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# Fibrous feeds in the Mediterranean area: Characterization and utilization

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**SUMMARY -** A brief description and a classification of the most important fibrous feeds of the Mediterranean area are presented. The major limiting factors to their utilization as animal feeds are then discussed: the main constraint is the poor nutritive value because of the very low digestibility as a consequence of the quality of the structural carbohydrate fractions. After the introduction of the methodological approach adopted to evaluate the nutritive potential of the studied feeds, the amounts produced and the possible beneficial effect on the socio-economic aspect of animal farming from the improvement of the nutritive value are finally discussed.

**Key words:** Fibrous feeds, Mediterranean basin, ruminant nutrition.

***RESUME -*** *"Aliments fibreux dans la région méditerranéenne : Caractérisation et utilisation". Une brève description et une classification des plus importants aliments fibreux dans la zone méditerranéenne sont présentées. Les principaux facteurs limitant l'utilisation sont discutés successivement : la limite la plus grande est représentée par la valeur nutritive modeste à cause de la faible digestibilité qui est une conséquence de la qualité des glucides de la paroi cellulaire. Après l'introduction sur l'approche méthodologique adoptée pour évaluer le potentiel nutritif des aliments étudiés, les quantités produites sont présentées et les probables effets positifs sur l'élevage animal, par conséquence de l'amélioration de la valeur nutritive, sont finalement discutés.*

***Mots-clés :*** *Aliments fibreux, bassin méditerranéen, alimentation des ruminants.*

## Characterization of poor feeds and by-products

All those feeds that are characterized by poor nutritive value and are the residues of crops and/or are the products of their industrial processing, are defined as "poor feeds" and "poor by-products". Poor feeds and by-products have in common some peculiar composition traits: a high content of crude fibre, a low level of crude protein, quite a poor digestibility due to the strong ligno-cellulosic bonds between lignin and both cellulose and hemicelluloses within the cell wall.

The association of this kind of feeds to other feeds in complete diets is quite a common technique, either because of the huge amount of available quantities even at the farm level or because of the compatibility of their chemical composition with the physiology of digestion of ruminant animals.

Furthermore, it must be stressed that the regular use of such crop residues in animal feeding results in disposing them, so contributing to reduce environmental pollution problems. In particular this is true for cereal crop residues (straws, stalks, brans). If these feeds are largely and properly utilized in complete balanced diets for ruminants, production costs can be reduced and sometimes the quality of animal products can be also improved. The scarcer the production of forages, the higher the importance of this additional availability. In fact, the use of agricultural by-products attains it largest diffusion in hill and mountain farming, where the rotational crop production is not a common practice.

On the other hand, the use of poor fibrous feeds and by-products is compulsory in those countries where the availability of feedstuffs is reduced and may represent a limiting factor to the animal production business. That is the real situation of most countries of the Mediterranean area, such as Algeria, Morocco, Tunisia and the most marginal areas of Spain, Portugal, Italy, Greece and Turkey. In all these areas the amount of available feedstuffs, particularly forages, is limited because of the effect of seasonal and climatic variability upon crop productivity. The water shortage, which is typical of certain zones together with the hot climate, and the prolonged exposure to the sun beams are severe constraints to cultures, generally speaking. In such situations the possibility of taking advantage of the use of poor feeds and by-products is indeed a fundamental resource to animal feeding.

If this is the situation, it is advisable to try to upgrade all these feeds. One way to do that is by means of chemical and physical treatments which can improve the feeds' degradability and digestibility and, as a consequence, their efficiency to be converted into animal products by the ruminants. Namely, the chemical treatments with alkali hydrolyse the chemical bonds between lignin and hemicelluloses and cellulose, allowing cellulolytic bacteria to attack the structural carbohydrates of cell walls, in order to utilize the energy of cellulose and hemicelluloses for their own survival purposes. The freed energy, otherwise unavailable, is then stored as ATP, which is finally converted into microbial proteins from amino acids and non-protein nitrogen (NPN). But the treatments may represent additional costs and, sometimes, contribute to environmental pollution problems. And both things cannot be bearable in the most difficult areas where the economical conditions are not easy.

A second attempt not to be neglected to face the problem of upgrading the poor feedstuffs is given by the possibility of associating the fibrous roughage and poor by-products with energy and/or nitrogen supplements, to say nothing of minerals and vitamins, in complete balanced diets meant to maximize the performances of large and small ruminants.

The roughage and by-products most commonly diffused and used can be subdivided into 6 categories, with reference to the type of culture that they belong to and to the chemical composition. By doing so, all the feeds that were studied by the single research units within the programme of the EU CAMAR project No. 8001-CT91-0307 are comprised within the scheme of Table 1.

Table 1. Classification scheme of fibrous feeds and by-products

| Culture | Part of the plant | Crude protein (%) | Crude fibre (%) | Characteristics† |
|---|---|---|---|---|
| Cereals | Straw, stalk, stem, ears, chaffs, hulls | 3-5 | 40-50 | Poor palatability, low ME†† content |
| Roots and tubers | Leaves, stems, skins, pulp | 9-15 | 10-25 | Medium palatability, medium ME content |
| Legumes | All the aerial part except seeds | 10-15 | 30-35 | Medium palatability, low ME content |
| Oil plants | All the aerial part, pods, hulls, skins | 2-10 | 30-35 | Poor palatability, low ME content |
| Vegetables | Leaves, stems, skins | 5-15 | 10-30 | Good palatability, medium ME content |
| Fruits | Leaves, stems, skins, pulp | 4-8 | 10-30 | Good palatability, medium ME content |

†With reference to ruminant nutrition
††ME: metabolizable energy

## Limiting factors to animal utilization

The poor fibrous feeds that we are now considering are generally characterized by a low or very low nutritive value, due to the low crude protein content and to the reduced overall digestibility. For this reason they cannot be expected to meet the nutritive requirements of farm animals, especially of growing and producing ones.

In those areas that are characterized by intensive forage cultures, poor feeds are often utilized either as "ballast" material or as the fibrous ingredients of the diet. On the contrary, under conditions of reduced rotational forage cultures, poor fibrous feed may represent the only feeds available.

Even if the ruminant animal takes advantage of the activity of the microbes living in symbiosis within its rumen to digest and metabolically utilize the energy content of the structural carbohydrates of cell walls of fibrous feeds, nevertheless the strong presence of lignin encrusting the hemicellulose layer is an important physical obstacle to microbial degradation. Furthermore, with fibrous feeds, the

size of particles coming out of the chewing activity of the ruminant animal, or resulting from chopping or milling, is an important limiting factor to the digestive utilization of cell walls: if the particles are too large, too a long time is needed to perform the degradation and the fore-stomachs are emptied before the degradation is completed; if too small, the transit rate is too fast and there is not enough time for the microbes to operate their cellulolysis. But, on the other side, if the particles are too large, in case they are retained a long time within the rumen, this may be good for the microbial activity, but is a severe limiting factor to voluntary intake. In any case, it must be said that the chemical composition of fibrous feeds is the most important limiting factor to their use. Fibrous feeds, as the only ingredient of a diet, cannot meet the requirements of producing animals. It is a very important aspect because most of the fibrous feeds that we are dealing with, not always are finely chopped or ground but fed as coarse roughage.

Hence, there is the necessity of utilizing such feeds as rationally as possible. If the hypothesis of chemical treatments is discarded because of the cost or of pollution problems, then the fibrous feeds must be associated within a diet with the proper other ingredients, in order to obtain correctly "balanced" complete diets capable of meeting the animals' requirements.

The physical properties and the chemical composition of poor fibrous feeds are therefore the major factors affecting the capacity of utilization of their nutrients by the animals for productive purposes.

As far as the physical properties are concerned, they can be modified by operating on the physical structure by means of physical treatments such as chopping and grinding. These two treatments result in improving the digestibility of the fibrous matter by providing particles of small size: the surface exposed to microbial attacks is enhanced. Besides, the dry matter intake may be increased as well, provided the particle size is not too coarse, so delaying their permanence within the rumen.

## Feeding value: Nutritive value and intake

Fibrous feeds and by-products cannot constitute the only feeding source. They must be associated with other ingredients in complete diets, capable of compensating for their missing nutrients and energy, as already said. The nutritive properties of poor feeds can therefore be exploited by associating them with feeds characterized by a better digestibility and a higher nitrogen content. In fact, if they are matched with the proper feeds which succeed in balancing the complete diet in terms of energy: nitrogen ratio, they may become of remarkable importance as animal feeds, because they contribute to enhance the nutritive balance of the ration. As a matter of fact, an adequate nitrogen concentration in the diet, borne by the major feeds, and associated with a degradable fraction of structural carbohydrates, borne by the fibrous poor feeds, causes the rumen microbes to increase their activity and to improve the digestion of fibre with the consequence of optimizing the efficiency of feed utilization (feed conversion rate). It is evident that the optimum level of association with good forages and/or with concentrates and the level of animal performances depend upon the nutritive value of the ingredients of the diet and on the category of animal production. Now then, it is necessary to take advantage of a balanced diet in terms of metabolic requirements of the animal. Even if the use of poor feeds is recommended for economical and nutritional reasons, such a diet must represent a compromise between the physical-chemical characteristics of the feed ingredients and the animals' requirements.

It is therefore possible to advantageously utilize the fibrous poor feeds in complete rations, because it is possible, to "manipulate" the efficiency of utilization of the diet itself by directly intervening on the diet composition, i.e. on the choice of ingredients and on how ingredients match with each other, for the final purpose of attaining the most convenient animals' performances. In fact, when the goal of the feeding strategy is the production (meat, milk, etc.), then the manipulation of the diet is aimed to the highest synthesis of microbial proteins, which is dependent on and linked to the amount of available energy, that is to the amount of ATP produced during the ruminal fermentation. Hence, the most important characteristic of a diet based on fibrous feeds is its available energy, on one side, and the amount of synthesizable microbial protein, on the other side, as a measure of its overall nutritive value.

Strictly speaking, in the practical rations for ruminant animals, fibrous feeds can be utilized without limitations or prejudices. Furthermore, their availability allows the farmers to breed animals even in the most difficult areas.

One more problem is represented by the poor palatability and, hence, the low dry matter intake of fibrous feeds, in general. When associated with other ingredients in complete diets, fibrous feeds are ingested at higher extents, due to the associative effect, which increases the digestibility. Before being employed, it is necessary to know very well both the physical and the chemical traits of a difficult feed. In fact, intake depends on the nutritive value, i.e. on the degradability and digestibility, on the presence of antinutrients and on possible unbalances or deficiencies in terms of amino acids, minerals and vitamins, that may negatively interfere with the animal's metabolism. This aspect must always be borne in mind, especially when the fibrous feeds have been treated with chemicals. The treatment results in upgrading the feed, but may exert a negative effect on the animals' performances if the residues of chemicals are above the tolerance level. In this sense, some treatments are to be preferred to others: ammonia or urea treatments on straws or stalks are preferable to alkali treatments because an excess of ammonia nitrogen can be utilized by the rumen microflora, provided that a sufficient amount of energy is available, but an excess of sodium may be detrimental to the health of microbes and animals.

## Methodological approach

The UE project CAMAR No. 8001-CT91-0307 "Exploitation of Mediterranean roughage and by-products", involved five research units: (i) in Italy, Dipartimento di Scienze Zootecniche (DISCIZO), Florence; (ii) in Spain, Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA), Madrid, and Servicio de Investigación Agroalimentaria (SIA) of the Regional Government of Aragón, Zaragoza; and (iii) in Portugal, Instituto Superior de Agronomia (ISA), Lisbon, and Estação Zootécnica Nacional (EZN), Fonte Boa. The project was aimed to study the utilization of some fibrous feedstuffs and some by-products available in the Mediterranean basin, to be used in diets for ruminants, in order to produce a kind of protocol for the most appropriate use.

The methods which were adopted in the five laboratories for the purpose of estimating the nutritive value of the studied feeds were: (i) chemical methods; (ii) *in vitro* methods; (iii) *in situ* methods; (iv) *in vivo* methods; and (v) comparative slaughter technique.

### Chemical methods

Samples of all the feeds and complete diets studied within the project were submitted to the chemical analysis for the nutrients (crude protein, ether extract, crude fibre, ash) and for the gross energy content (heat of combustion) according to the AOAC methods (1990). The fibre fractions after Goering and van Soest (neutral detergent fibre, NDF, acid detergent fibre, ADF, acid detergent lignin, ADL) were determined as well (Goering and van Soest, 1970).

### *In vitro* methods

Two different *in vitro* techniques have been used: (i) the classical Tilley and Terry method (Tilley and Terry, 1963), modified by Alexander and Mc Gowan (1966), by the research units of INIA-Madrid and ISA-Lisbon; and (ii) the "rumen simulation technique" (Czerkawski and Breckenridge, 1977), by the research unit of EZN-Fonte Boa. This latter method is to be considered the most reliable of the two. In fact, it is a continuous system that simulates the real rumen conditions much better than the former one. Furthermore, it is possible to measure the gas production and to withdraw samples to be analysed for volatile fatty acids (VFA), $NH_3$ and whatever else, from time to time.

### *In situ* methods

A couple of research units (INIA-Madrid and ISA-Lisbon) utilized the *in situ* nylon bag technique of Ørskov and McDonald (1979) as a means to study the degradation kinetics of the studied feeds and to estimate the maximum degradation rate.

### *In vivo* methods

By the research units of INIA-Madrid and SIA-Zaragoza the classical *in vivo* digestibility trials with adult wethers were carried out as a first step to the estimation of the nutritive value of feeds.

### The comparative slaughter technique

The nutritive values of the complete diets, based on wheat straw and studied at the research unit of DISCIZO-Florence, were measured by means of the comparative slaughter technique, as proposed by Thomson and Cammell (1979a,b, 1980) with growing lambs. By slaughtering the lambs at the end of a growth experimental period and by comparing their body content of energy and nitrogen with the same contents of reference lambs slaughtered at the beginning of the experimental period, it is possible to measure the amounts of energy and nitrogen retained. During the growth period the digestibilities of energy and nitrogen were also measured. It was then possible to estimate the fractions of digestible energy and retained energy and the fractions of digestible nitrogen and metabolizable protein.

## Amounts produced in the world and in the Mediterranean area

It has been difficult to get information about the amounts of fibrous feeds and by-products other than those related to cereal crops. But, it must be stressed that the fibrous feeds and by-products of cereal origin are those most widely diffused and utilized. This is the reason why hereinafter the estimates of the amounts of cereal by-products only, as reported by FAO (pers. comm.), are given in Table 2.

Table 2. Cereal by-products (straws) availability in the decade 1983-1992† (source: FAO, pers. comm.)

| | DM (kt) | CP (kt) | ME (MJ x $10^9$) | TDN (kt) |
|---|---|---|---|---|
| World | 4,423,920 | 268,779 | 33,540 | 2,263,950 |
| Africa | 343,564 | 21,147 | 2,710 | 182,925 |
| North & Central America | 1,193,356 | 71,876 | 9,375 | 632,813 |
| South America | 380,253 | 23,283 | 2,959 | 199,732 |
| Asia | 1,628,882 | 98,116 | 11,990 | 809,325 |
| Europe | 504,276 | 32,120 | 3,830 | 258,525 |
| Oceania | 53,199 | 2,497 | 380 | 25,650 |
| Former USSR | 320,390 | 19,740 | 2,296 | 154,980 |
| Developed countries | 1,515,161 | 92,541 | 11,777 | 794,948 |
| Developing countries | 1,679,830 | 99,583 | 12,637 | 852,998 |
| Planified countries | 1,228,929 | 76,655 | 9,126 | 616,004 |

†DM: dry matter; CP: crude protein; ME: metabolizable energy; TDN: total digestible nutrient

With reference to the preceding decade (1970-1981), the dry matter production of cereal straws was increased 36% at world scale, 56% in developed countries, 34% in developing countries and 19% in planified countries. The first producing continent is Asia with 44% of the total dry matter of cereal straws, followed by North and Central America with 27%, Europe with 11.4%, Africa with 7.8%, South America with 8.6% and Oceania with 1.2% (see cake graph in Fig. 1).

Quite interesting is the trend of the individual cereal grains and, therefore, of the relative straws, in the same decade (1970-1981), as shown by the graph of Fig. 2, where it can be seen that the most relevant increases were those of maize, wheat and rice.

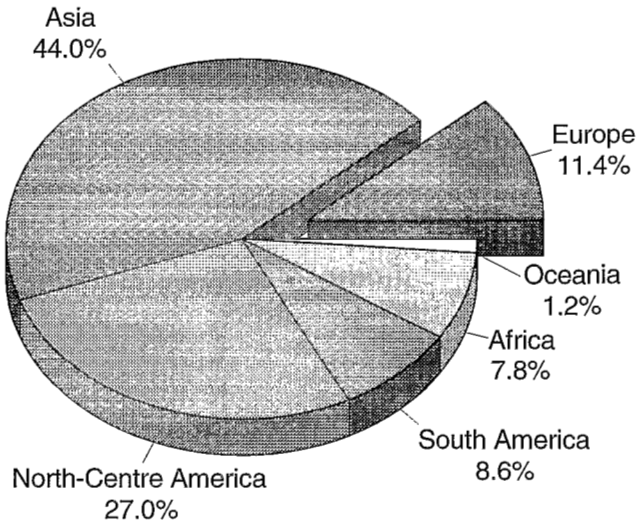


Fig. 1. World production of cereal straws.

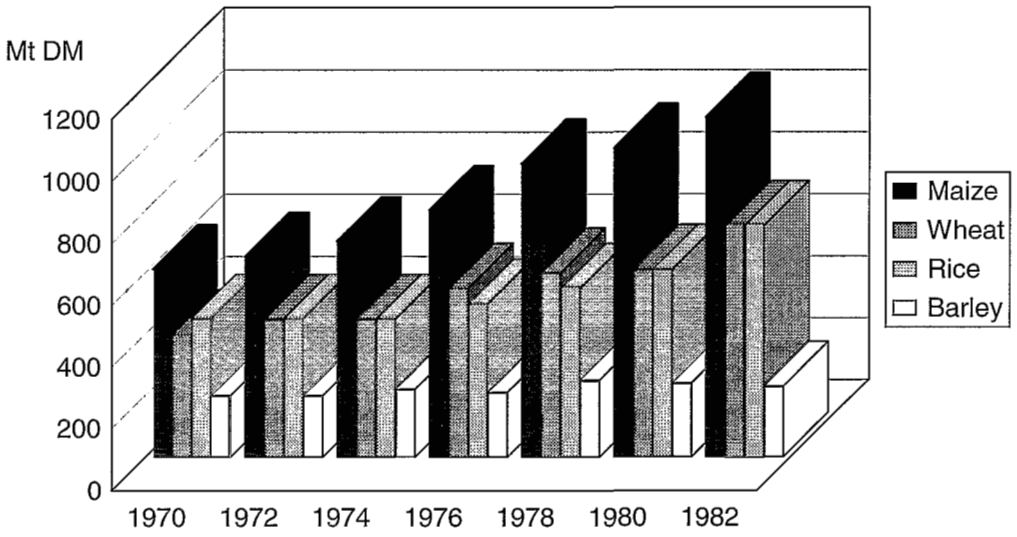


Fig. 2. Trend of the world production of cereal grains in the 70's.

For the cereal straws only, according to FAO data, the production calendar relative to the period 1983-1992, for some Mediterranean countries, is shown in Table 3.

Table 3. Production calendar of cereal straws in the period 1983-1992 (Mt) (source: FAO, pers. comm.)

| | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|---|---|---|---|---|---|
| World | 130,637 | 150,541 | 136,387 | 132,010 | 125,571 | 121,892 | 112,625 | 121,480 | 117,197 | 117,058 |
| France | 200 | 200 | 250 | 300 | 253 | 258 | 266 | 275 | 280 | 285 |
| Italy | 160 | 189 | 176 | 175 | 177 | 160 | 160 | 160 | 160 | 160 |
| Spain | 219 | 245 | 242 | 224 | 220 | 210 | 220 | 183 | 230 | 230 |

At a world scale, there is a clear trend towards a slow down of cereal production, even if it doesn't seem so for France and Spain.

## Socio-economic aspects of the area

The different socio-economic realities of the Mediterranean countries result in a multiplicity of aspects, certainly not free from economical and productive problems that characterize the area. If we consider the various countries of the Mediterranean basin: Portugal, Spain, France, Italy, Greece, Turkey and those of the northern bank of Africa, and the various aspects of their territories, we realize that close to fertile and productive zones are poor and marginal areas, often in the same country. That means that in a few miles distance either intensive production techniques or extensive ones are employed. It is consequent that both the animal breeding techniques and the crop techniques are functional to the type of territory and settle where the manufactory industries permit agricultural and animal farming to survive.

The prevalence of marginal zones in the Mediterranean countries makes even more difficult the survival of animal farming because to the difficulty of the practice of animal breeding, the asperity of the territory and the climate, prevailingly dry and hot, are added. All this contributes to slow down the possibility of increasing or, sometimes of keeping alive animal husbandry. Dry areas (Spain and Turkey), desert areas (Morocco, Tunisia), marginal areas (Portugal, Italy) represent the major cause of the scarce evolution of agriculture in these countries. Hence, the importance of being able to take advantage of local feed resources, in order to permit the maintenance of a production reality. The possibility of using feeds of minor value for the nutrition of farm animals in certain areas may mean a remarkably significant and not negligible aid to the breeder. In some instances, it may be considered as a guarantee to keep alive one production sector that, at the moment, is affected by serious problems of survival. Furthermore, the possibility of utilizing the by-products of the industrial transformation of certain crops and certain zonal cultures, may help to solve another problem: the high production cost of traditional feeds on one side and the disposal of residual by-products. It is clear that in such condition the rational use of poor feeds and by-product in the feeding of animals is the premise to the success of the animal breeding activity.

## Introduction to the following chapters

Aim of the project was the study of the nutritional characteristics of some fibrous feeds available in the Mediterranean countries, namely cereal and legume straws, in order to get correct information on their nutritive value measured when employed in complete balanced diets for the ruminant animals. And from the research work carried out by the 5 research units involved in the project a great deal of interesting results came out. These results allow us to produce useful directions about their correct use in the practice of feeding.

Each research unit studied the same material for the 5 year-span of the project and, as a consequence, hereinafter five specific chapters will follow, each dealing with the results relative to one or to one group of specific feedstuffs. In particular, the following subjects will be dealt with: (i) the use of urea, both as a chemical for the treatment of fibrous feeds and as a nitrogenous supplement; (ii) the nutritional characteristics of maize stover, when treated; (iii) the characterization and utilization of some legume and rice straws; and (iv) the possibility of supplementing wheat straw with protein feeds of different origin.

One chapter will deal with the mathematical model named as "surface analysis technique", which was adopted to check the strength of associative effects between ingredients, when present.

Finally some general indications and recommendations are given.

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