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Towards better utilisation of non-conventional feed sources by sheep and goats in some African and Asian countries

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SUMMARY – Current pattern of utilisation of non-conventional feed resources (NCFRs) in Africa and Asia and techniques for their efficient use in small ruminant feeding are discussed in this paper. Chronic feed deficits represent a major constraint to animal production in many developing countries. Expanding the feed resource base through utilisation of NCFRs, especially those that do not compete with human food and can grow in marginal lands has become a compelling task. The NCFRs include a variety of feeds from perennial crops, multipurpose trees and shrubs, and feeds of industrial origin or agro-industrial by-products (AIBPs). A wide range of AIBPs are available in Africa and Asia (olive cake, citrus pulp, grape marc, etc.), however, these sources are still not fully and appropriately integrated into livestock feeding. Three main reasons may explain this situation: (i) the unbalanced supply of nutrients, mainly energy and nitrogen; (ii) the presence of undesirable compounds (tannins, saponins, glucosinolates, etc.); and (iii) the difficulties to store for long periods. Several technologies have been developed to overcome this problem. Ensiling technique was tested on some AIBPs such as olive cake and citrus pulp and was found to conserve the feeding value of these feed sources. In practice, however, the adoption of this technique is still limited. Of particular interest is the feed block (FB) technology. FBs are a solidified mixture based on AIBPs that can be used as a balanced supplement for animals fed poor quality roughages. In addition it is a mean for preserving several high moisture AIBPs. Farmers find the blocks easy to make, store, transport and feed. This technology offers attractive cost:benefit ratios of up to 1:5 and is becoming popular in many Asian and African countries. Numerous multipurpose browse trees and shrubs have been identified as having significant potential in agroforestry systems in African and Asian regions. Saltbushes (*Atriplex nummularia* and *A. halimus*) and spineless cactus (*Opuntia ficus indica* f. *inermis*) a drought tolerant shrub species widespread in North Africa may reduce the use of conventional feedstuffs, mainly concentrate feeds. Diets based on these NCFRs or other shrub or tree species have been developed for sheep and goats raised under harsh conditions. *Moringa oleifera*, originally from northwest India is present now in many countries and has many potential uses (animal feed, human consumption, medicinal uses, etc.). Lately, this plant has received considerable attention. As an animal feed source, Moringa foliage and seeds are considerably high in crude protein and the utilisation of Moringa foliage has been found to increase animal productivity. The presence of anti-nutritive factors, particularly tannins, at high levels in some forage trees and other feedstuffs could adversely affect livestock production and health. However, it is possible to increase the nutritive value of tannin-rich browse with compounds such as polyethylene glycol (PEG), which preferentially bind to tannins, making plant proteins more available for digestion. This strategy is highly useful in situations where feedstuffs contain high concentrations of tannins. Administering PEG in FBs was found to be a valuable technique to deactivate tannins in *Acacia cyanophylla* foliage and thus to improve sheep performance. Additionally, though tannins in forage legumes have generally been classified as anti-nutritional, it is possible that tannins could be used advantageously to improve production, especially through reduction in protein degradation of many oil seed cakes/meals in the rumen.

Key words: Crop residues, agro-industrial by-products, fodder trees, fodder shrubs, efficient utilisation, sheep, goat.

***RESUME –** "Optimisation de l'utilisation des ressources alimentaires non conventionnelles dans quelques pays africains et asiatiques". Les perspectives de valorisation des ressources alimentaires non conventionnelles (RANC), en particulier les résidus de récolte, les sous-produits agro-industriels (SPAI) et les arbres/arbustes fourragers dans l'alimentation des ovins et caprins, sont discutées dans cet article. La présence du cheptel ovin et caprin, essentiellement dans les zones arides et semi-arides des continents africain et asiatique marquées par un faible potentiel fourrager incite à la valorisation des ressources alimentaires locales potentiellement utilisables dans l'alimentation des petits ruminants. L'alimentation de ces animaux est basée sur les parcours naturels, généralement dégradés et quelques résidus de récolte, notamment les pailles. D'autres RANC sont faiblement utilisées à cause de : (i) leur faible teneur en énergie et azote utilisable ; (ii) la présence de substances anti-nutritives (tannins, saponins, glucosinolates, etc.) ; et (iii) la difficulté de leur utilisation pendant des périodes plus au moins longues. Quelques techniques ont été développées et ont prouvé leur efficacité. L'efficacité de la technique d'ensilage, utilisée d'habitude pour la conservation des fourrages cultivés, a été prouvée pour la* *conservation de quelques SPAI, en particulier les grignons d'olive. Néanmoins, cette technique demeure faiblement adoptée par les éleveurs. La technologie des blocs alimentaires semble une alternative prometteuse. Il s'agit d'un mélange solidifié à base de SPAI permettant un apport équilibré, synchronisé et échelonné des nutriments aux ruminants recevant des fourrages pauvres. Evidemment, cette technologie à la portée des petits éleveurs, permet d'alléger le coût d'alimentation du cheptel à travers une réduction de l'utilisation des aliments concentrés. D'autres usages possibles des blocs alimentaires sont rapportés dans cet article. Les arbustes représentent une autre source importante de biomasse consommable disponible tout au long de l'année même pendant les périodes de disette. Le potentiel fourrager de quelques espèces pastorales ligneuses a été discuté. Outre leur usage dans d'autres domaines, le cactus inerme (*Opuntia ficus indica *f.* inermis*) et les atriplex (*Atriplex nummularia *et* A. halimus*) sont considérés en Afrique du Nord comme des ressources fourragères capables de subvenir aux besoins des ovins et caprins élevés dans des conditions difficiles sans avoir besoin de recourir aux aliments conventionnels, notamment les aliments concentrés.* Moringa oleifera *est une autre espèce prometteuse originaire du nord-ouest de l'Inde et est répandue dans de nombreux pays. Elle peut être utilisée dans différents domaines, en particulier pour la consommation humaine, l'industrie pharmaceutique et comme ressource fourragère de qualité. Le feuillage et les grains de Moringa sont riches en matières azotées totales dont une grande partie se trouve sous forme de protéines dégradables au niveau de l'intestin. La présence de composés secondaires, en particulier les tanins, dans certains arbres/arbustes fourragers réduit la valeur alimentaire de ces ressources fourragères et pourrait affecter directement la santé des animaux. Certaines techniques ont été proposées pour pallier ce problème. Le polyéthylène glycol (PEG) est un polymère synthétique efficace permettant de désactiver les tanins. Son utilisation pourrait être rendue plus efficace, lorsque sa consommation est synchronisée avec celle des tanins. L'enrichissement des blocs alimentaires en PEG et leur distribution aux animaux soumis à des régimes riches en tanins s'est avéré le meilleur moyen permettant d'atteindre cet objectif. Certains travaux préliminaires semblent écarter le reproche négatif souvent attribué aux tanins en tant que composés non désirables. La protection des protéines alimentaires par une simple incorporation de certaines sources de tanins (e.g. feuillage d'*Acacia cyanophylla*) dans la ration des petits ruminants semble une technique biologique capable d'améliorer la productivité du cheptel ovin et caprin. Les recherches sur cet aspect devraient continuer. Enfin, il semble évident que le rôle de l'éleveur est crucial pour l'efficacité et l'adoption de n'importe quelle technologie développée dans le domaine de l'élevage. L'approche participative de l'éleveur dans tous les processus d'évaluation et de transfert des technologies est à encourager.*

Mots-clés : *Résidus de récolte, sous-produits agro-industriels, arbres fourragers, arbustes fourragers, valorisation, petits ruminants.*

Introduction

With a combined flock of *ca.* 1325 millions of sheep and goats, Africa and Asia are home to *ca.* 25.8 and 48.7%, respectively of the world's total small ruminant population of *ca.* 1778 millions (FAO Database, 2001). Most of these animals are raised in arid and semi-arid zones, which suffer continuously from feed shortage. In all countries there has been considerable growth in sheep and goat numbers over the last four decades. Feed supplies have risen but at a lower rate than that of livestock population.

The availability of feed resources and their rational utilization for livestock represents possibly the most compelling task facing planners and animal scientists in the world. The situation is acute in numerous African and Asian countries where chronic annual feed deficits and increasing animal populations are common, thus making the problem a continuing saga. Efficient utilisation of the available feed resources is an extremely compelling task and the search for urgent solutions is justified by two interrelated reasons: (i) the concept of self-reliance which strives to achieve targets of food production based on the use of indigenous resources; and (ii) the fact that feeding and nutrition are possibly the most important factors influencing production. This paper focuses on the potential use of local non-conventional feed resources (NCFRs) and examines strategies that can accelerate their utilisation as feed constituents to bridge the wide gap existing between supply and demand for the feed in Asian and African countries.

Feed resources for sheep and goats and constraints

In most African and Asian countries, cultivated forages, when available, are fed in priority to cattle. The diets for sheep and goats are based on four main categories of feed sources: native pastures or rangelands, crop residues, agro-industrial by-products (AIBPs) and other NCFRs, mainly fodder shrubs and trees.

Rangelands

Native pastures are still the most important feed source for sheep and goats. They account for the largest share of the land surface of numerous countries in Africa and Asia. Grazing off-takes from these lands is subject to great variations. Rapid increase of flock size as associated to the lack of appropriate management strategy (stocking rate, grazing period and duration, rangeland management, etc.) are the main causes of continuous degradation of rangelands. Therefore, biomass off-taken by grazing animals cannot in general match their nutrient requirements. Farmers are obliged to integrate other local feed sources, which are, in most cases, low in essential nutrients. Feed grains and other concentrates, due to their high cost and seasonal availability, comprise smallest feed category in these countries. However, in drought conditions, spectacular increases in feed imports from other regions occur, resulting in higher contribution of concentrate feeds in livestock diets, which increase the feeding cost.

Crop residues

Crop residues are mainly fibrous material that is by-products of crop cultivation. Due to the intensity of and emphasis on crop production in Africa and Asia, great amounts of several by-products are produced annually. While these feed sources, particularly cereal straws, provide the bulk of livestock feed, their nutritive value is often so low that farmers must supplement them with feed grains and other concentrates. Crop residues available in the target area include, mainly, cereal straws, stubbles, olive tree leaves and twigs.

Most common crop residues (i.e. straws and stubble) have a low crude protein content, in the range 2-5% on a dry matter (DM) basis. This suggests a basic limitation in the value of some of the residues (e.g. wheat and barley straw) around the border line of the 6-7 per cent dietary crude protein level required for promoting voluntary feed intake (VFI). Most of the residues are deficient in fermentable energy, as reflected by the relatively low organic matter digestibility, and also the limited availability of minerals.

Cereal straws

Straws correspond to the residue (leaves, awns, stems) remaining after the mature crop (i.e. grains) has been harvested. Straws may have high market values in times of drought and other harsh conditions when roughages are scarce and grains have to be imported. For example, in Tunisia the sale price of straw bales in such periods may reach 3 to 4-fold that in periods of good harvest. Cereal crop residues are expected to provide energy for ruminants in the form of digestible fibre. It is generally agreed that they should be accompanied by small amounts of suitable nitrogen supplement, such as oilseed cakes. If their nutritive value is low or the desired level of production is well above maintenance, farmers, must in addition, feed an energy supplement such as cereal grain to ensure biological and economical efficiency. Such supplement feeds are often more expensive than crop residues. Improving the nutritional value of straws and the efficiency of their use in mixed diets is an attractive option for increasing livestock production.

Stubbles

Stubbles refer to those residues left after grain harvesting and straw collection. They include stems, small portion of leaves, grains and weeds. Although stubbles provide important biomass for ruminant animals, their feeding value and strategy for efficient integration into livestock feeding are still poorly investigated. Available studies showed that total biomass measured after straw removal was 4 to 6 t DM/ha, including wheat stubble and weeds (Guessous *et al*., 1989). Some Moroccan studies have dealt with the feeding value of stubbles and their effect on sheep performance. Botanical composition of stubble and chemical composition vary greatly with grazing period. Large amounts of grains are available in the beginning of the grazing period. According to Guessous *et al*. (1989) and Outmani *et al.* (1991), the nutritive value of diet off taken by stubble grazing ewes, mainly crude protein and energy contents decreased with the number of week of grazing. Crude protein content of stubble was below 5% DM and this crop residue was high in fibre.

Agro-industrial by-products

The increasing human demands for several foods (i.e. olive oil, vegetables, wine, fruit juices, etc.) led to a considerable increase of lands occupied by crops producing these feeds. Consequently, huge amounts of agro-industrial by-products are available in numerous African and Asian countries (e.g. molasses, olive cake, winery marc, etc.), which are still not fully utilised in livestock feeding. Most of these AIBPs are low in, and/or not balanced for, main nutrients. Moreover, the difficulty of the use of these feed sources as fresh material for extended periods and the lack of efficient ways for their integration in feeding calendars may account for their under-utilisation. A brief description of the potential use of some abundant AIBPs in livestock feeding is discussed in following sections.

Molasses

Sugar extraction generates molasses, an energy-rich by-product. Molasses contain 50-60% sugar, with some minerals, especially K and Ca. It is, however low in crude protein and do not contain fibre. It can be mixed with urea in liquid licks, in mixtures of molasses, urea and vitamins to spray on poor quality roughages, or formed into blocks.

Olive cake

Huge amounts of olive cake are available in the Mediterranean basin where olive crop is a key agricultural sector. The pressure (traditional) and centrifuge systems are the main processes used for oil extraction. The solid residue generated after extraction of oil is called olive cake (about 33 and 25% of the amount of olives, respectively). The nutritive value of this by-product differs with the processing system. Crude olive cake is obtained with the pressure system. It is high in water (24%) and oil (9%), which cause rapid fermentation. Therefore, the period of utilisation of crude olive cake as fresh material is short. The olive cake obtained through solvent extraction differs substantially in composition (low in fat and moisture). Evidently, the nutritive value of these by-products varies greatly with the processing system. The integration of this feed source in sheep and goat is limited. The main limiting factor is its low energy and digestible protein contents and its richness in lignin. Depending upon the processing, crude protein in olive cake varies between 8 and 12% DM, but almost 80 to 90% of nitrogen is fixed on lignocellulose, thus not digestible. The high intake of olive cake as consequence of low particle size renders its digestibility low. The resultant of these nutritive characteristics is a low energy (0.21-0.35 feed units for meat production/kg DM) and digestible crude protein content [10-30 g/kg DM, acid detergent fibre (ADF) bound nitrogen is 80 to 90% of total nitrogen]. Therefore, studies seem to suggest that the contribution of olive cake to the diet of sheep should not exceed 30-40%, otherwise animal performance (growth and reproduction) will be drastically affected (Nefzaoui, 1999).

Tomato pulp

Tomato crop is an important crop in most countries in the region. It is consumed by humans raw vegetable, but a great part of the crop is transformed to the processed foods by agro-industrial industries. High amounts of residues are generated accounting for about 4.5% of the fresh weight. The high crude protein (22-25% DM basis) and energy [8.9 MJ of metabolizable energy (ME)/kg DM] contents classify this by-product among the feedstuffs having high potential for their use in livestock feeding. However, the main constraint limiting its wide use is its high moisture content (about 80% of crude material) and the transportation of fresh tomato pulp is difficult and its period of use cannot be extended for long time.

Browse foliage

Fodder trees and shrubs have high potential value as a source of feed for domestic livestock and wildlife. They can be successfully integrated into production systems to provide additional feed resources for use in mixed diets of livestock, fuel and mulch, to control erosion when planted as wind breaks and to maintain or rehabilitate degraded areas of rangelands. Numerous shrub and tree species have been investigated and the multiple attributes of some of them have been confirmed. The potential use of some typical shrub/tree species widespread in Africa and Asia is discussed below.

Cacti

Cacti have been projected by de Kock (1980), as "camel of the plant world", "living fodder bank" and "nature's fodder bank". This succulent plant species withstand drought conditions and is widespread in Africa, mainly in north and south parts, and America. Cacti are characterised by high water use efficiency and their pads are covered with thick epidermis and stomata are closed over the day but are opened at night. Therefore, water evaporation in this plant species is reduced. Cacti are multipurpose range species, which could be used mainly to provide forage for livestock, fruit for human and to a less extent for animal consumption, and as a tool to combat desertification. Pads of cacti are high in soluble carbohydrates, calcium, potassium, vitamin A, but are low in fibre and crude protein. Cacti are also considered as a source of water for animals raised under harsh environments (Nefzaoui and Ben Salem, 2002). Supplementing poor roughages such as straws with cactus, increased straw intake, diet digestibility, and improved microbial activity but decreased cellulolytic activity (Ben Salem *et al*., 1996). Ben Salem *et al*. (2002b) showed that protein nitrogen supply improved the nutritive value of cactus-based diets fed to lambs and increased daily body weight gain. There was further improvement when the level of by-pass proteins in the diet was increased. Worth noting that cactus pads may reduce the use of concentrate feeds, and therefore the feeding cost. The complementary role between cactus pads and atriplex, halophyte shrub species, as alternative feed resources is well documented (Ben Salem *et al*., 2002c).

Moringa oleifera

In a recently published scientific book (Fuglie, 2001), moringa has been described as a miracle tree. It has in numerous uses. Among the many attributes of this remarkable tree are the coagulant properties of its seeds which is used in many countries for purification of turbid water. The seed oil is edible, and the remaining meal can be used as a source of coagulants for water purification. It can also be used as a protein meal (crude protein approx. 60%) in livestock diet. The leaves of this tree are also edible and are highly nutritious. These are consumed throughout West Africa and in some countries of Asia. As livestock feed, moringa leaves (crude protein approx. 25%) could also provide a high quality protein since its amino-acid composition is similar to the FAO reference protein for growing child. Moreover, total protein digestibility of these leaves is high (85-90%, rumen digestibility is 49%; the rest would be available post-ruminally). Leaves are also free of anti-nutritive factors (e.g. phenols, tannins, saponins, etc.) and high in iron (up to 582 mg/kg DM), in beta-carotene (up to 400 mg/kg DM) and in vitamin C (up to 9.2 g/kg DM). Lately, this plant has received a lot of attention. Moringa foliage has been found to increase animal productivity (Foidl *et al*., 2001).

Tanniniferous leguminous species

It is well documented that the presence of secondary compounds mainly tannins in a wide range of shrub species hamper their fodder potential (Makkar, 2003). Tannins may cause toxicity when present in the hydrolysable form (HT) and reduce considerably the nutritive value of browse and tree foliage when they are present in the condensed (CT) and/or HT form. Tannins form complexes mainly with proteins and also with carbohydrates, amino acids and several minerals; thereby, reduce intake, digestion and animal growth. The negative effect of these secondary compounds on the nutritive value of numerous shrub and tree species available in Africa and Asia has been demonstrated. *Acacia cyanaophylla* Lindl. (syn. *A. saligna*) is an evergreen leguminous fodder shrub/tree, which generates high consumable biomass. Although high in crude protein, the nutritive value of acacia foliage is low. High levels of tannins (largely CT) and lignin account contribute to this problem. The intake of acacia foliage, its digestibility and the daily body gain in sheep and goats fed this shrub species are low. Ben Salem *et al.* (1997, 1999) showed that tannins decreased availability of acacia proteins and also those of the whole of the diet. Recent studies conducted in some countries, mainly in Tunisia, suggest that tannins in foliage and pods of several shrub species could be advantageously integrated into livestock feeding as to increase by-pass proteins.

Main constraints on use of some feed resources

Numerous factors may account for the limited use of several crop residues, AIBPs and NCFR. The main constraints are listed below:

(i) Low nutritive value.

(ii) Short period of utilization (seasonal availability).

(iii) High moisture content (e.g. citrus pulp, tomato pulp, olive cake, etc.).

(iv) High cost of handling and transportation from the production site (tomato pulp, olive cake, grape marc, etc.) to the farm.

(v) Farmers are not aware of the nutritive value of some feed sources and the way for their efficient integration in livestock feeding.

(vi) Competition with alternative users (fuel, compost, etc.).

(vii) Presence of anti-nutritional factors (phenolic compounds mainly tannins, saponins, etc.).

(viii) Dehydration may cause loss of protein value (Maillard reactions).

(ix) Lipid peroxidation (rancidity of high fat products, e.g. olive cake).

(x) Mould growth (aflatoxins) may cause toxicity.

Techniques to enhance feedstuff utilization

A set of technologies has been investigated in Africa and Asia to improve the nutritive value of low quality feed sources. The most popular ones include ammonia treatment of cereal and rice straws and mixing several AIBPs in the form of hard feed blocks.

Supplementation

Adequate supply of nutrients may improve the nutritive value of low quality diets. From farmer's practical point of view, it is believed that supplementation with grains and other concentrate feeds is the only way to provide a balanced feed. However, in drought conditions, the use of concentrates is excessive leading to a significant increase of feeding cost. Some alternative feed sources are used by farmers (olive cake, bread wastes, etc.), but being not aware of the nutritive value of these sources diets distributed to small ruminants are often unbalanced for the main nutrients and not adapted to the physiological state of the animal. Appropriate use of several by-products and browse foliage could replace partially or totally common grains and concentrate feeds without causing any negative effect on livestock performance. Cost-effective feeding systems should be developed for those farmers.

Chemical treatment of straws

One alternative to reducing the use of supplementary feeds is to improve the quality of cereal crop residues by chemical treatment but this requires additional labour and materials and reduces flexibility in use. Ammonia gas or ammonia generated from urea under anaerobic conditions, renders fibre more fragile and disrupt the complex between lignin and other digestible components in fibrous feedstuffs including straws. Advantages of this technique on the nutritive value of straw and livestock performance are well documented in the literature. Ammonia treatment increases crude protein content, intake and digestion of treated straws, thereby improve livestock productivity. However, in absence of adequate supplements mainly true protein, energy and minerals benefit from this technology may be limited. The high cost of urea and to a less extent of plastic sheet to cover treated straw are considered as main limiting factor for wide adoption by farmers. Attempts have been made to reduce the cost of ammonia treatment. Ben Salem *et al*. (1995) showed that mud could be used to cover urea-treated straw instead of plastic sheet. The increase of straw intake, digestibility and Barbarine lamb growth was similar for the two treatments (Table 1). Mud is traditionally used by small farmers to cover straw stacks.

Table 1. Mud as an alternative to plastic sheet for covering urea-treated straw given to Barbarine lambs† (Ben Salem *et al.*, 1995)††

	US	ATS	UTS-plastic	UTS-mud
Crude protein in straw (g/kg DM)	31	78	76	78
Straw intake (g DM/kg $W^{0.75}$)	47.8 c	60.9 a	54.2 b	55.2 b
Organic matter digestibility of the diet (%)	58.8 b	63.6 a	61.9 ab	60.1 ab
Crude protein digestibility of the diet (%)	32.7 b	51.9 a	52.1 a	54.2 a
Gain (g/day)	56.6 b	95.6 a	92.1 a	92.6 a

†Lambs were supplemented daily with 300 g concentrate.
††US: untreated straw; ATS: ammonia-treated straw; UTS-plastic: urea-treated straw covered with plastic sheet; UTS-mud: urea-treated straw covered with mud.

Ensiling

Numerous AIBPs, although available in large amounts and some of them being rich in certain nutrients (e.g. tomato pulp high in crude protein, orange and citrus pulp high in energy, etc.), are not widely used in livestock feeding. Because of high moisture, olive cake and tomato pulp, for example, become rancid and mouldy. Ensiling technique can be safely used for extended storage of these by-products alone or combined with other by-products (molasses, wheat bran, etc.). Hadjipanayiotou (1999) found olive cake silage well preserved judging from its aroma, colour, pH and the lack of any mould. Replacing part of barley hay and straw given to lactating ewes, goats and cows with olive cake silage had no effect on milk yield and fat-corrected milk yield. Citrus pulp and wheat straw silage was incorporated by Scerra *et al*. (2000) in lamb diets to replace oat hay and 30 of commercial concentrate. Live weight and carcass weights were similar among treatments. Lambs on silage produced carcasses with a better muscular conformation and with a lower fatness score. The use of AIBPs silage seems to be a convenient and economically viable method for producing sheep with similar or better performance than that obtained with common feed resources. In practice, however, the adoption of silage technique is still limited.

Feed block technology

Another way to utilise AIBPs mainly those high in moisture is through feed block technology. About 60 countries in the world are using these alternative supplements for ruminant feeding. An exhaustive review on this technology was prepared by Ben Salem and Nefzaoui (2003) and therefore, manufacturing procedure of feed blocks, their different ways of utilisation, effect on intake, digestion and livestock performance will not be developed in the present paper. This technology provides flexibility to extension workers and farmer to choose the ingredients to be included in the feed block and its use as supplements in drought and other harsh conditions. In addition, the blocks can be prepared when the ingredients' cost is low and stored for later use. These cost-effective supplements are solidified mixture of some agro-industrial by-products (e.g. olive cake, tomato pulp, grape marc, molasses, etc.) urea, binder (e.g. cement and/or quicklime) and minerals and vitamins. These blocks are considered as catalytic supplements able to enhance digestion of low quality fibrous feedstuffs through balanced, synchronised and fractionated supply of main nutrients to the animal on poor diets. Feed blocks may be also used as vehicle of several minerals (e.g. Cu, Zn) to improve reproduction performance of small ruminants (Al-Haboby *et al*., 1999), as carrier of several reagents mainly polyethylene glycol (PEG) to deactivate tannins in fodder shrubs and trees (Ben Salem *et al*., 2000; Ben Salem *et al*., 2002a) and to provide antihelminthic medicines to control gastrointestinal parasites in browsing animals (Anindo *et al*., 1998), and of rumen modifiers such as saponins to decrease protozoa in the rumen, leading to higher efficiency of microbial protein production. Of particular interest is the possible use of feed blocks to partially or totally replace expensive concentrate feeds commonly distributed to ruminants on low quality roughages, and therefore to reduce feeding cost. Some examples are reported in Table 2.

Table 2. Replacement value of feed blocks on concentrate feeds† (H. Ben Salem, unpublished data)

Animal	Roughage (*ad libitum*)	Supplement††	Roughage intake (g DM/d)	Block intake (g DM/d)	DOMI (g/kg $W^{0.75}$)	DCPI (g/kg $W^{0.75}$)	Growth (g/d)
Lambs	Wheat straw	500 g concentrate	235	–	46.3	2.9	63
		125 g concentrate + block (1)	254	392	38.2	4.7	66
Lambs	Oat hay	–	770	–	50.4	3.4	76
		Block (2)	759	420	54.3	5.9	91
		Block (3)	924	346	59.2	5.7	90
		Block (4)	903	425	56.0	5.4	90
Goats	Kermes oak	–	331	–	17.4	1.0	–
		Block (5)	627	113	46.6	33.0	–

†DOMI: digestible organic matter intake; DCPI: digestible crude protein intake.

††Formula (crude matter basis):

Block (1): olive cake (44%), rapeseed meal (10%), wheat bran (15%), wheat feeds (15%), quicklime (8%), urea (2%), salt (5%), mineral and vitamin supplement (MVS, 1%).

Block (2): olive cake (40%), apple pulp (20%), wheat bran (20%), quicklime (10%), urea (4%), salt (5%), MVS (1%).

Block (3): olive cake (40%), sesame residue (20%), processed barley (20%), quicklime (10%), urea (4%), salt (5%), MVS (1%).

Block (4): olive cake (30%), citrus pulp (30%), processed barley (20%), quicklime (10%), urea (4%), salt (5%), MVS (1%).

Block (5): olive cake (37%), cactus fruit (30%), wheat bran (15%), quicklime (10%), urea (4%), salt (4%).

Deactivation of secondary compounds

It is now been established that the nutritive value of acacia foliage is low and animals receiving this shrubs species lose weight. These negative effects were attributed to tannins in acacia foliage. Several attempts have been done to deactivate these compounds. Air-drying failed to improve the nutritive value of acacia, satisfactory results were obtained on feeding PEG-4000 with the acacia leaves. PEG-4000 binds to tannins, preventing formation of tannin-protein complexes, and also it has a higher affinity for tannins hence liberates proteins from the already formed tannins-proteins complexes. Several ways of PEG supply (PEG in concentrate, in drinking water or as solution sprayed on plant material) have been investigated on sheep fed tannin-rich diets. Though positive effects on digestion and animal growth have been obtained, further investigations should be conducted to determine the optimal level of PEG. Additionally, Getachew *et al*. (2001) showed that the slow release of PEG in the *in vitro* incubation system (gas method coupled with determination of microbial protein) containing tannin-rich feed produced higher microbial protein in the rumen as compared to one-time delivery of the same amount of PEG in the system. Additionally, the requirements of PEG decreased substantially when PEG was used in the *in vitro* system in the slow-release form. A possible practical way to enhance the efficiency of PEG is to incorporate PEG in hard feed blocks. Moreover, feed blocks could be an efficient way for seed dispersal of leguminous species and thus for the rehabilitation of degraded rangelands.

Shrub-mixed diets

Range species which contribute to a large extent to livestock feeding contain in most cases, high level of proteins. Admittedly, protein is the most limiting nutrient in the diet of livestock which because of its limited supply should be used more efficiently to promote efficient fermentation of roughage in the rumen for improved animal performance. Moreover, it is well documented that browse foliage, high in antinutritional-factors can not be offered to ruminants as a sole diet. But it could be mixed with other feedstuffs to form a balanced feed and also to dilute the effect of anti-nutritive factors present. The complementary role between spineless cactus and saltbushes, mainly *Atriplex nummularia* and benefit from the association of these drought tolerant species was highlighted (Ben Salem *et al*., 2002c). Cactus pads high in soluble carbohydrates make better use of the high amount of soluble nitrogen in atriplex foliage. Abundant water in cactus pads facilitates excretion of the excessive salt in atriplex foliage. On the other hand, atriplex may overcome nitrogen and fibre deficiency in cactus pads. Negative effects of condensed tannins in *Acacia cyanophylla* foliage could be decreased when tannin-free foliage is fed with this leguminous shrub species. It was recently demonstrated that lambs on acacia-based diets supplemented with cactus and atriplex grew at rate of about 30 g/day. Shrub mixed diet could be a cost-effective solution to make better use of low quality browse foliage without any need for addition of expensive chemicals like PEG (Ben Salem *et al*., 2002d).

Tannins in browse foliage to increase by-pass proteins

Though tannins in forage legumes have generally been classified as anti-nutritional, it is possible that tannins could be employed advantageously to improve production. Consequently, attempts should be made to reduce ruminal degradation of proteins in several range species (*Atriplex nummularia*, etc.) and concentrate feeds (rapeseed meal, soyabean meal, etc.), thus increase ruminal supply of protein by feeding forage legumes containing high concentration of soluble phenolics. Benefit expected from protein protection in the rumen is well documented. Nevertheless, in the majority of studies reported in the literature, chemicals, mainly formaldehyde, have been used to protect protein from degradation in the rumen. This procedure is generally used by industries. *In situ* protection of feed proteins using foliage browse tannins is a biologic technique which may be adopted by smallholders. This could be achieved through association of small amount of tannin-containing foliage with protein rich feedstuffs, e.g. soybean or rapeseed meals, etc. In a recent study, Ben Salem *et al.* (2002b) concluded that acacia tannins could be advantageously used to increase rumen undegradable proteins in cactus-based diets fed to lambs (Table 3). These findings warrant further investigations on other tannins and protein sources.

Table 3. Supplementing cactus-based diets with urea, protected or unprotected soybean meal proteins (Ben Salem *et al*., 2002b)

	(Spineless cactus + barley straw) *ad libitum* +[†]						SE	Significance
	–	U	S	SF	SA100	SA200		
Dry matter intake (g/kg $W^{0.75}$)								
Cactus	33.0	40.8	43.0	57.2	56.1	46.4	3.44	***
Straw	15.7	17.6	13.8	13.8	12.5	13.9	0.74	**
Diet digestibility (%)								
Organic matter	67.1	69.0	74.8	76.7	79.7	74.3	2.75	
Crude protein	7.9	49.3	73.1	67.8	72.0	71.6	4.14	***
Daily gain (g)	–14	–17	79	75	102	82	8.0	***

[†]U: urea; S: soybean meal; SF: formaldehyde treated soybean meal; SA100: soybean meal with 100 g acacia foliage; SA200: soybean meal with 200 g acacia foliage.
*P < 0.05, **P < 0.01, ***P < 0.001.

Agro-industrial by-products and browse foliage to replace common feed resources

The feeding cost in drought conditions is high. Several authors investigated the replacement value of some agro-industrial by-products and browse foliage for common feed resources, particularly concentrate feeds. Liu *et al*. (2001) concluded that mulberry (*Morus alba*) leaves might be used as a protein supplement (crude protein 230 g/kg DM) to ammoniated straw diets to fully substitute for rapeseed meal (crude protein 420 g/kg DM) given to sheep. Lambs supplemented with 100 g rapeseed meal grew at similar rate than those supplemented with 240 g mulberry leaves. Ben Salem *et al*. (submitted) showed that *Atriplex nummularia*, high in crude protein (180 to 250 g/kg DM) and cactus pads, high in soluble carbohydrates may replace soybean meal and barley grain, respectively.

Conclusion

The main reason for the poor animal production in numerous African and Asian countries is the inadequate supply and low level of feeding due to serious shortage of feedstuffs. A major gap exists between the requirements and supplies of nutrients for small ruminants. There is a clear justification for building up feed resources. Both continents have considerable amounts of crop residues such as straws, olive cake, molasses and other AIBPs. Several factors may account for their limited use, among which are their low nutritive value and difficulty for handling and using for extended periods. It is essential to increase feeds by growing more fodders, propagating agro and social forestry, improving the nutritive value of crop residues and utilising other NCFRs. Crop residues, AIBPs and browse foliage are certain an increasingly important role as feeds in the future, as human and livestock populations expand. A special attention should be given to efficient integration of multipurpose fodder shrubs and trees as fodder bank in feeding calendars of sheep and goats under harsh climates. Several promising technologies discussed in this paper may increase the efficiency of local alternative feed sources (AIBPs, fodder shrubs, etc.) thereby improve livestock production. Some of these technologies are still not adopted by farmers. The involvement of farmers provides path for discussion of the appropriateness of the technologies enabling researchers to change, modify or refine their technology to better respond to the practical conditions. The involvement of local extension agencies in technology development, assessment and transfer is equally important.

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