Utilization of low quality resources by small ruminants in Mediterranean agro-pastoral systems: the case of browse and aftermath cereal stubble

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Abstract

Browse and cereal stubble represent the two most important resources for grazing small ruminants in dry Mediterranean areas. The purpose of the present review is to provide updated information regarding their nutritional value. In a mixed Mediterranean environment, browse represents at least 40% of goat’s diet. Most browse species in the Mediterranean are rich in tanniferous phenolic substances. Polyethylene glycol (PEG) can bind tannins irreversibly over a wide range of pH and is efficient in alleviating the negative effects of tannins. Supplementing with PEG improves intake and digestibility in grazing goats and sheep and has the potential to be economically profitable. The chemical composition of wheat stubble is affected by the cultivar of wheat and climate, but not tillage management. The quality of stubble from early maturing is lower than from late maturing cultivars. Stubble contains more protein in years of lower rainfall. If grains escaped from the harvest combine (2% of grain yield) are included, digestibility of OM from different components ranges between ±80% (grain) to ±40% (stem). Also, the energy requirement of sheep grazing on stubble may be 70% higher than in shaded feedlot. Therefore, the body condition changes of sheep grazing on stubble exhibit a cyclic pattern consequent with temporal changes in nutritive quality. Because stubble grazing is concurrent with the onset of oestrous season, supplementation with grains from legume species-rich in degradable protein is needed to prevent impairment of body condition. Supplementing browsing goats with PEG, and sheep grazing cereal stubble with moderate amounts of legume grain, may enable the use of these traditional resources in the frame of sustainable production systems.

Résumé

Les broussailles et les chaumes de céréales représentent les deux plus importantes ressources alimentaires des petits ruminants pâturant sur les zones sèches du bassin méditerranéen. En milieu méditerranéen, la broussaille représente au moins 40% du régime des chèvres. La plupart des espèces de broussailles rencontrées en Méditerranée est riche en substances phénoliques de type tannins. Le polyéthylène glycol (PEG) peut lier les tannins de façon irréversible sur une très large plage de pH et il est efficace pour limiter les effets négatifs des tannins. La supplémentation en PEG améliore la consommation et
la digestibilité des chèvres et des moutons au pâturage et elle a le potentiel d’être économiquement rentable. La composition chimique des chaumes de céréales dépend du cultivar de blé et du climat mais non des conditions du labour. La qualité des chaumes des variétés précoces est moins élevée que celle des cultivars tardifs. Les chaumes contiennent plus de protéines dans les années à faible pluviométrie. Quand le grain s’échappant de la moissonneuse-batteuse (2% des grains) est pris en compte, la digestibilité de la matière organique de différents constituants se situe entre 80% pour le grain et 40% pour les tiges. Le besoin énergétique du mouton pâturant sur des chaumes peut être de 70% supérieur à celui des animaux en feedlot à l’ombre. Par conséquent, le changement de l’état corporel des moutons pâturant sur des chaumes présente un profil cyclique en relation avec les changements de la valeur nutritive de l’ingéré dans le temps. Comme le pâturage des chaumes intervient en même temps que le démarrage de la saison d’estrus, la supplémentation en grains légumineuses riches en protéines dégradables est nécessaire pour éviter des inadaptations de l’état corporel. La supplémentation des chèvres sur broussaille par du PEG et le pâturage des moutons sur chaumes de céréales avec des apports modérés de grains de légumineuses permettent l’utilisation de ressources traditionnelles dans le cadre de système de production durable. © 2000 Elsevier Science B.V. All rights reserved.

**Keywords:** Mediterranean pastures; Sheep; Goats; PEG; Browse

1. Introduction

The terrestrial vegetation of both sides of the Mediterranean Basin has been used for grazing small ruminants for livestock for more than 5000 years. However, the evolution of land utilization has been different between the Northern, and South-Eastern shores of the Mediterranean. In the Northern Mediterranean, agriculture and animal husbandry have withdrawn from large regions that had been traditionally cropped. This has resulted in a recovery of ligneous vegetation (brush encroachment) that is prone to fire (Bourbouze and Rubino, 1992). Low grazing pressure, or removal of goats from woodlands, also have undesirable ecological effects on bio-diversity (Perevolotsky, in preparation). Therefore, an effort is made to restore woodland grazing, mainly by goats. (Seligman and Perevolotsky, 1994; Léger et al., 1996). In the Southern and Eastern shores of the Mediterranean more and more areas are being cropped, mainly with rainfed cereals, owing to the pressure of growing population (Bourbouze and Rubino, 1992), at the expense of natural pastures. Scrublands and woodlands are subsequently submitted to extreme grazing pressures, whereas the quantitative importance of grassland-where the land can be tilled-is continuously decreasing. The association of wheat and barley cropping with small ruminant farming is a common feature shared by many Mediterranean countries, and summer transhumance to cereal stubble fields is traditional.

New production systems involving small ruminants and the utilization of open, communal pastures have recently emerged. These systems are generally based on improved breeds of small ruminants because the income from traditional breeds is low (Landau et al., 1995). The Anglo-Nubian, Damascus, and Boer goats substitute for Mamber goats in Israel (Landau et al., 1995). Alpine goats substitute for the traditional Rove goat in the French region of Provence (Napoleone and Hubert, 1989). Prolific Awassi sheep may in the future be replaced by prolific Awassi, in which prolificity is increased by the FecB gene (Elisha Gootwine, personal communication). These productive animals are able to utilize the natural Mediterranean ligneous vegetation as do the traditional breeds. However, the nutritional value of these resources does not cover the requirements for maintenance and production of these improved animals.

At the eve of the third millenium, ligneous (bushes and trees) vegetation and cereal stubble still represent the two most important resources for grazing small ruminants in the Mediterranean. The purpose of the present review is to provide updated information regarding the nutritional value for sheep and goats of (i) natural woodland and scrubland, and (ii) cereal stubble; and (iii) to review the ways of...
upgrading these resources by using feed supple- 
mentation.

2. Woodland and scrubland as a food resource 
for small ruminants

2.1. Goats and sheep as users of mediterranean 
browse

In many traditional systems in the Mediterranean 
Basin, small ruminants are the main source for red 
meat for human consumption. Farmers keep mixed 
herds of sheep and goats as a strategy to maximize 
the use of environmental resources (Bourbouze and 
Rubino, 1992). The proportion of goats in the herd 
increases with an increase in aridity or the proportion 
of woody species in the range. Among the domestic 
ruminants, goats are best adapted to utilizing highly-
fibrous low- protein forages, frequently under 
conditions of water scarcity (Silanikove, 1986, 1997). 
When the percentage of herbaceous vegetation in 
pasture is high, sheep are preferred in most cases 
over goats. This trend probably reflects the facts that 
when considering the local breeds, sheep are better 
producers of meat in comparison to goats in respect 
to growth rate, feed conversion efficiency, and 
dressing percentage. The importance of goats in- 
creases whenever milk production becomes the most 
important element in productivity and when environ-
mental conditions are harsher (Noy-Meir, 1979).

Goats and sheep are mixed feeders. However, 
under mixed forage conditions goats consume larger 
proportion of browse than sheep (Trabalza-Marinuc-
ci et al., 1993). Goats utilize tannin-rich foliage 
better than sheep (Silanikove et al., 1994; 1996a). 
The cell wall digestibility of Acacia pendula, 
Casuarina cristata and Heteroderedrum oleifolium 
were 4 to 9 percentage units higher in goats than in 
sheep (Wilson, 1977). On Mediterranean woodland 
and brushland, browse constitutes more than 60% of 
goat diets (Kababya et al., 1998; Perevolotsky et al., 
1998; Decandia et al., 1998). The physiological basis 
for the apparent advantage of goats over sheep and 
cattle in utilizing tanniferous forage has been inten-
sively studied. Dominigue et al. (1991) reported that 
during eating goats secrete more saliva containing a 
higher level of nitrogen than sheep. In observations 
of masticated vs. unmasticated samples, Provenza 
and Malechek (1984) observed a 50% reduction in 
the concentration of tannins contained in masticated 
samples collected from the esophagus in goats 
consuming a tannin-rich foliage (blackbrush twig). 
This reduction may be related to binding of the 
tannin by salivary proteins. However, Distel and 
Provenza (1991) did not detect proline-rich proteins 
in the saliva of goats fed blackbrush twig, indicating 
that if specific tannin-binding proteins exist in the 
saliva of goats, they most likely differ from those 
found in mule deer, rats and mice. Both salivary and 
ruminal mechanisms may need to be considered to 
clarify the apparent advantage of goats in digesting 
tannin-rich forages. Based on ruminal degradation 
data (Silanikove et al., 1996b) and positive response 
to adaptation (Gilboa, 1996), Silanikove et al. 
(1996c) concluded that ruminal fermentation is the 
main mechanism for neutralization of the antinutri-
tional effects of tannins in goats. The physiological 
basis of the adaptation of goats to tannin-rich 
nutrition needs further exploration.

2.2. Selection strategies of ranging goats

As mentioned, in the Mediterranean area goats are 
more numerous in areas dominated by woody 
species. Goats are opportunistic feeders: time spent 
grazing species depends generally on the relative 
frequency of encounters, but this relationship de-
PENDs on species of vegetation and habitat visited 
(Kababya et al., 1998). Goats that are allowed to 
exploit freely a Mediterranean environment consist-
ing of scrubland and woodland will organize their 
feeding behaviour to select dietary components in 
such a way that the concentration of available (non-
linked to ADF) protein, NDF and condensed tannins 
(CT) in the total diet remains relatively constant 
throughout the year (Kababya et al., 1998). Browse 
represented 60% and 7%, respectively, of the diet of 
goats and sheep feeding freely in Mediterranean 
woodland (Leclerc, 1985). Thus, unlike sheep (Le-
clerc, 1985) and cattle (Rothman, 1999), which do 
not consume browse during the green season, browse 
constitutes at least 40% of the diet selected by goats 
at all times (Nefzaoui et al., 1993; Kababya et al., 
has shown that adaptation of the microbial system in
the rumen forms a very important element to utilize high-tannin foliage. Thus maintaining intake of browse sufficient to preserve their adaptation to tannin-rich food is justified on the long run because this type of forage is available to them in large amount all year around. This pattern of diet selection, however, is not compatible with milk yield maximization. Indeed, selection of goats by men in harsh Mediterranean environment was traditionally based on breeding success and lifetime performance (Santucci, 1984). In contrast to energy, protein cannot be stored over a long period in goats. Therefore, a decrease in protein intake in June is followed immediately by a drop in milk yield (Landau et al., 1993; Kababya et al., 1998). This pattern is preserved even if concentrate is supplemented (Landau et al., 1993), suggesting that the trigger for drying off is environmental (decreasing day length or ambient temperature). As energy intake remained steady, the drop in milk yield results in increased body weight and body conditioning scoring (Kababya et al., 1998). In August, at the onset of the oestrous season, goats are able to increase their protein intake from the summer depleted range (Kababya et al., 1998). It seems, therefore, that in June goats select a ‘self dry off-self fattening diet’ in late spring and a reasonably good diet in late summer that improve the chance of reproductive success.

This feature, shared by dual-purpose Mediterranean breeds like Mamber (Kababya et al., 1998) and Rove goats (Napoleone and Hubert, 1989), but not by the more specialized Alpine (Napoleone and Hubert, 1989) and Saanen (Landau et al., 1995), is consistent with the long-term genetic selection by traditional farmers in the Mediterranean Basin, which focused on the maximization of reproductive performance in the face of low supplementation.

2.3. Tannins in browse species

Most browse species are dicotyledons that are rich in tanniferous phenolic substances (Leinmuller et al., 1991). Tannins are complex phenolic metabolites of plants with a molecular weight > 500, containing sufficient phenolic hydroxyl and carboxyl groups to precipitate proteins and effectively form strong complexes with carbohydrates (starch and cellulose). This is done under conditions that prevail in the digestive tract (Kumar and Vaithyanathan, 1990; Leinmuller et al., 1991). Tannins may be divided into hydrolizable and condensed forms, which may be differentiated by their structure and reactivity towards hydrolytic reagents. The chemistry of the two groups of tannins has been extensively reviewed (Haslam, 1981). Generally, leguminous shrubs and tree leaves contain both types of tannins. Quantitative partitioning of total tannins in a plant sample into hydrolizable and condensed types cannot be performed reliably because of limitations in their chemical assays (Hagerman, 1988; Hagerman and Butler, 1989).

The content of tannins within a species depends on phenologic stage (Table 1). Within a given species, tannin content is similar in Western and Eastern parts of the Mediterranean (Table 1). Hydrolizable tannins are more prone to induce toxicity in ruminants than are condensed tannins, whereas condensed tannins are associated with antinutritional effects (Kumar and Vaithyanathan, 1990; Leinmuller et al., 1991). Generally, there is an inverse relationship between the concentration of tannin in browse material and voluntary feed intake by ruminants (Kumar and Vaithyanathan, 1990). The effect of tannins on feed intake is well demonstrated by the dose-response relationship between PEG supplementation and feed intake in sheep and goats (Silanikove et al., 1994, 1996a). A condensed tannin content of 3% or above in the browse not only acts as a feeding deterrent (Provenza, 1995), but also reduces ruminal degradability of that feedstuff (Silanikove et al., 1996b) and of the whole diet (Silanikove et al., 1997a). Hence, when leaves were offered as a sole feed they did not sustain the maintenance requirement of the animals (Silanikove et al., 1994, 1996a), and weight gain, milk yield and wool growth was reduced (Kumar and Vaithyanathan, 1990). Silanikove et al. (1996a) reported that tannin concentration in leaves of approximately 20% of DM drastically reduced leaf intake, and goats fed such diets lost weight rapidly (100 g/day).

The negative effects of tannins on palatability and digestibility in ruminant are multifactorial (Kumar and Vaithyanathan, 1990; Leinmuller et al., 1991; Silanikove et al., 1996a, 1997b; Aharoni et al., 1998). One aspect is astringency and reduced palatability as a result of the interaction between tannins and salivary proteins and irritation of gut mucosa. Many investigators view the major effect of
Table 1
Composition (% of DM) of some ligneous components of goat diets from Western and Eastern shores of the Mediterranean

<table>
<thead>
<tr>
<th>Spp.</th>
<th>Season</th>
<th>CP</th>
<th>ADI-CP*</th>
<th>NDF</th>
<th>ADF</th>
<th>ADL</th>
<th>Ash</th>
<th>CT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quercus ilex-Sardinia²</td>
<td>spring</td>
<td>10.12</td>
<td>19.16</td>
<td>57.95</td>
<td>37.73</td>
<td>16.25</td>
<td>4.14</td>
<td>3.64</td>
</tr>
<tr>
<td></td>
<td>summer</td>
<td>8.53</td>
<td>22.93</td>
<td>56.19</td>
<td>37.49</td>
<td>15.18</td>
<td>3.96</td>
<td>8.06</td>
</tr>
<tr>
<td>Quercus suber-Sardinia²</td>
<td>spring</td>
<td>9.96</td>
<td>20.47</td>
<td>53.02</td>
<td>36.14</td>
<td>18.35</td>
<td>5.66</td>
<td>12.65</td>
</tr>
<tr>
<td></td>
<td>summer</td>
<td>10.73</td>
<td>13.42</td>
<td>51.63</td>
<td>34.02</td>
<td>14.13</td>
<td>3.72</td>
<td>14.00</td>
</tr>
<tr>
<td>Quercus calliprinos-Israel³</td>
<td>yearly</td>
<td>10.96</td>
<td>15.3</td>
<td>51.77</td>
<td>43.11</td>
<td>19.83</td>
<td>5.48</td>
<td>6.03</td>
</tr>
<tr>
<td>Quercus calliprinos-Israel³</td>
<td>young</td>
<td>13.32</td>
<td>n.d.</td>
<td>45.04</td>
<td>35.57</td>
<td>14.81</td>
<td>3.80</td>
<td>4.20</td>
</tr>
<tr>
<td>Israel-Quercus boissieri³</td>
<td>yearly</td>
<td>11.07</td>
<td>8.49</td>
<td>47.53</td>
<td>35.39</td>
<td>14.85</td>
<td>7.29</td>
<td>3.40</td>
</tr>
<tr>
<td>Pistacia lentiscus Sardinia²</td>
<td>spring</td>
<td>9.57</td>
<td>25.05</td>
<td>42.17</td>
<td>31.01</td>
<td>20.04</td>
<td>4.93</td>
<td>18.49</td>
</tr>
<tr>
<td></td>
<td>summer</td>
<td>9.92</td>
<td>27.80</td>
<td>42.03</td>
<td>34.74</td>
<td>23.24</td>
<td>4.59</td>
<td>21.74</td>
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<tr>
<td>Pistacia lentiscus-Israel³</td>
<td>spring</td>
<td>8.75</td>
<td>n.d.</td>
<td>n.d.</td>
<td>n.d.</td>
<td>n.d.</td>
<td>n.d.</td>
<td>11.8</td>
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<tr>
<td></td>
<td>summer</td>
<td>7.50</td>
<td>n.d.</td>
<td>n.d.</td>
<td>n.d.</td>
<td>n.d.</td>
<td>n.d.</td>
<td>10.7</td>
</tr>
<tr>
<td>Pistacia lentiscus-Israel³</td>
<td>yearly</td>
<td>5.20</td>
<td>n.d.</td>
<td>63.4</td>
<td>52.5</td>
<td>33.4</td>
<td>3.12</td>
<td>23.5</td>
</tr>
<tr>
<td>Rhamnus alaternus-Sard.³</td>
<td>spring</td>
<td>14.26</td>
<td>3.13</td>
<td>23.14</td>
<td>14.17</td>
<td>5.59</td>
<td>8.19</td>
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<td>summer</td>
<td>11.90</td>
<td>4.15</td>
<td>21.87</td>
<td>14.67</td>
<td>6.18</td>
<td>9.27</td>
<td>6.33</td>
</tr>
<tr>
<td>Rhamnus lycioides-Israel³</td>
<td>spring</td>
<td>11.88</td>
<td>n.d.</td>
<td>n.d.</td>
<td>n.d.</td>
<td>n.d.</td>
<td>n.d.</td>
<td>1.90</td>
</tr>
<tr>
<td></td>
<td>summer</td>
<td>8.12</td>
<td>n.d.</td>
<td>n.d.</td>
<td>n.d.</td>
<td>n.d.</td>
<td>n.d.</td>
<td>0.40</td>
</tr>
<tr>
<td>Rhamnus lycioides-Israel³</td>
<td>yearly</td>
<td>13.66</td>
<td>7.2</td>
<td>37.22</td>
<td>32.0</td>
<td>18.36</td>
<td>9.76</td>
<td>1.61</td>
</tr>
<tr>
<td>Pyrus amigdaloformis Sard.²</td>
<td>spring</td>
<td>11.66</td>
<td>11.18</td>
<td>40.89</td>
<td>25.02</td>
<td>10.44</td>
<td>6.46</td>
<td>4.61</td>
</tr>
<tr>
<td></td>
<td>summer</td>
<td>11.55</td>
<td>12.16</td>
<td>39.32</td>
<td>22.27</td>
<td>11.19</td>
<td>7.18</td>
<td>3.80</td>
</tr>
<tr>
<td>Pyrus syriaca-Israel³</td>
<td>yearly</td>
<td>10.19</td>
<td>8.73</td>
<td>31.58</td>
<td>21.97</td>
<td>8.90</td>
<td>9.52</td>
<td>2.36</td>
</tr>
</tbody>
</table>

*as percentage of total CP.
²Cabiddu et al., 1998.
³Gilboa, 1996.
⁵Perevolotsky, 1994.

Tannins to be a reduction of feed protein availability and depression in activity of digestive tract enzymes. These effects are mediated by the tendency of tannins to form complexes with proteins. Tannins may bind and reduce the digestibility of several carbohydrates in the gut, particularly cellulose, starch and pectin. Tannins may impair the activity of various microorganisms in the rumen by adhering to the membranes of protozoa or by forming complexes with bacterial cell walls. Tannins may reduce the availability of some minerals, such as iron. Finally, tannins, particularly the hydrolyzable ones, may induce gut irritation and systemic toxicity (Blood and Radostits, 1989).

2.4. Polyethylene-glycol (PEG) as means to neutralize the detrimental effects of tannins

Polyethylene Glycol (PEG) is a polymer that can bind tannins irreversibly over a wide range of pH, and its presence reduces the formation of a protein-tannin complex (Jones and Mangan, 1977). PEG was supplied to grazing ruminants by: (i) spraying of tannin-rich browse (Kumar and Vaithiyanathan, 1990), (ii) mixing with tannin-rich harvested leaves (Kumar and Vaithiyanathan, 1990), and (iii) oral-drenching of animals grazing on tannin-rich pasture (Pritchard et al., 1988; Terril et al., 1992). These procedures have been reported to increase feed intake and digestibility in goats and sheep, and wool growth in sheep; however, they are either impractical under field conditions (drenching) or uneconomical (spraying, harvesting and mixing). Recently, a new direction that is practical for field application has been proposed. Administration of PEG to sheep and goats is carried out once daily by mixing it with small amount of concentrates (Silanikove et al., 1994, 1996a; Decandia et al., 1998) or by dilution in the drinking water (Perevolotsky, unpublished data). The logic behind this approach relates to the finding that as with monogastric animals a considerable portion of the antinutritional effects of tannins occurs in the intestine by depressing of the activity of the pancreatic enzymes (Silanikove et al., 1994, 1996a).
Thus, despite the rapid washout of PEG from the rumen as a water-soluble molecule, the typical MRT of fluid in the entire gastrointestinal tract (approximately 40 h, Silanikove et al., 1993) allows effective neutralization of ruminal and post ruminal effects of tannins by PEG. In fact, twice a day provision of PEG was no more effective than once-daily provision in terms of positive effects on intake and digestibility (Silanikove et al., 1994).

Browse constitutes the majority (approximately 60%) of the natural vegetation selected by goats on Mediterranean scrubland year around (Meuret, 1997; Perevolotsky et al., 1998; Kababya et al., 1998; Decandia et al., 1998). In ecosystems dominated by varieties of oak (ca. 10% condensed tannins) providing goats with a daily dose of 10 g PEG yielded the best cost-benefit response in terms of improved intake and organic matter digestibility (Silanikove, 1996a). In woodland dominated by *Pistacia lentiscus*, in which CT content reaches 20%, the daily dose of PEG needed by goats to neutralize the effects of CT amounts to 25 (Silanikove et al., 1996c) or even 50 g (Decandia et al., 1998). In addition, PEG prevented the negative effect of concentrates rich in starch on browse intake, and allowed using expensive dietary protein from soybean meal without wasting it in tannin-linked complexes (Silanikove et al., 1997b). The cost of 10 g PEG (0.09 US $ under Israeli conditions) is cheap, when compared to the cost of increased digestible organic matter or protein that it allows. Consequently, it appears that the use of PEG under paddock conditions is potentially economically profitable. This aspect was tested with range-fed goats. Experiments were carried out in locations representing different types of management systems in Israel (see Landau et al., 1995 for review on the management systems, which are used for goat farming in Israel) and in Italy (Decandia et al., 1998). Most interestingly, PEG-supplemented Sarda goats spent more time foraging on tanniferous species, and less on herbaceous, ingested more dry matter and digested more protein than unsupplemented counterparts (Decandia et al., 1998). Although PEG-supplemented goats ingested generally more DM, and digested more protein and energy from browse, production responses were different among breeds. In Mamber goats weight gain during pregnancy and higher birth weight of the kids were noted (Gilboa, 1996), whereas the most noticeable response was an increase in milk yield in Anglo-Nubian (Gilboa, 1996) and Sarda goats (Decandia et al., 1998). Higher milk yield in Mamber goats supplemented with PEG was reflected in higher growth rate of kids, but this effect vanished after weaning (Gilboa, 1996). PEG-feeding was associated with lower content of lactose in milk, but this effect may be confounded with its effect on milk yield (Gilboa, 1996).

3. Mediterranean crop aftermath a food resource for small ruminants

Rainfed winter small grain farming is a typical Mediterranean activity. After natural pastures are dry and depleted, flocks are turned to stubble grazing when wheat and barley have been harvested. In Southern and Eastern Mediterranean countries, animals are kept on stubble from June to September. Cereal stubble covers more than 20% of the annual energy requirements of sheep (Perevolotsky and Landau, 1988). In spite of their quantitative importance, cereal stubble is a resource under siege because: (i) wheat growers-who are not always stock owners-claim that weed infestation is correlated with grazing (Arnold, 1980; Rabinowitz, 1995), (ii) biological systems analysts contend that utilization of wheat aftermath by baling in feedlot rations is economically preferable to grazing because it decreases energy wasting at pasture (Ungar, 1990) and (iii) in semi-arid areas, more and more wheat is grown using a no-till straw-mulching technology that optimizes water utilization (Amir et al., 1996), but seems incompatible with grazing.

3.1. The composition of cereal stubble

A recent survey of 8 wheat fields in the semi-arid region of Israel (Rosilio et al., 1998), in agreement with a Moroccan study (Guessous, 1992) has shown that harvested grain represents 34% of the total wheat biomass accumulated in the field. Baled straw and stubble represented 27 and 39% of wheat biomass, respectively. Fallen grain following mechanic harvesting represented 2% of total biomass after harvest of oat grain in Portugal (Abreu and Freitas,
1988), 2% of wheat in Morocco (Guessous, 1992), 2% of all cereal in Spain (Vera y Vega and Fernandez de Mesa, 1988), and 1.4% of wheat in Israel (Zaban, 1981). Surprisingly, no such data exist on traditional harvesting of wheat. Stubble may be partitioned into small, delicate-mostly from leaf-parts (43%) and rougher-mostly from stem-parts (57%) that differ in crude protein and metabolizable energy (Rosilio et al., 1998). In studies carried out in Syria, head, leaf and stem components represented 4%, 54% and 42% of biomass, respectively (Rihani et al., 1991). Thorough examination of wheat stubble (devoid of grain) in the Mediterranean part of Australia established that the leaf:stem ratio ranges between 0.41:0.46 to 0.20:0.71, the rest being composed of dust and weeds (Wales et al., 1990). Chemical composition of wheat stubble is affected, besides harvesting technology, by wheat cultivar and climate: early-maturing stubble contain more NDF, ADF and lignin, and less protein than late-maturing cultivars. This results in lower energy content in stubble from early-maturing wheat (Rao and Dao, 1994). Within a given cultivar, stubble contain more protein in years of lower rainfall (Guessous, 1992). Tillage management does not affect stubble quality (Rao and Dao, 1994).

3.2. Nutritional value of cereal stubble

Table 2 presents data on the nutritional value for sheep of stem, and of the two leaf components of a typical Mediterranean straw (58% stem). The digestibility of the leaf components is ca. 55%, comparable to 57% in an Israeli study (Rosilio et al., 1998), and of the stem components ca. 32%, compared with 42% in the stem component of stubble in Israel. In Syrian studies at ICARDA, the digestibility of Organic Matter was 72%, 49% and 44% for head, leaf and stem components, respectively (Timothy Treacher, personal communication). If grain escaped from the harvest combine is included, digestibility of OM from different components ranges between ca. 80% (grain) to ca. 40% (stem). The paradox of stubble is well explained by this heterogeneity: stubble may be regarded as an excellent resource that provides for more than maintenance requirement for sheep, or as an extremely poor feed that does not deserve being grazed.

The first issue to clarify the nutritional value of stubble for sheep is intake. This question has been addressed by studying the dynamics of wheat stubble disappearance by Guessous (1992): the CP content of stubble decreases 30% over 30 grazing days, and the digestibility decreases 12% because of the selective pattern in which sheep utilize this resource. First, residual grain and leaf are consumed, followed later by stem components. This means that lower stocking density, i.e. higher offer of stubble per animal, will result in intake of stubble richer in N and more digestible, as shown for housed goats fed straw by Owen et al. (1986) and by Rihani et al. (1991) in sheep grazing on barley stubble. This is consistent with the observation that sheep will gain weight when first turned to stubble and loose weight later, depending on stocking rate (Coombe et al., 1987). In addition, a cyclic pattern of body weight

<table>
<thead>
<tr>
<th>Stubble component</th>
<th>LB</th>
<th>LS</th>
<th>S</th>
<th>All Stubble</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic matter (OM)</td>
<td>863</td>
<td>889</td>
<td>954</td>
<td>922</td>
</tr>
<tr>
<td>NDF</td>
<td>708</td>
<td>753</td>
<td>854</td>
<td>783</td>
</tr>
<tr>
<td>Ash-free NDF</td>
<td>667</td>
<td>724</td>
<td>834</td>
<td>776</td>
</tr>
<tr>
<td>ADF</td>
<td>517</td>
<td>486</td>
<td>496</td>
<td>498</td>
</tr>
<tr>
<td>Lignin</td>
<td>45</td>
<td>48</td>
<td>77</td>
<td>67</td>
</tr>
<tr>
<td>Residual ash</td>
<td>90</td>
<td>67</td>
<td>17</td>
<td>36</td>
</tr>
<tr>
<td>Silica</td>
<td>54</td>
<td>41</td>
<td>1</td>
<td>34</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>5.7</td>
<td>3.1</td>
<td>2.1</td>
<td>3.4</td>
</tr>
<tr>
<td>In Vitro Digestibility of OM</td>
<td>540</td>
<td>550</td>
<td>320</td>
<td>410</td>
</tr>
</tbody>
</table>
changes was found in sheep grazing barley stubble, illustrating the periodic grazing on ungrazed, rich stubble, and depleted stubble (Rihani et al., 1991). There exists a number of methodological pitfalls in the evaluation of stubble intake by sheep. Firstly, disappearance from the field is not equivalent to ingestion by sheep: in particular, a major proportion of grain (80-95%) disappears from the soil surface in the first 3 months after being shed, due to ant, and in particular, *Messor* spp. activity (Ofer, 1980). Ants and rodents also predate on leaf components (Michaël Luria, in preparation). Secondly, collecting representative samples of stubble is difficult, because the composition of samples depends on their location relative to the combine track. This limitation has been partially solved by fitting the width of the sampling quadrat to the width of the harvesting combine (Rihani et al., 1991). Thirdly, the classical methods for intake evaluation in grazing animals are based on the use of undigestible markers, such as n-alkanes, given orally and recovered in the feces (Mayes et al., 1986). An equilibration of ca. 7 days, under steady state, is required before feces is grab-sampled. These methods are not appropriate for sheep grazing wheat stubble, whose diet, i.e., a mixture of grain, leaf and stem components may be very different from day to day (Rihani et al., 1991). A modification of Penning and Hooper’s (1985) method based on short-term weight changes, using ±10 g weighing scale, that takes into account irreversible weight losses, has been successfully used to evaluate the intake (but not its components) of stubble by sheep in the Negev of Israel. The grazing day was consisted in two grazing bouts from 06:00 to 12:00 and 14:00 to 20:00. Between grazing bouts, water was supplied and sheep were allowed to rest. Sheep were harnessed and excreta were gathered for all the duration of grazing. Irreversible loss weight was measured between 06:00 to 07:00, 11:00 and 12:00 and 19:00 to 20:00. Temperatures were above 30°C and IWL reached 400 g*h⁻¹. An error of 10 min in weighing time could induce an error of 70 g in stubble intake, which could be cumulated 3 times and would be additive to the weighing error, thence, accurate recording of weighing time is critical. Sheep consumed ca. 800 g of stubble, 25% less than estimated by disappearance from the field, similar to the estimation of Vera y Vega and Fernandez de Mesa (1988) but inferior to the disappearance values reported by Rihani et al. (1991). Variation between animals was very high. This modified Penning and Hooper method would best be performed in oesophageal-fistulated animals to provide both quantitative and qualitative estimation of stubble components eaten.

### 3.3. Supplementation of small ruminant kept on cereal stubble

When productive sheep are kept on depleted stubble, or stocking rate is high, supplementation is needed to prevent impairment of body condition. This is not necessarily so in goats, because when straw is given as the sole feed, N-recycling is more efficient in goats than in sheep (Tisserand et al., 1991). In addition, N recycling is more efficient in goats originating from arid zones, such as Bedouin Sinai goat, than in counterparts from temperate regions, such as the Saanen (Silanikove et al., 1980; Silanikove, 1986).

Although reciprocal interactions between supplemental feeding and cereal stubble have not been published, to our knowledge, rules derived from studies with low-quality roughage (Fick et al., 1973) can be extrapolated to cereal stubble. Relatively small amounts of degradable protein stimulate consumption of these roughages, whereas small amounts of starchy energy supplementation have negligible effect. At higher levels of starchy energy, but not protein, supplementation, the intake of stubble is decreased: grazing Sarda ewes decreased their intake of mature standing hay when supplemented corn grain, but not soya-bean meal, given on an iso-energetic basis (Molle et al., 1995). Grains from legume species, such as sweet lupine, which are rich in degradable protein, are advantageous in that their substitution ratio with cereal stubble is relatively low (42 g for each 100 g of supplement; Brand et al., 1998). Protein from sunflower meal was superior to urea in mitigating weight loss in sheep grazing on cereal stubble and formaldehyde treatment of protein supplements was not beneficial (Coombe et al., 1987).

### 3.4. Profitability of stubble grazing

Every year, decisions regarding the fate of wheat fields after grain harvesting are taken: should wheat
straw be harvested or should all the stubble stay for grazing? And, if straw is harvested, is stubble grazing profitable? Although the questions are mainly economical, ecological understanding of what happens to wheat standing biomass after grain harvesting should be helpful to take decisions. A computer model has been developed to predict wheat stubble intake by sheep and subsequent performances (increase or decrease in body mass) in West-Australian Mediterranean conditions (Orsini and Arnold, 1986). Input parameters are grain yield harvested from the paddock of stubble (from which stubble biomass is calculated), mean yearly rainfall (from which digestibility is calculated), rate of supplementary feeding and type of sheep. The model predicted correctly (within 2 s.d. of actual values) the decrease in intake over days and subsequent decrease in liveweight.

A modelling approach has been developed to ease the decision whether to bale straw (and feed sheep in feedlots) or allow direct sheep grazing of wheat aftermath stubble (Ungar, 1990). Input parameters of the model include biomass, rate of disappearance, intake of animal for satiation and stocking rate. It was found that a critical parameter for decision was the energy cost of grazing on stubble. Stubble are grazed in the summer, when temperatures are high, but also at the onset of the oestrous season for small ruminants. At that period, a decrease in body condition may be harmful to reproductive performance, whereas an increase in body condition may boost ovulation and reproduction performance (Landau and Molle, 1997).

Maintaining homeothermy in the summer is a challenge. In such condition, energy requirements for maintenance are 73% increased (Benjamin et al., 1977). If this extra demand for energy has to be covered by feed supplementation, then the profitability of stubble grazing may be questionable. Calibration of the increase of energy requirements vs. heat stress increments should contribute to solve this issue.

4. Conclusion

In traditional Mediterranean production systems, local breeds of small ruminants used natural ligneous tannin-rich vegetation and cereal stubble as major dietary components. Five thousand-year adaptations resulted in fitting production performance to the low nutritional potential of these resources. However, the economical performance of these production systems is low. At the eve of the third millennium, income from such animals must be compatible with modern standards of living, inferring that more productive animals must be included in these systems. Research developments, such as PEG supplementation, allow to decrease the deleterious effects of tannins in shrubs, and improve the profitability of goat farming in Mediterranean scrubland and woodland. Deeper understanding of cereal stubble utilization by sheep has been reached. In particular, optimal utilization of stubble can be reached by using progressive supplementation of small amounts of legume grains. These developments will possibly allow to improve the sustainability of these fragile production systems.

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