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The use of local feeds for rabbits

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SUMMARY - The particularities of rabbit production determine that they can be raised on feeds that in other species are related to low productivity. The results of different studies in which crop residues, forages, industrial by-products and protein concentrates are not mixed as a balanced pelleted diet show low growth performances or else a labour cost increment. So, the only realistic way to increase the utilization of local feeds is through their inclusion in commercial pelleted diets. However, this practice has actual disadvantages since the chemical composition of fibrous feeds is, in most cases, highly variable and the data on their nutritive value are scarce and vary according to the evaluation method used in their determination. The substitution method seems to be the most accurate to obtain valuable estimations on the nutritive value of by-products, provided that the substitution levels used are similar to the practical levels of inclusion in commercial diets. Moreover, the fibre of the different by-products can affect digestive parameters related to the diarrhea incidence, such as the retention time. So, the recommended dietary fibre level should vary with the type of fibre predominating in the diet, the use of indigestible fibre being more adequate to express the "ballast" effect of fibre in rabbits than that of the fibre content. From 77 data obtained from different studies, a prediction regression equation to determine the indigestible fibre content of complete diets was calculated. Legume grains can totally replace soybean meal in rabbit diets. However, to improve their utilization in practice it seems to be necessary to determine the energy value and the actual amino acid content in each variety, especially for sulphur amino acids. Also sunflower, cottonseed and rapeseed meals can be used as the only protein source, taking into account that lysine is the main limiting amino acid for the two first meals. Few studies have been made about the effect of antinutritive factors of these protein sources on growth and mortality rates in rabbits. So it should be interesting to go deep into this subject to confirm the slight effect reported on these parameters.

Key Words: Rabbits, unconventional feeds, nutritive value, fibre sources, protein sources, antinutritive factors.

RESUME - "L'utilisation d'aliments locaux pour l'élevage du lapin". Les spécificités de la production cunicole permettent l'utilisation d'aliments qui chez d'autres espèces donneraient lieu à une faible productivité. Les résultats de différents essais où l'on a utilisé des sous-produits de récoltes, des fourrages, des sous-produits industriels et des concentrés de protéines sous forme de granulés, sans qu'il existe une composition équilibrée, montrent des résultats de croissance assez faibles, ou bien une augmentation du coût de la main-d'oeuvre. Par conséquent, la seule façon rationnelle d'augmenter l'utilisation des ressources locales en alimentation animale est de les incorporer dans les granulés du commerce. Cependant, cette pratique présente en fait des inconvénients car la composition chimique des aliments fibreux pour bétail est dans la plupart des cas très variable, et les données concernant leur valeur nutritive sont très réduites et varient selon la méthode d'évaluation utilisée lors de cette détermination. La méthode de remplacement semble être la plus exacte afin d'obtenir des estimations utiles concernant la valeur nutritive des sous-produits, à condition que les niveaux de remplacement utilisés soient semblables aux niveaux pratiques d'incorporation dans les préparés commerciaux. De plus, la fibre contenue dans les différents sous-produits peut affecter les paramètres digestifs liés à l'incidence de la diarrhée, tels que le temps de rétention. Par conséquent le niveau de fibre recommandé pourrait varier selon le type de fibre prédominant dans le régime ; la notion de fibre indigestible étant plus apte à exprimer l'effet de lest de la fibre chez les lapins que la teneur en cet élément. A partir de 77 données obtenues lors de différentes études, a été mise au point une équation de régression visant à prédire la teneur en fibre indigestible de plusieurs régimes complets. Certaines légumineuses peuvent remplacer complètement les graines de soja dans les régimes pour lapins. Cependant, afin d'améliorer leur utilisation dans la pratique, il semble nécessaire de déterminer l'énergie qu'elles apportent et la teneur en acides aminés pour chaque variété, spécialement pour les acides aminés soufrés. On peut également utiliser les graines de tournesol, de coton et de colza comme uniques sources de protéines, en tenant compte du fait que la lysine est le principal acide aminé limitant pour les deux premiers régimes. Il n'y a que peu d'études sur l'effet des facteurs antinutritionnels de ces sources de protéines sur le taux de croissance et de mortalité chez les lapins. Il serait donc intéressant d'approfondir ce point afin de confirmer le léger effet qui a été trouvé en ce qui concerne ces paramètres.

***Mots-clés:** Lapins, aliments non conventionnels, valeur nutritionnelle, sources de fibre, sources de protéines, facteurs antinutritionnels.*

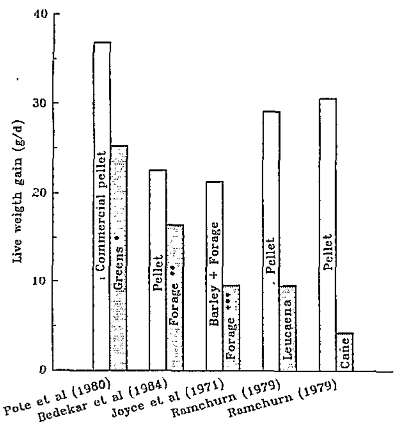
Introduction

The digestive system of rabbits determines that they can be raised on feeds that in other non-ruminant species are related to low productivity. Moreover, because of their high growth rates and prolificacy, rabbits have a lower feed conversion rate than ruminants fed with similar diets. Thus, this species is particularly suitable for achieving a profitable utilization of fibrous resources.

Most of the unconventional local feeds of the Mediterranean area can be classified as: i) crop residues (Table 1), ii) industrial by-products (Table 2), iii) forages and iv) legume grains and oil seed meals. Some of these feeds, as crop residues (except cereal straw) and green forages have a high moisture content (Table 1) and in small farms are usually offered directly to rabbits. This practice implies a high risk of microbial contamination and a waste of feed, and requires high labour. Moreover, live weight gains are lower than those obtained with commercial control diets (Figure 1). The differences in growth performance with respect to control diets were high when only a single ingredient was offered (Ramchurn, 1979) and low when a mixture of greens was supplied because of its more balanced composition (Joyce *et al.*, 1971, Pote *et al.*, 1980, Bedekar *et al.*, 1984).

Table 1. By-products of different vegetables (Boucqué and Fiems, 1988)

Crops	By-product	Estimated yield (t ha^{-1})	DM-content (%)
Beans	stalks + leaves	5,0	17
Cabbages	stalks	40,0	15
Carrots	leaves	30,0	15
	washed roots	10,0	11
Cauliflower	stalk + leaves	25,0	10
Cauliflower (winter)	leaves	5,0	12
Gherkins	stalks	30,0	10
Leeks	leaves	4,0	10
Peas	green haulms	9,0	25
Turnip	leaves	30,0	15



* Clover, vegetables, grape leaves and compfrey.
** Ray-grass and clover.
*** Festuca, ray-grass and clover.

Fig. 1. Live weight gains of rabbits fed with greens as only feed compared to those obtained with a control diet.

Table 2. By-products of agro-industrial origin (from Boucqué and Fiems, 1988)

Product (100 kg)	By-product (kg)	% Dry matter
Citrus fruits	10-12 kg DM citrus pulp	16,4
Sugar beets	5 kg DM beet pulp	11,0
Apples	4,2 kg DM apple marc	14,4
Tomato	3 kg skin	13,0
	1,5 kg seeds	11,0
Almond grains	170 kg hulls	90,0
Sunflower	8 kg hulls	90,0
Cottonseed	44 kg hulls	89,5
Safflower	45 kg hulls	91,3
Olives	33-40 kg olive pulp	87,5
Wheat	14 kg bran	90,0
	12,6 kg middlings	90,0
	0,3 kg shorts	90,0
	1,1 kg red dog	90,0
	60-100 kg straw	90,0

One possible way of promoting the use of local feeds while maintaining acceptable rabbit performance could be to supply a pelleted diet together with dry forages or greens.

When dry forages (chopped hay or wheat straw) are added to an *ad libitum* pelleted diet, there are some increments in live weight gains, but the decrease in the conventional pellet intake is low (0-8%, Table 3). Higher decreases in concentrate intake are obtained when dry forage is offered together with a low fibrous pelleted diet (Reyne and Salcedo-Miliani, 1981) or with rolled cereals (Sánchez *et al.*, 1981).

When greens are given *ad libitum,* pellet intake can be reduced by 40 to 55% (Table 4) without differences in live weight gains with respect to the control diet. Taking into account the wide variation of greens composition, a minimal amount of pellets (50 g/d) should be offered. Feeding management has a great influence on greens intake: Cabrero and Tarafa (1984) when offering fresh alfalfa on the top of the cage observed a small reduction of pellet intake (5.5 to 12%, depending on the fibre level of the pelleted feed); they also observed that fresh alfalfa intake increased significantly with age.

From these results it can be deduced that pelleted diets supplemented with dry forages or greens should have a low fibre level and in many cases a high protein content, i.e. orchard residues, high in fibre and low in protein content should be supplemented with a pelleted poultry diet.

There is some information on the comparative palatability of various greens: sunflower leaves, green bean wines, red clover forage, carrot tops and cauliflower leaves were highly palatable: 90-100% of these materials were consumed when 100 g were offered for a 4-h period; corn leaves and grape leaves showed an intermediate and low palatability, respectively (Harris *et al.*, 1983 a).

Another practice system that also permits to reduce the feeding costs is the utilization of unpelleted diets such as mixtures of mixing cereals, legume grains, dry forages and by-products in the farm, to supply the nutrients required to attain high performances. Wastage of unpelleted feed is high in dusty diets and at early ages and low when meal is molassed (5-6% of molasses) or mixed with water (60% meal: 40% water).

Table 3. Effect of dry forage supply on feed intake and live weight gain

Intake					
Dry forage	Complement	Decrease in pellet intake as % of ad libitum intake	Relationship complement/forage	Live weight gain (g/d)**	Reference
Alfalfa hay	Barley rolled	—	69/31	27,5	(1)
	Oat rolled	—	59/41	32,1	(1)
	Corn rolled	—	61/39	27,9	(1)
	Pellet (27,5 % ADF)	6,8	—	36,0 (-1%)	(2)
Grass hay	Pellet (27,5 % ADF)	6,8	—	40,9 (+24 %)	(2)
	Wheat bran unground	—	—	27,2 (+14 %)	(3)
	Wheat bran finely ground	—	—	21,0 (+10 %)	(3)
Wheat straw (untreated)	Pellet (11,7 % CF)	8,0	93/7	31,0 (-3)	(4)
	Pellet (4,1 % CF)	0,0	84/16	26,6 (+18 %)	(4)
	Pellet* (8,3 % ADF)	—	95/5	29,9	(5)
Wheat straw NaOH	Pellet* (8,3 % ADF)	—	95,5/4,5	27,1	(5)
Wheat straw NH_4OH	Pellet* (8,3 % ADF)	—	94/6	28,7	(5)

* Pellet was offered at 115 g/d
** Variations with respect to live weight gain of control without forage added are in parenthesis.
(1) Sánchez et al. (1981).
(2) Harris et al. (1984).
(3) Robinson et al. (1986).
(4) Reyne and Salcedo-Miliani (1981).
(5) Payne et al. (1984).

Table 4. Decrease in pellet intake when greens are supplemented ad libitum, that permits maintaining live weight gains similar to that of control diet (without added greens).

Greens added	Decrease in pellet intake as % of ad libitum intake	Live weight gain (g/d)	Reference
Cabbage residue	41 %	31.9 (+5.2%)	Shqueir et al. (1985)
Swedes		35.6 (-1.9%)	Partridge et al. (1985)
Carrots		38.5 (+6.0%)	"
Yellow turnips	53-55 %	33.4 (-7.9 %)	"
Fodder beet		36.4 (0%)	
Greens*	47 %	37.2 (+1.2%)	Pote et al. (1980)
Leucaena	40 %	27.1 (-6.8 %)	Ramchurn (1979)
Sugar cane	40 %	27.7 (-9.4 %)	"

* The largest portion of the greens consisted of lettuce, cabbage and red clover.
** Numbers in parenthesis are non significant variations with respect to live weight gain of control without forage added.

However, rabbits show preference for pelleted diets. Pelleting increases feed energy value, feed intake and live weight gain and improves feed conversion rate. Diet composition also affects the differences between pelleted and unpelleted diets; unpelleting highly fibrous diets results in a large decrease in live weight gain (32%, when a diet with a 54% of alfalfa hay was offered, Harris *et al.,* 1983 b) and can promote weight loss (diets with a 60% of wheat straw, Machin *et al.*, 1980). Moreover, the supply of unpelleted diets requires frequent cleaning and low cage densities to prevent high mortality rates.

On the other hand, pelleting increases the cost of the feed and presents a disadvantage for achieving an effective use of local resources "in situ".

In conclusion, if the objective is to increase significantly the utilization of unconventional feeds, the only realistic way is through their inclusion in commercial pelleted diets.

To make an efficient use of these feeds it is necessary to know some aspects about their nutritive value in rabbits based on the following criteria:

(1) Reliable data on the nutritive value
(2) Prevention of digestive and/or metabolic disorders
(3) Effect on voluntary intake
(4) Variability of chemical composition between batches or suppliers
(5) Negative effect on pellet quality
(6) Fat oxidation risk

Alternative fibre sources

The fact that rabbits have a dietary requirement for fibre permits the inclusion in the diet of a wider range of by-products than in other non-ruminant animals. Alfalfa hay is the most common source of fibre used in rabbit diets in which it can be included at high levels with no deleterious effects. However, the replacement of alfalfa hay by other fibre sources can decrease the feeding costs. Data about the energy content of the majority of by-products, although necessary for diet formulation, are scarce and vary according to the evaluation method used for their determination. In the following section data on nutritive value and maximum inclusion levels of the main by-products obtained in the Mediterranean area are discussed. The ability of each by-product to meet fibre requirements will be considered later.

BY-PRODUCTS WITH A HIGH FIBRE CONTENT

Wheat straw, sunflower and oat hulls, grape marc, olive pulp, bean straw and tomato and apple residues are included in this group. All these by-products are high in fibre and lignin and low in protein (Table 5). Because of this, their contribution to the digestible energy content of rabbit diets is limited. Therefore, they should be mainly considered as cheap indigestible fibre sources. Moreover, their chemical composition (except wheat straw) is highly variable according to the process used in each region.

Wheat straw is a usual ingredient in rabbit diets: in Spain it is included at different proportions in 33% of commercial diets (Roca *et al.*, 1987). It provides a high proportion of crude fibre (Table 5) of low digestibility (ADFD = 15%, de Blas *et al.*, 1989), thus, its digestible energy content is also low (**665 Kcal DE/Kg DM,** de Blas *et al.*, 1989).

Treatment with sodium hydroxide to improve the nutritive value of straw is effective for rabbits (to a greater extent than if using NH4OH, Partridge *et al.*, 1984, Payne *et al.*, 1984). Villamide (1989) has obtained an energy value of **NaOH treated straw of 1030 Kcal DE/Kg.** Although no other energy values have been reported in the literature, some estimates can be obtained from several works: 500-800 Kcal/Kg DM for untreated wheat straw (Partridge *et al.*, 1984) and higher values (700-1300 Kcal DE/Kg DM) for treated straws (Spreadbury and Davidson, 1978, Partridge *et al.*, 1984, Masoero *et al.*, 1984, Gippert et al., 1988).

NaOH treated straw, which is normally commercialized ground and pelleted, has a higher cost than untreated straw, but its transport cost is lower and its management easier. The increase of Na concentration in the diet (up to 5%) has no deleterious effect on rabbit performance and moreover, it improves pellet quality. However, since an energy value improvement resides in the increase of fibre digestibility, treated straw has a lower value as indigestible fibre source.

In general, when a 20-30% of straw inclusion was balanced with an increase in protein concentrates to substitute alfalfa hay, no significant differences were found in growth parameters (de Blas *et al.*, 1979, Lindeman et al., 1982, Mercier et al., 1980, Masoero *et al.*, 1984, Partridge *et al.*, 1984). Furthermore, as shown in Table 6, Carabaño *et al.* (1989) have observed a high digestibility of crude protein and high cecal ammonia concentration in fibrous diets with a high content in

Table 5. Chemical composition of some fibrous by-products of the Mediterranean area (1) (% on dry matter basis)

	Ash	Crude protein	Crude fibre	ADF	NDF	ADL	Ether extract	Reference
Alfalfa hay	11.6	16.0	28.6	–	–	–	3.1	(5)
Wheat straw	9.8	3.0	42.5	46.1	51.7	23.5	0.7	(6)
Oat hulls	4.5	2.1	33.1	–	–	–	0.6	(5)
Sunflower hulls	12.0	4.9	55.8	64.7	–	31.6	2.4	(7)
Grape marc	3.8	11.8	51.0	–	–	–	0.4	(5)
Grape seed meal	6.6	25.9	22.4	38.0	46.5	28.2	1.2	(8)
Olive pulp (2)	11.2	12.2	36.6	58.9	71.9	28.7	3.9	(9)
Olive pulp (3)	3.7	12.8	29.0	–	–	–	23.9	(10)
Bean straw	8.3	9.5	33.9	36.4	–	6.8	0.6	(7)
Tomato skin	4.2	19.0	58.2	–	69.2	8.9	7.9	(11)
Tomato skin and seeds	3.9	25.0	37.2	–	51.0	6.7	21.6	(11)
Apple marc	6.7	9.3	22.1	30.7	–	12.7	5.9	(7)
Wheat bran	5.2	17.8	10.1	12.6	41.0	4.2	4.4	(12)
Orange pulp	6.1	6.4	12.4	23.7	21.5	1.2	0.4	(13)
Lemon pulp	13.4	5.8	12.6	–	–	–	1.1	(14)
Beet pulp	3.7	7.4	21.6	26.9	55.8	1.5	1.1	(13)
Carob bean coarse grained (4)	4.5	4.9	8.5	–	–	–	0.5	(15)

(1) Values have been selected from studies on rabbits in which the nutritive value or the effect on some criteria were studied, except for carob bean.
(2) Defatted
(3) Partially grained.
(4) Carob bean contains 43.4 % of sugars
(5) Maertens and de Groote, 1984 a.
(6) de Blas et al., 1989
(7) Gippert et al., 1988
(8) Cavani et al., 1988
(9) Tortuero et al., 1989
(10) Leto and Giaccone, 1981
(11) Battaglini and Costantini, 1978
(12) Villamide et al., 1989
(13) de Blas and Villamide, 1990
(14) Leto et al., 1984.
(15) Fredella et al., 1983

protein concentrates and straw. A high cecal ammonia concentration has been related to an increase in the risk of diarrhea mortality by some authors (Morisse *et al.*, 1985) but no significant differences were observed in that work for this parameter. On the other hand, technological aspects of feed manufacture normally limit the **inclusion level of straw at 10-15%.**

Energy value of **oat hulls**, which have a lignin content ranging from 2 to 10% (Welch *et al.*, 1983) was estimated using the substitution method by Maertens and de Groote 1984 b) as 683 kcal DE/kg DM (CFD = 11.7%). From data of Spreadbury and Davidson (1978) a higher value can be obtained **(1089 kcal DE/kg DM),** similar to that found by Gippert *et al.* (1988) for **sunflower hulls (1075 kcal DE/kg DMO),** a highly lignified by-product (Table 5). On the other hand Gippert *et al.* (1982) did not observe a decrease in the performance with diets in which sunflower hulls were included at 10-15%. However, these feedstuffs impaired pellet quality and final aspect of feed. For these reasons the recommended **maximum levels of inclusion are 3-5%.**

There is a lack of information on the nutritive value for rabbits of **olive oil industry by-products.** Martínez and Fernández (1980 a) obtained a digestible energy content of **1000 kcal DE/kg DM** for a diet containing 90% of molassed (8%) **partially defatted olive pulp** and 10% of sunflower meal.

Table 6. Effect of fibre source on fattening performance, digestibility and ammonia concentration of cecal contents (Carabaño et al., 1989)

	Diet A	Diet S	
Diet ingredients*			
Barley grain	24.5	24.5	
Soya-bean meal	7.5	7.5	
Sunflower meal	–	15.0	
Alfalfa hay	50.0	–	
Wheat bran	15.0	7.0	
Barley straw	–	43.0	
Diet composition (% DM)			
Crude protein	15.7	14.1	
Crude fibre	16.9	17.2	
Fattening performances			
Live weight gain (g/d)	35.15	38.00	NS
Feed conversion rate (g/d)	3.96	3.55	NS
Diarrhea mortality (%)	9.5	14.30	NS
Digestibility			
Crude protein digestibility (%)	55.23	71.08	$P < .01$
Crude fibre digestibility (%)	18.90	8.85	$P < .05$
Ammonia concentration			
(mg $N\text{-}NH_3$/100 ml)	9.38	14.98	$P < .001$

* Mineral and vitamin supplements and pellet binder are 3 % in both diets.

Recently, Tortuero *et al.* (1989) have observed that substitution of alfalfa hay by olive defatted pulp at 30% in isonitrogenous diets increased feed conversion rate. At 20% they observed an increase in kidney weight. Taking into account that olive pulp has a negative influence on final colour of feed and on fat composition of rabbit meat when olive pulp is not defatted (Leto and Giaccone, 1981), the lack of reliable nutritive values, and the variability of by-products of the olive oil industry, a **maximum inclusion level of 5-8% is recommended.**

Grape marc contains a variable proportion of grape skins and stalks, grape seeds being usually separated for oil extraction. An increase in the proportion of stalks tends to increase the content of lignified fibre. The energy value of grape marc supplied as a single ingredient has been determined by Martínez and Fernández (1980 a) and using the substitution method by Maertens and de Groote (1984 b). In the former study a low digestible energy content was observed **(400 kcal DE/kg DM)** caused by the low digestibilities of organic matter (15%), crude fibre (12%) and crude protein (13%), which can be attributed to their high fibre (22%), and lignin (34%) contents and to a high feed intake. The DE value obtained by Maertens and de Groote (1984 b) when grape marc was included in a balanced diet was higher **(738 kcal DE/kg DM)** in spite of the higher CF and the lower ether extract contents of the grape marc used in this study (Table 5).

Studies in which the effect of different inclusion levels of grape marc substituting alfalfa hay was studied (Parigi-Bini and Chiericato, 1980; Pérez de Ayala, 1989) show that the high tanin content of grape marc *decreases protein digestibility of the others feedstuffs* that are included in grape marc diets, by binding to the protein of the rest of the diet. This high tanin content seems to be also responsible for the low value of cecal ammonia concentration (2.60 mg of NH_3-N/100 ml) observed by Fraga *et al.* (1990) in a diet with a 25% of grape marc, indicating an effect on the proteolytic capacity of microorganisms as occurs in ruminants. This level of ammonia would be insufficient to allow a proper microbial growth in the rumen and probably in the cecum.

The diets in which grape marc was used in relatively high levels to substitute alfalfa hay (Parigi-Bini and Chiericato, 1980, Pérez de Ayala, 1989) had a crude protein content higher than practical requirements suggested by Lebas (1984). Probably because of this, no differences in live weight gain and feed conversion rate were observed up to 32% of grape marc inclusion in diet. On the other hand, the lower content of lysine and methionine of grape marc protein when comparing to alfalfa hay protein should be taken into account when a high level of substitution is used. In diets with a lower protein content (comparing to practical recommendations) and taking into account the high variability and the risk of rancidity when this by-product is not defatted, **the level of inclusion of grape marc should be limited to 10-15%.**

Grape seed meal, another by-product of grape industry, has a higher protein content than grape marc and alfalfa hay (Table 5). Cavani *et al.* (1988) have studied, in fattening diets with 17% protein content, the effect of 10 and 20% inclusion levels substituting a mixture of alfalfa hay and soybean meal. They have not observed differences in growth rate but the feed conversion rate was higher when the by-product was included at 20% level, suggesting that **the maximum level inclusion should be near 10%.**

The use of the **integral grape seed meal** (12.6% ether extract on DM, Alicata *et al.,* 1988) substituting a **15%** of alfalfa hay promotes a slight improvement of the live weight gain and of the feed conversion rate without a significant increase in the fat content of the rabbit carcass. However, they obtained an impairment in rabbits performance when 20% of alfalfa was substituted by this by-product. An energy value of **2217 kcal/kg DM** has been proposed by INRA (1984) for integral grape seed meal.

The inclusion of **tomato skin** at levels of 4, 8 and 12%, substituting a mixture of oats and alfalfa hay has not negative influence on diet digestibility coefficients of cell walls but decreases the CPD, probably due to its high (27.7% DM) lignin content (Falcao e Cunha and Lebas, 1986). Battaglini and Costantini (1978) have observed that the energy value of tomato skin (with a lower lignin content, see Table 5) is 45% that of the **tomato skin and seeds,** probably due to its lower and higher contents in ether extract and fibre, respectively (see Table 5). They also substituted **10% of oats by 10% of tomato skin and seeds** with slightly, but no significant positive effects on live weight gain and feed conversion rate.

Schurg *et al.* (1980) obtained a decrease in live weight gains when **apple marc** was included at levels higher than 10%. In spite of its relatively high lignin content (12.7%, Table 5), Gippert *et al.* (1988) have obtained an energy value of apple marc of 2600 kcal/kg DM, which is much higher than the value proposed by INRA in 1984 (**1822 kcal/kg DM**).

Italian researchers have studied the chemical composition and the nutritive value of some dry residues of other vegetable industrial processes (mainly of freezing industry). They observed that these residues have a high ash (from 12.6 to 34.7% DM) and crude protein contents (from 18.3 to 35% DM) and a very variable content of lignin (from 3.3 to 13.1% DM). When **8% of sweet pepper** residue was used to substitute alfalfa hay (Grandi and De Angelis, 1983 a) no differences were found in rabbits performance. However, the inclusion of **eggplant** residues (Grandi and De Angelis, 1983 b) should be restricted at 3.5% . The residue of **vegetable marrow** was used to substitute 10% of alfalfa hay and wheat bran mixture without differences in rabbit performances (Grandi, 1981).

The interest of substituting alfalfa hay by other dry forages grown in the Mediterranean area (Table 7) has been studied mainly by Italian researchers too. They did not obtain differences in rabbits performance when **red clover** (*Trifolium pratense* L.), birdsfoot trefoil (*Lotus corniculatus* L.) and ray grass (*Lollium perenne* L., var. *lenta* and var. *vejo*) hays substituted 30, 32, and 14% of alfalfa hay, respectively (Grandi and Battaglini, 1988 a, b; Grandi, 1983). On the other hand, the substitution of 35% of alfalfa hay with **sulla hay** (*Hedysarum coronarium* L.) slightly increased rabbits performance (Cucchiara, 1989).

Table 7. Chemical composition and digestible energy content of several dry forages* (% on dry matter basis)

	Ash	Crude protein	Crude fibre	Ether extract	Gross energy	Digestible energy	Source
Clover red	9.8	14.6	30.6	3.02	4.270	–	(1)
Birdsfoot trefoil	11.0	15.7	27.1	–	4.380	2.730	(2)
Sulla	–	14.5	20.6	–	–	–	(3)
Ray-grass							
var. lenta	–	12.2	26.3	2.25	4.340	2.030	(4)
var. vejo	–	10.5	25.7	1.6	4.250	1.810	(4)

* Values have been selected from works on rabbits in which the nutritive value or the effect on some parameters were studied.
(1) Grandi and Battaglini, 1988 a.
(2) Grandi and Battaglini, 1988 b.
(3) Cucchiara, 1989.
(4) Grandi, 1983.

Table 8. Effect of fibre source on mean retention time and several digestive parameters (Fraga et al. 1990)

	Diet*					
	25 % AH	51,5 % CiP	29 % BP	25 % GM	11 % RH	
Diet composition (% DM)						
Crude protein	21.6	22.2	21.4	19.2	19.4	
Crude fibre	9.4	9.6	11.0	10.0	10.8	
ADL	2.2	1.0	2.3	9.1	4.4	
Mean retention time (h)	16.5[a]	17.9[a]	17.8[a]	9.3[b]	21.3[a]	P < .001
Digestive parameters						
Stomach content wt, % of BW	2.4	3.2	3.8	2.9	3.3	NS
Cecum content wt, % of BW	5.5[bc]	9.1[a]	7.4[ab]	4.4[c]	6.5[bc]	P < .001
Cecal crude fibre (% DM)	14.4[c]	16.5[b]	17.1[b]	11.6[d]	23.1[a]	P < .001
NH_3, mg NH_3-N/100 ml	6.3[b]	10.4[a]	11.2[a]	2.6[c]	8.2[ab]	P < .001

* In the five diets, 60 % of dietary CF was supplied by each of the following supplementary fibre sources: alfalfa hay (AH), citrus pulp (Cip), beet pulp (BP), grape marc (GM) and rice hulls (RH).

BY-PRODUCTS WITH MEDIUM FIBRE CONTENT

Wheat bran is a feedstuff widely used in rabbit diets. Thus, in Spain it is used in 79% of the commercial diets (Roca *et al.,* 1987). As other wheat milling by-products, wheat bran is quite palatable and has a low density; this last characteristic impairs pellet quality and because of this a **maximum level of inclusion** in practical diets of **25-30%** is recommended. Data obtained about its digestible energy content are quite different, ranging from **3132 kcal dE/kg DM** (Fekete and Gippert, 1986), similar to cereal grains, to **2680 and 2727 kcal DE/kg DM**, obtained by Gippert *et al.* (1988) and Villamide *et al.* (1989), respectively. Digestibility of crude protein is high (around 76%), but lysine and triptophan contents are low.

Citrus pulp is a plentiful by-product in the Mediterranean area. It is obtained wet (16% DM, Table 2) but is normally dried until a DM content of 88% is reached. To facilitate this process $(OH)_2Ca$ is usually added to the wet pulp. The high pectin (30% on DM) and low lignin (Table 5) contents of citrus pulp determine the high digestibility of its carbohydrate fraction.

Citrus pulp is a quite palatable feedstuff but its inclusion at high levels in rabbit diets promotes a decrease in feed intake. This decrease is related to the effect of citrus pulp on the rate of passage and on weight contents of stomach and cecum that, sometimes, can be the causes of high fibre digestibility of citrus pulp diets. Thus, Martinez and Fernandez (1980 b) estimated a digestible energy content of **3.800 kcal/kg DM** when citrus pulp was offered as a single ingredient; however, data obtained by the substitution method by De Blas and Villamide (1990) were lower and dependent of fibre level of the basal diet (**3130 and 2700 kcal DE/kg DM**, the last value being obtained when citrus pulp was included in a high fibrous diet with a similar composition to the commercial ones).

The results obtained when different levels of citrus pulp were used in fattening trials (Martinez and Fernandez, 1980 b; Leto *et al.,* 1984; Pérez de Ayala, 1989) indicate that **the maximum level** of orange and lemon pulps (both have similar chemical compositions and nutritive values, see Table 5) that should be recommended in practical diets is 10-15%.

Beet pulp has similar characteristics to citrus pulp although its palatability is lower and its fibre content higher (Table 5). The intake of beet pulp diets is also low as a consequence of its effect on the weight of the contents of stomach and cecum. Thus, the nutritive value of beet pulp when it was determined as a single ingredient (3400 kcal DE/kg DM, Martínez and Fernández, 1980 a), was higher than when it was determined using the substitution method by De Blas and Villamide (1990) (**2957 and 2382 kcal DE/kg DM,** this last value corresponding to a diet with a similar composition to the commercial ones).

Data obtained in our laboratory (G. García, unpublished) from diets in which barley was substituted by beet pulp indicated that the energy value of beet pulp is 72% of that of barley and near **2250 kcal/kg DM**. The energy value of beet pulp estimated when alfalfa hay was substituted by beet pulp in isofibrous diets (15% CF, W. Motta, unpublished) was higher: the inclusion of moderate amounts of beet pulp seems to have a synergistic effect on alfalfa fibre digestibility in the same way as occurs in ruminants (Silva *et al.,* 1989).

From the results obtained in works in which fattening diets with different levels of beet pulp inclusion were studied (Frank and Seroux, 1980; Harris and Johnston, 1980; Evans *et al.*, 1983) **a maximum level of inclusion** of beet pulp of **15-20%** is recommended.

Carob bean is obtained from seedpods of the carob tree. Because of its high sugar content, it is very palatable and its inclusion in practical diets increases the palatability of feed (Cheeke, 1987). Thus, in Spain, it is included in 14% of practical diets (Roca *et al.*, 1987). The nutritive value of carob bean has not been studied, but **levels of 7-10%** have been utilised without negative effects in commercial diets (González and Rial, 1988). However, some batches are exposed to fermentative processes because of their high index of microbial contamination.

In summary, we can conclude that the administration of a feedstuff as a single ingredient is not recommended to evaluate the nutritive value of fibrous by-products because of the high influence of the fibre source on the retention time in the different segments of gut and thus on digestibility coefficients. The substitution method seem to be more accurate to obtain valuable estimations for practical conditions. For the design of the experimental diets, the following criteria should be taken into account (Villamide, 1989):

a) The levels of substitution should not be very high (lower than 25-30%) in order to avoid differences in levels of intake, transit times, etc, and should include the practical levels of inclusion in commercial diets (estimated as the level in which other raw material of similar chemical characteristics is included).

b) The basal diet should be as similar as possible to a practical diet. Its CP content should not be lower than 15-18% to avoid a deficit of CP in the diet with the highest inclusion level. The level of CF should be moderated (12-14%) according to chemical composition of the by-product and the previously defined levels of substitution.

VALUE OF BY-PRODUCTS TO MEET FIBRE REQUIREMENTS

Little is known about how the fibre of the different by-products can affect the retention time and other parameters related to the diarrhea incidence. Gidenne et al. (1986) using ytterbium as a marker of the solid-phase of the digesta compared three fibrous diets in which 45% of alfalfa hay was substituted by beet pulp or wheat bran. They found that the mean retention time of beet pulp and wheat bran diets were 1.8 and 3.6 h longer than that of the alfalfa diet although these diferences were not significant. The higher value obtained with the wheat bran diet is surprising, taking into account that higher retention times are normally associated to higher fibre digestibility. However, neither Villamide *et al.* (1989) nor Gippert *et al.* (1988) have obtained high values of fibre digestibility for wheat bran (15.1% ADFD and 18.4% CFD, respectively). The values of ADF digestibility of wheat bran obtained by Robinson *et al.* (1986) were also low and did not depend on particle size (8.1 and 7.9% for unground and finely ground bran, respectively) another factor that can influence fibre digestibility in the cecum.

Mean retention times of citrus and beet pulps diets were 0.7 and 1.4 h longer than that of an alfalfa diet in the study of Fraga *et al.* (1990). However, the effect of source of fibre was more important when the weights of some segments of gut and their contents were considered (see Table 8), agreeing with the results of Candau *et al.* (1979) and Auvergne *et al.* (1987). In studies of gastro-intestinal motility, the increment of the weight of stomach and cecal contents has been related in studies of gastro-intestinal motility (Fioramonti *et al.*, 1978; Pairet *et al.*, 1986) to a greater difficulty of evacuation attributable to the physical properties of pulp fibre, that could be responsible for an antral hipermotility. These facts can determine the high DE content of citrus and beet pulps obtained when these feedstuffs were supplied as single ingredients (Martínez y Fernández, 1980 a, b) or included in low-fibre basal diets (De Blas and Villamide, 1990).

The values of cecal turnover as soft feces were 50, 32 and 32% in diets with alfalfa hay, citrus pulp and beet pulp, respectively (Fraga *et al.*, 1990). These low values were similar to those obtained by Carabaño *et al.* (1988) in diets with 5% of CF level and could imply a higher risk of diarrhea than that of alfalfa diets.

The influence of substituting alfalfa hay by more lignified sources of fibre (grape marc and rice hulls) was also studied by Fraga *et al.* (1990) (see Table 8). There were no differences in the weight of the digestive contents, but the mean retention time and the cecal level of crude fibre were significantly lower in the diet with grape marc. Therefore, grape marc fibrous particles seem to have a high rate of passage through the gut, and their addition to the diet could contribute to prevent digestive disorders more effectively than the traditional sources of fibre. This effect can also explain the low nutritive value obtained when grape marc was supplied as a single ingredient (Martínez and Fernández, 1980 a). In this way, the high level of daily intake of olive pulp diet (Martínez and Fernández, 1980 a) suggests that the fibre of olive pulp could have a similar digestion pattern than that of grape marc. Although Tortuero *et al.* (1989) did not determine directly the rate of passage with olive pulp diets, they observed variations in some criteria that suggest a low retention time in such diets. However, the utilization of rice hulls (with a lignin content of 19.2% DM) as fibre source tended to increase the weights of stomach and cecum contents and increased the mean retention time with respect to the values obtained with the alfalfa diet.

All these results implied that the level of fibre recommended should vary with the type of fibre predominating in the diet. To avoid this inconvenience, some authors (Lebas, 1984; De Blas *et al.,* 1986) have also expressed the minimal fibre requirements as indigestible crude fibre (ICF) content. However, practical utilization of this unit presents difficulties derived from the lack of reliable data on fibre digestibility of different feedstuffs, the high variability of its determination (Maertens and De Groote, 1984 b; Fekete and Gippert, 1986; Villamide, 1989) and the wide range of fibre sources included in rabbit diets.

On the other hand, some authors (Van Soest, 1985; Cheeke, 1987) have observed that other factors than chemical ones (such as particle size, bulk density or water holding capacity) can affect fibre digestibility. In this manner, the large water holding capacity of pulps contribute towards the high retention time and digestibility of fibre obtained with pulp diets. On the other hand, the physical characteristics of lignified feedstuffs have hardly been studied.

For these reasons, Pérez de Ayala (unpublished data) tried to predict the dietary ICF level of a complete diet using a stepwise regression analysis in which the independent variables were the dietary content of CF, ADF, NDF, ADL, percentage of ADL in NDF and three variables A, B and C to indicate the level of inclusion (%) in diets of: citrus and beet pulps (A), of alfalfa hay (B), and of straw, tomato skin, grape marc, rape hulls and rice hulls (C), obtaining the following equation:

$$ICF(\%) = -0.036 + 0.82 \times CF(\%) - 0.071 \times A,$$

$$n=77,\ R^2=0.86,\ P<0.001$$

This equation shows that, when pulps were not included in the diet, a dietary level of 14% CF corresponds to 11.3% ICF according to the recommendations of Lebas (1984) and De Blas *et al.* (1986). However, to obtain 11.3% of ICF in a diet in which 30% of pulp is included, the dietary CF level should be increased up to 16.5%. There were no sufficient differences in CF digestibilities of diets with alfalfa hay and those of more lignified fibre sources so that the analysis introduces variables B or C.

In summary, the use of indigestible fibre instead of crude fibre seems to be more adequate to express the ballast effect of fibre in rabbits. Nevertheless, other factors have a supplementary effect. In this way, grape marc or rice hulls show differences with respect to alfalfa hay which cannot be explained only by their different indigestible fibre contents. On the other hand, the low lignified fibre and high pectin contents of beet and citrus pulps do not show any ballast effect; on the contrary they should be probably restricted to avoid an excessive entry rate of fermentable material in the cecum. All in all, we can conclude that no index is completely satisfactory and that more work should be done on the digestible characteristics of fibrous by-products, including possible interactions in the cecal digestion among different types of fibre and between fat and fibre.

Alternative protein sources

In the last twenty years there has been an increasing interest in Europe to find alternative feeds for substituting imported soybean meal. Many seeds of temperate crops with a high protein content like legume grains have been studied for their inclusion in non-ruminant diets as the main source of protein and amino acids. In addition, the meals resulting from oil extraction from seeds of industrial crops grown in the Mediterranean area like sunflower, cotton, rape, flax and hemp, have been studied for the same purpose. Because of their chemical composition differences, the possibilities of including legume grains and oilseeds in rabbit diets will be studied separately.

LEGUME GRAINS

Chemical composition

Chemical composition of the main legume grains is summarized in Table 9. Legume grains are characterized by high protein and starch levels and relatively low crude fibre and fat levels. Protein (40%), fibre (16%) and fat (10%) contents of lupine are the highest, meanwhile its starch content is very low (0.5%).

Crude fibre content in legume grains depends mainly on the proportion of testa in the seed, which in faba bean varies from 13% to 17%. This implies a CF content in the whole seed ranging from 6 to 11%. Seroux (1984) working with five French lines reported a CF variation from 7 to 10%, the lowest values (8% as average) corresponding to spring cultivars and the highest to the autumn ones (10% as average). The lower proportion of testa in other legume grains like peas (8.7%) soybean (9.2%) or chickpeas could explain their lower CF contents (Table 9).

Starch is the main carbohydrate of faba bean (30-45%) and peas (32% for wrinkled peas and 48% for smooth peas), and allows cereals to be replaced by these legume grains in the diet.

Table 9. Chemical composition (% DM) of legume grains and soybean meal with respect to rabbit requirements *

	Faba bean (Vicia faba)	Peas (Pisum sativum	Lupin (Lupinus sp)	Chickpeas (Cicer arietium)	Soyabean meal 44 % CP	Rabbits requirement
Crude protein	27.0	26.2	40.1	27.2	48.3	18.0
Starch	40.9	49.5	–	–	–	–
Crude fibre	8.3	6.3	16.0	3.3	8.4	15.7
Ether extract	1.14	1.45	9.9	5.0	2.0	–
Lysine (g/100g CP)	5.12	7.19	4.57	6.27	6.35	4.06
Methionine+cystine	2.08	2.48	2.17	3.12	2.99	3.75
Tryptophan	0.83	0.90	0.78	0.80	1.34	0.81
Threonine	2.18	3.95	3.61	2.89	3.93	3.44

* Mean value from Seroux (1984), INRA (1984), Lebas (1988) and Cole et al. (1989).

Crude protein content in faba bean is on average, similar to that of peas or chickpeas but lower than that of lupine or soybean. However, this value ranges widely (from 23 to 34%, Newton and Hill, 1983) depending mainly on cultivar: the spring cultivars have higher protein content (31.4%) than autumn ones (26.5%). However it is necessary to take into account that similar differences can be obtained when the same variety is grown in different years (Seroux, 1984).

The **amino acids** profile of the legume grains protein (Table 9) is characterized by a low content of sulphur amino acids (from 60 to 80% of rabbit requirements, INRA, 1984). Threonine content is also relatively low in faba bean and chickpeas. Thryptophan content is only low for some varieties of these legume grains. Although lysine content can be lower than that of soya bean, it is always greater than rabbit requirements. There is a large range of variation in the amino acid contents of legume grains mainly due to differences among varieties. However, part of this variation could be explained by differences in the analytical method used, especially for sulphur amino acids and thryptophan. So, Cole *et al.* (1989), using the same analytical method, reported relatively closer ranges of variation for 9 different faba bean varieties (4.3-5.5 g/100 g CP for lysine, 1.9-2.4 g/100 g CP for sulphur amino acids and 1.8-2.1 g/100 g CP for threonine). In addition, it should be noted that an increase in protein content of a variety is not directly related to a parallel increment for each amino acid. Thus, several authors have reported a negative relationship between protein and lysine content in faba bean (Bond, 1970; Cole *et al.,* 1989). Lebas (1988) has also observed that a high protein (26%) variety of chickpeas had lower content of lysine, sulphur amino acids, threonine and thryptophan than other variety with a medium (22%) protein content.

Antinutritive factors

The content of several antinutritive factors (ANFs) in legume grains is the main reason to restrict their use in non-ruminant diets. Generally these ANFs are not very toxic in rabbits, but could reduce growth rates.

Tannins are phenolic compounds which may be produced from cross-links with protein and other large molecules inhibiting many enzymatic systems and reducing protein availability. Tannins are mainly located in the testa of faba bean and their concentration depends on the variety, being related to seed and flower colour (Griffiths and Jones, 1977). White flowered varieties have lower tannin content than coloured ones (see Table 10). Dehulling the seed may reduce also tannin concentration, but it should be noted that this method of processing reduces also the concentration of sulphur amino acids and lysine, which are in higher concentrations in the testa than in the cotyledon (Marquardt *et al.,* 1975). Seroux (1984) studied the effect of tannin content on rabbit growth rates with diets in which soybean meal was replaced by two faba bean varieties, one of them tannin free (Blanche) and the other with 5 g/kg DM of tannins (Ascott). Both varieties induced similar live weight gain and feed conversion rate compared to the control diet.

Certain legume grains and cereals contain some substances (proteins and carbohydrates) which have **trypsin inhibitor** activity. These inhibitors decrease the protein and amino acids availability for growth. Moreover, trypsin inhibitors may produce a pancreatic hypertrophy that could increase sulphur amino acids requirements for the synthesis of pancreatic enzymes accentuating the deficiency in sulphur amino acids of legume grains. In Table 11 is summarized the antitrypsic factor content of legume grains and cereals according to different authors. Sánchez *et al.* (1984) could not observe pancreatic hypertrophy in rabbits fed with raw soybean, mainly due to the diffuse nature of the gland in this species. Microscopic evaluation of pancreatic tissues neither revealed discernible abnormalities. However, raw soya bean diet reduced live weight gains about 30% compared to the soybean control diet. Residual trypsin inhibitor values lower than 25.6 TIU/mg in diets with extruded soya bean did not affect growth or feed conversion rates.

Table 10. Distribution of tannin (% DM) in seed of coloured and white flowers of faba beans (Griffiths and Jones, 1977)

	Testa	Cotyledon	Whole grain
White flower	0.32-0.5	0.74-0.88	0.75-0.81
Coloured flower	5.34-7.42	0.78-0.91	1.34-2.00

Table 11. Trypsin inhibitor activity (units/mg) of legume grains and cereals*

	Trypsin inhibitor activity
Legumes	
faba bean	0.5-6.2
chickpeas	1.68-11.9
soya bean	21.1-74.5
field bean	10.9-25.9
peas	
spring cultivars	2.3-4.9
winter cultivars	7.9-15.9
lupine	0.16-0.29
Cereals	
barley	1.60
wheat	0.14
corn	0.80

* Values from: Newton and Hill (1983), Leterme et al. (1989), Saini (1989) and Savage (1989).

The structure and chemical properties of **lectins** differ among legume species. Their main effect is the damage of the intestinal mucose that can result in an increment of diarrhea incidence. Lectin activity is measured "in vitro" by the level of agglutination of blood erythrocytes. The susceptibility to lectins varies for different animal species. Thus, erythrocytes from sheep, cows, and chickens do not agglutinate in presence of extracts from faba or soybean, but both legumes cause agglutination of erythrocytes from pigs and rabbits, being lectins of soybean more toxic than those of faba bean (Marquardt *et al.*, 1975).

Lectins of field beans (Phaseolus vulgaris) seem also to have negative effects on growth rates in rabbits. Sánchez *et al.* (1983) reported a high decrease of live weight gain (38.6 vs 10 g/d) when soybean meal was totally replaced by raw Pinto beans. Also diarrhea was very prevalent in rabbits fed raw Pinto beans. Autoclaving raw beans improved growth rate up to 20 g/d and reduced diarrhea incidence, but feed intake remained low (72.8 vs 122.9 g/d for the control diet) and similar to diet with raw beans.

Alkaloids are ANFs especially present in some varieties of lupine. These compounds are responsible for the bitter taste and determined an accused depression in the growth rate of rabbits. Johnston and Uzcategui (1988) obtained a lower growth rate (16 vs 26.3 g/d) in rabbits fed with diets where soybean meal was totally replaced by raw "chochos" *(Lupinus mutabilis)*. Toasting the "chochos" did not improve growth rate, but when "chochos" were debittered with water bath and cooking the performances were similar to those of control diet. Also Seroux (1984), using two varieties of "sweet" lupines (with a low alkaloid content), did not find differences in growth or feed conversion rates in relation to diets with soybean meal.

Energy value

Energy value of legume grains has been hardly studied in rabbits. INRA (1984) proposes a similar energy value (about 2800 kcal DE/kg) for faba bean, peas and lupines. However, taking into account the results obtained in growth assays and the little effect of ANFs, it could be considered that the energy value of these legumes should be higher and closer to the values proposed for pigs. Thus, Lebas (1988) estimated an energy value for **chickpeas of 3100-3200 kcal DE/kg.** This is an intermediate value between wheat and soybean meal, considering that, in the experimental diets, chickpeas are equivalent to a mixture of 55-60% cereals and 40-45% soybean meal without changes either in growth rates or energy digestibility. Colin and Lebas (1976), Seroux (1984), and Berchiché *et al.* (1988) also reported that peas and faba bean are equivalent to a mixture of cereals and soya bean meal (65-70%/30-35% and 50%/50%, respectively) in growth assays. However, specific studies should be done to confirm this item.

Practical utilization of legume grains

Since the 70s, French researchers have been studying the possibility of legume grains inclusion in rabbit diets. Seroux (1984) studied different levels of inclusion for several French varieties of lupines, peas and faba beans. There was no influence of level of inclusion on growth, feed conversion or mortality rates when soybean meal was totally replaced by 21% of lupines or 30% of peas or faba beans.

Higher inclusion levels of peas or faba bean may reduce growth rates. Frank *et al.* (1979) studied inclusion levels for peas of 15, 30 and 45% in fattening rabbits diets. Up to 30% of inclusion, growth rate remained similar. At 45%, growth rate slightly decreased. No toxic effects were observed, so that it is possible that amino acid deficiency could have occurred. Berchiche and Lebas (1984) found that methionine supplementation was necessary to reach high performances when faba bean supplied 60% of total protein, in a semipurified diet. Though, the same authors (Berchiche *et al.*, 1988) in a later assay, did not find significant differences in growth performances when protein of soybean meal was totally replaced by faba bean protein (37% of inclusion) in a practical diet. Also in pigs, several authors (Henry *et al.*, 1976; Henry and Bourdon, 1977; Davidson, 1977; Palisse *et al.*, 1984) have reported that it is necessary to supply methionine, threonine, or thryptophan to maintain growth performances when the level of inclusion in the diet of faba bean or peas is to be raised up to 30 or 35%.

Other legume grains like chickpeas or field bean, which are mainly used for human consumption, have been studied to include them in rabbits diets. Lebas (1988) reported that the inclusion of chickpeas up to 20% replacing partially soybean meal had no negative effects on growth rates. However, it should be noted that in some varieties of chickpeas, threonine could be a limiting amino acid.

Sánchez *et al.* (1983) studied the effects of inclusion at 40% of raw and autoclaved Pinto bean in rabbit diets substituting partially soybean meal and cereals. Both growth rate and feed intake were depressed either with raw or autoclaved beans. Johnston *et al.* (1989) also observed a low palatability when raw or toasted Andean field beans (Canario and Bayo beans) were offered on a free choice basis. However, other heat treatments should be tested to increase their palatability and possibilities of inclusion in rabbit diets, because of their relatively high protein and amino acid content (23% of CP and 1.43% of lysine).

OILSEED MEALS

Sunflower is the second most important oil crop in the world, being grown extensively in the Mediterranean area.

Sunflower meal is characterized by high protein (from 32 to 39%) and crude fibre (from 16 to 28%) contents which vary inversely (see Table 12). The proportion of oil that remains in the meal is generally low (near 1%) and varies depending on the extraction process.

On the other hand, the amino acid profile of sunflower meal is balanced except for lysine, which has a lower level than rabbit requirements (Table 13). On the other hand, the relatively high content of sulphur amino acids, threonine, and tryptophan can make sunflower meal an adequate complement to legume grains, Berchiche *et al.* (1988) observed that partial replacement (38%) of faba bean by sunflower meal improved growth and feed conversion rates (43.8 vs 40.7 g/d and 3.45 vs 3.59 g/d, respectively).

Table 12. Chemical composition and nutritive value of oil seed meals by several authors (% DM)

	CP	CF	EE	Digestible energy kcal/kg DM	Digestibility (%) CP	Digestibility (%) CF	Reference
Sunflower meal	35.6	17.8	2.2	3100	81.8	29.3	(1)
	33.4	27.6	1.1	2397	75.5	4.6	(2)
	38.6	20.0	1.8	2749	84.0	0	(3)
	39.0	16.5	0.6	3438	89.9	28.8*	(4)
	32.3	25.1	1.2	2462	72.9	17.3*	(4)
Rapeseed meal							
Var. Jet Neuf	36.8	12.6	1.5	3148	76.3	8.7	(2)
Var. Erglu	42.8	13.2	1.7	2992	77.3	11.2	(2)
	37.9	13.9	3.2	2786	69.0	11.3	(3)
Cottonseed meal							
Prepress solvent extracted	36.7	19.6	2.8	–	–	–	(5)
Expeller extracted	27.2	23.2	8.9	–	–	–	(5)
Flaxseed meal	37.4	10.0	1.7	2952	72	4	(3)
Hempseed meal	28.6	31.5	12.4	2033	76.6	9.8	(6)

* Digestibility of ADF (%)
(1) Martínez and Fernandez (1980 a)
(2) Maertens and De Groote (1984 b)
(3) Fekete and Gippert (1986)
(4) Villamide et al. (1990)
(5) Mc Nitt et al. (1982)
(6) Lebas et al. (1988)

Table 13. Composition of amino acid of oilseed meal protein with respect to rabbit requirements (g/100 g CP)

	Sunflower meal	Rapeseed meal	Cotton seed meal	Rabbits requirements
Lysine	3.63	5.92	4.20	4.06
Methionine + cystine	3.64	4.18	3.02	3.75
Tryptophan	1.36	1.19	1.19	0.81
Threonine	3.85	4.42	3.39	3.44

* Mean value from NRC (1984), INRA (1984) and NRC (1988)

There are no specific studies about the maximum level of inclusion for sunflower in rabbit diets, but its low energy value could be the main cause to limit it. The digestible energy value of sunflower meal is highly variable (from **2400 to 3400 kcal DE/kg DM**) and depends mainly on its crude fibre content. Villamide *et* *al.* (1990) found an accurate relationship between energy value of sunflower meal and its crude fibre content:

DE (kcal/kg DM) = 4679 - 86 (% CF on DM) ; R^2=0.884

Although only five data were included in the equation, this type of relationship could be adapted to predict energy value of sunflower meal as occurs in other non-ruminant species. So, Pérez *et al.* (1986) reported in pigs a similar equation:

DE (kcal/kg DM) = 4690 - 79 (% CF on DM) ; R^2=0.918

In the same way, crude protein digestibility seems to be negatively related to crude fibre content varying from 73 to 89% (see Table 12). However, these values are higher than others from feedstuffs with similar fibre content, like alfalfa (64% of CPD, Maertens and de Groote, 1984 b) possibly due to the fact that protein (mainly in the cotyledon) is not chemically bound to the fibre (mainly in the hull). This fact together with the high level of indigestible fibre content of sunflower meal can permit a reduction of alfalfa inclusion in the diet with improvements in the nutritive value of the diet and growth performances (Carabaño *et al.*, 1990).

Rape is grown extensively in Canada, Europe and Asia for both industrial and edible oil. The meal resulting from oil extraction of rapeseed is characterized by a low ether extract content, a high protein content and a medium crude fibre content (see Table 12). The rapeseed meal protein is balanced in essential amino acids with respect to rabbit requirements (see Table 13). Because of this, rapeseed meal has been used to replace soya bean meal in rabbit diets with similar growth performances (Colin and Lebas, 1976; Throckmorton *et al.*, 1980). However, it should be noted that its protein digestibility is lower than that of soya bean meal, varying from 69 to 77 (Table 12). The CF content and the presence of tannins in the hull (2-3%) of rapeseed meal can be the reason of these low values. Also, energy value (**2786-3148 kcal DE/kg of DM**) could be relatively low by this effect.

The level of inclusion for rapeseed meal in non-ruminant diets is limited by the presence of glucosinolates in the cotyledon. Glucosinolates are glycosides with sulphur-containing aglycogens, which are goitrogenic, causing inhibition of the thyroid gland.

There are no specific studies about glucosinolates effects on growing rabbits. Lebas and Colin (1977), comparing normal or dehulled rapeseed meal, did not find differences in growth rate. Also, Maertens and de Groote (1984 b) did not find differences in the nutritive value of two rapeseed meal varieties with different contents of glucosinolates. Furthermore, the double zero grain varietes are low in glucosinolates so that meal from these varieties could be nontoxic for rabbits (Cheeke, 1987).

Colin and Lebas (1976) and Throckmorton *et al.* (1980) studied the effect of increasing inclusion levels of rapeseed meal replacing soybean meal. Levels of inclusion higher than 12-14% resulted in a slight decrease of growth rate compared to control diet. However, up to 18% the differences were not significative.

Cottonseed meal is the second most important source of protein in USA, but the availability of this product is low in the Mediterranean area except for Egypt.

Chemical composition depends on the type of processing used for oil extraction and the efficiency of dehulling process. Thus, protein content is higher (up to 40%) when oil is prepressed and solvent extracted than when it is mechanically extracted (27%). Inversely, crude fibre and oil contents are lower in the former meals than in the latter ones (see Table 12). The amino acid profile is unbalanced in lysine, methionine, and threonine (see Table 13). Cheeke and Amberg (1972) found that the addition of lysine and methionine to a diet with cottonseed meal increased growth rate.

The potential toxicity problems from gossypol seem to be the main cause of limiting cottonseed meal in rabbit diets. However, levels of 0.04% of free gossypol should be acceptable (Mc Nitt, 1981). Hence, Mc Nitt *et al.* (1982) observed that total replacement of soya bean meal by cottonseed meal (0.04% free gossypol) permitted high growth performances, similar to the control diet.

Some experimental works have been published about the utilization of other oil seed meal like flaxseed meal or hempseed meal as protein sources in rabbit diets. Fekete and Gippert (1986) studied the nutritive value of **flaxseed meal** using the subtitution method. They found that the energy value (2952 kcal DE/kg DM) and the crude protein digestibility (72%) were lower than for soybean meal, but similar to other oilseed meals like rapeseed meal. Cheeke (1987) also reported that a possible deficiency in lysine should be accounted for when flaxseed meal was used as the only protein concentrate source.

Lebas *et al.* (1988) studied the replacement of sunflower meal by **hempseed meal** (0, 10, 20 and 30% of inclusion). There were no differences in growth rate (36 g/d, as average) but feed conversion rate was significantly higher in diets with 20 or 30% of hempseed meal (3.46 vs 3.27). The hempseed meal energy value estimated from these results was 2033 kcal/kg DM, similar to that of an alfalfa hay of good quality.

In summary, we can conclude that faba beans, peas, chickpeas and "sweet" varieties of lupine can totally replace soybean meal in rabbit diets. However, to improve legume grains utilization, it seems to be necessary to determine their energy value and the actual amino acid content in each variety, especially for sulphur amino acids, threonine, and tryptophan.

Also, sunflower, cottonseed, and rapeseed meal can be used as the only concentrate protein source, taking into account that lysine is the main limiting amino acid for the first two meals. On the other hand, the relatively high content in sulphur amino acids, threonine, and tryptophan makes these oil seed meals an adequate complement of legume grains to meet amino acid requirements in the diet. On the other hand, CF content of oil seed meals seems to be a good index to predict their nutritive value. However, more studies are necessary to obtain an accurate relationship between these variables.

Few studies have been done about the effect of ANFs on growth and mortality rates in rabbits. Thus, it is interesting to gain insight about this subject to confirm the slight effect reported on these parameters.

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