutrition of the rabbit , 2nd edition, CAB International,Wallingford, UK. 222-233.

Gidenne T., Lebas F., 2006. Feeding behavior in rabbits. *In* Bels V., Feeding in domestic vertebtates, CAB International, Wallingford, UK. 179-194.

Gidenne T., Lebas F., Fortun-Lamothe L., 2010. 13. Feeding behaviour of rabbits. *In* de Blas C., Wiseman J., Nutrition of the rabbit, CAB International Ed., Wallingford, UK. 233-252.

Gidenne, T., García, J., Lebas, F., Licois, D., 2010. Chapter 10. Nutrition and Feeding Strategy: Interactions with Pathology. *In* de Blas C., Wiseman J., Nutrition of the rabbit 2nd ed., CAB International Ed, Wallingford, UK. 179-199.

Lebas F., 2004. Reflections on rabbit nutrition with a special emphasis on feed ingredients utilization. *Proc 8th World Rabbit Congress, Puebla Mexico*, 686-736 available in the WRSA website http://world-rabbit-science.com/WRSA-Proceedings/Congress-2004-Puebla/Puebla-2004-a.htm

Lebas F., 2013. Estimation of protein digestibility and digestible energy content of raw materials for the rabbit, with a system of equations [in French] 15e Journées de la Recherche Cunicole, 19-20 Nov. 2013, Le Mans (France), Accepted Communication.

Lebas F., Coudert P., Rochambeau H. de, Thébault R.G., 1997**.** The Rabbit - Husbandry, Health and Production *FAO publ.*. *Rome*, 223 pp. (book available online in the FAO website http://www.fao.org/docrep/t1690E/t1690e00.htm).

Mirabito, L., Dumont F., Galliot P., Souchet C., 2005. Group housing of breeding does : behavior [in French] , 11e Journées de la recherche cunicole 29-30 nov.2005, Paris, 57-60

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