Small ruminant feeding strategies in smallholder systems: A synthesis of global experiences and recommendations for Ethiopia

ILRI PROJECT REPORT

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Small ruminant feeding strategies in smallholder systems: A synthesis of global experiences and recommendations for Ethiopia

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June 2012

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Editing, design and layout—ILRI Editorial and Publishing Services, Addis Ababa, Ethiopia.

Citation: Thorpe, W., Wamatu, J., and A.J. Duncan. 2012. **Small ruminant feeding strategies in smallholder systems: A synthesis of global experiences and recommendations for Ethiopia**. Addis Ababa, Ethiopia, ILRI.

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Foreword

This report is an output of a six-month project 'Fodder and feed in livestock value chains in Ethiopia – trends and prospects' commissioned by the Australian Centre for International Agricultural Research. The project was led by ILRI together with the Ethiopian Institute for Agricultural Research, the Amhara Regional Agricultural Research Institute and the International Center for Research in the Dry Areas.

The project aimed to develop a preliminary understanding of how feed components of intensifying livestock production systems in Ethiopia are changing as systems intensify and how this is reflected in the feed-related elements of focal value chains. The project outputs included three synthesis reports along with a series of field reports that can be accessed via links in the synthesis reports. This report presents the findings of a desk study on successful feeding strategies for sheep applicable to the Ethiopian context.

Information on the project is online at http://elfproject.wikispaces.com

Abstract

A literature search and feedback from key informants confirmed the authors' own view that while there are many well-documented theoretical options for improved feeding strategies, there has been limited uptake in smallholder small ruminant (SR) systems. Experiences show that a farmer participatory, action-research based approach building upon a good understanding of the product value-chain, will be much more likely to succeed than previous efforts. Applying that approach in Ethiopia to address improvements to common property resources, crop residues, planted forages and ration formulation (smart feeding) has the potential to significantly improve SR meat production through better feeding. Promising entry points are improving reproductive rates and enhancing fattening. Determining what intervention or interventions have potential at which location will require applying to each value chain and location participatory methods and tools such as those being refined in the current ELF project: VCA (value chain assessment), FEAST (feed assessment tool) and Techfit (technology prioritization). These tools can catalyze the collaboration between research and development staff that will be required to overcome the previous lack of impact of research to improve feeding strategies.

Introduction

This short report contributes to the ACIAR-funded ELF Project and addresses the Project Deliverable: "Synthesis of experiences with successful small ruminant feeding strategies from elsewhere with recommendations for how they could be modified for Ethiopia".

The context is the Project's aim to better understand "how feed components of livestock production systems in Ethiopia are changing as systems intensify and how this is reflected in the feed-related elements of focal value chains". The implication is that the recommendations from the synthesis will serve as potential feed-based interventions for improving the livelihoods of smallholders keeping sheep and goats (small ruminants, SR) and that these interventions will contribute to the intensification of the SR production.

In this report the term "smallholder" covers the range of households depending for their core livelihood on practices that range from 'landless small-scale livestock-keeping' to 'pastoral systems that use extensive areas of common property pastures'. In rural Ethiopia, as in many tropical developing countries, the large majority of smallholder households practise small-scale crop-livestock farming in which subsistence food production is the major objective and any surpluses may be sold.

Identifying successful small ruminant feeding strategies

A three-pronged approach was taken to identify successful small ruminant feeding strategies from elsewhere that could be relevant to small ruminant production in Ethiopia:

- the authors drew on their knowledge of current and past R&D activities and the related literature;
- an electronic search of the global literature on small ruminant systems was carried out;
- key informants were approached for their advice, for information about any undocumented successes and for links to the grey literature.

Given the minor roles of SR milk and fibres relative to meat production in Ethiopia, and the apparent large scope for the increased domestic and export marketing of SR meat, it was decided to focus the search for successes on smallholder SR meat production.

Broad consensus

Feedback from the key informants, persons of long experience in their regions, confirmed the authors' own view – and the results of the literature search - that while there were many well-documented theoretical options for improved feeding strategies[1], there was limited uptake (successes) in smallholder SR systems.

Broadening the search beyond SR to smallholder dairy and beef fattening provides some examples of successes. However, while these were highlighted during the recent FAO electronic conference that assessed the "*Successes and failures with animal nutrition practices and technologies in developing countries"* (FAO, 2011; Owen et al, 2012)*,* the overall conclusion from the conference was that the general lack of adoption of the many technologies and approaches considered by the review resulted from:

- the failure of scientists to involve farmers when developing new technologies;

[1] See Appendix for selected examples.

- the failure to demonstrate convincing benefit: cost ratios; and,
- the weakness of extension services.

The conference built upon and updates the results of several reviews. These include Ben Salem and Smith's assessment of feeding strategies to increase small ruminant production in dry environments (Ben Salem and Smith, 2008) and the extensive publications by Devendra in Asia (e.g. Devendra, 2010; Devendra and Leng, 2011). Although the latter reviews highlight the success of integrating SR with plantation crops, these systems are not found, at least as yet, in Ethiopia.

It is possible that there were gaps in our literature search as a result of the often poor linkages and information flows between the research and development communities. For example, in the 2006 regional workshop "Goats – Undervalued Assets in Asia" (Gray and Wagner, 2008), it was concluded by the participants that accessing the lessons from development projects and research that often precedes new projects was difficult, and that much information remained unpublished in the files of implementing and funding agencies. However, given the scope of our key informant network and the extent of the formal publications that document apparent successes (e.g. the 2005 special edition of Tropical Grasslands Vol. 39), it seems unlikely that our search has missed significant success stories related to specific improved feeding strategies for smallholder sheep and goat production.

On the other hand what was highlighted throughout was the range of theoretical options but their lack of practical adoption, which emphasizes the need for the farmer participatory, action-research based approach described by Horne and Stür (2003) and typified by the successful adoption of planted forages in upland systems in the Philippines reported by Gabunada et al (2007). Success depended not just on the improved nutrition from planted forages but their key role in labour-saving, soil conservation and catalyzing market-oriented opportunities for the livestock keepers.

Therefore, it is our view that successful feed-based interventions will depend upon long-term inter-institutional approaches that address through participatory methods the broad basis of smallholder livelihoods (i.e. beyond but including livestock), household coping and risk management strategies and the market context of SR meat production. Targeting *successful small ruminant feeding strategies from elsewhere* and applying them within Ethiopia will require building upon and improving our current understanding of the livelihood systems of smallholders and of their farming systems and, within that livelihood and systems context, the value chains for sheep and goat meat.

Table 1: *Major sheep production systems in Ethiopia*

Production Systems	Environment	Characteristics of production systems	
		Main products	**Scale of production and management†**
Sub-alpine sheep–cereal	Sub-alpine (>3000 m)	Meat, fibre, manure, skin; unreliable, long-season barley	Medium scale sheep production; semi-intensive/extensive, low-input
Highland cereal–livestock	Highlands (2000–3000 m)	Mainly cereal, cropping; meat, manure, skin	Small-scale sheep production; semi-intensive, low-input
Highland Perennial crop	Highlands (1500–2000 m)	Mainly perennial, cash crops (coffee, inset, khat); meat, skin	Minor sheep production; semi-intensive, low-input; some practice tethering
Lowland crop–livestock system (agro-pastoral)	Sub-moist/ moist lowland (≤1000 m)	Cereals, sesame, cotton; meat, skin	High level of livestock keeping; extensive/semi-intensive, low-input
Pastoral	Semi-arid/arid (≤1000 m)	Meat, milk, skin; minimal or no cropping	Rangeland-based, large-scale sheep production; extensive, low-input

† Based on feeding, veterinary care, housing practices.
Source: Solomon Giwaz et al. (2010) from Solomon et al. (2008).

Sheep and goat meat production in Ethiopia

Solomon Gizaw et al (2010) describe in detail the sheep and goat production and marketing systems in Ethiopia. Their classification for sheep production, presented in Table 1, captures the variation in agro-ecology, the main products from the systems and the scale of production and management (based on feeding, veterinary care, housing practices). Extensive/low-input production of sheep meat comes from the "Pastoral" and "Subalpine sheep–cereal" systems, while the "Highland cereal–livestock", the "Highland perennial Crop" and the "Lowland crop–livestock (agro-pastoral)" systems can be considered mainly semi-intensive, low-input production.

To design specific projects and select sites representative of household populations having similar feed resource constraints, this broad classification of sheep production systems (Table 1) can be overlain on the more detailed livelihoods classification presented in the Livelihoods Atlas for Ethiopia (GoE/USAID-Ethiopia, 2011). As well as defining local livelihood zones (see, for example, page 123 for the 27 livelihood zones in the Amhara Region, three of which specifically mention sheep and goats), the Atlas provides - based on extensive, repeat household surveys - maps showing the areas in which sheep and goats cover at least 5% of annual total income requirements (page 41). As expected the major determinant of the crop-livestock-based livelihood zones are the staple cereal and root/tuber crops. Examples are: "North Shewa Highland Sheep and Barley" and "Tekeze Lowland Sorghum and Goats".

Testing successful feeding strategies in Ethiopia

While the location-specificity of feed resources, community and household resource endowments and market linkages and their utilization within livelihood zones will determine the opportunities for, and the returns to, feed-based intensification, the characteristics of the five sheep production systems (Table 1) and the related goat systems suggest some broad areas of potential intervention. These relate to farmers' current production practices and the major classes of feed resources in Ethiopia.

The principal feed resources in SR production systems are: natural grazing and browse (often as common property resources); crop residues and crop stubbles; fallow grazing; crop by-products and other concentrate feeds (e.g. brewers grains); and, planted forages (Solomon Gizaw et al, 2010). At any specific location the relative importance of each of these feed classes in supporting production will reflect current land use (public vs private; cropping vs grazing) and cropping practices (Table 1). Opportunities for, and the returns to, feed-based interventions for increasing meat production will also depend on how the flock and its age/sex classes, e.g. ewes/does and pre-slaughter animals, are managed.

Determining what intervention or interventions have potential at which location will require applying to each value chain and location participatory methods and tools such as those being refined in the current ELF project: VCA (value chain assessment), FEAST (feed assessment tool) and Techfit (technology prioritization). The analysis should be capable of showing whether there is potential for feed-based interventions to improve, for example, the performance of breeding females. The expected return will more total live weight of weaned lambs/kids produced per ewe or doe per year. On the other hand – or in addition - a promising entry-point is the better feeding of slaughter stock prior to their sale to increase profit. While other production cycle entry-points may have potential, within current SR systems in Ethiopia these two – improving the performance of breeding females and of fattening/finishing, and especially the latter - seem most promising.

There are various feeding strategies that have been demonstrated elsewhere and/or in Ethiopia for achieving this improved performance.

Common property resources (CPR): These remain important feed resources for significant proportions of Ethiopia's sheep and goat populations and improving the biomass production of degraded CPR can increase overall flock performance and conserved forage can be targeted at specific production objectives, e.g. fattening. In western India, propagated through BAIF and other NGOs, increased fodder and fuel availability has been achieved through introducing village committees to manage degraded CPR and develop silvi-pastures (Rangnekar, pers. comm.). In Ethiopia a similar approach to regenerating CPR has been successful in increasing fodder availability through community-based management in the Fogera and Atsbi-Womberta benchmark sites of the IPMS project (Berhanu Gebremedhin et al, 2010).

Atriplex spp for small ruminants in Tunisia and Morocco

Atriplex (saltbush) is a fodder shrub well adapted to dryland climates and soils. It is a useful protein supplement. Additional benefits of Atriplex include provision of fuelwood and control of soil erosion. The impact of introducing Atriplex as an alley crop with barley in crop/livestock production systems in arid and semi-arid areas of Morocco and Tunisia by ICARDA between 1999 and 2005 was assessed. Results indicated that Atriplex alley cropping (with barley) technology was adopted by 33% of farmers in the targeted community in Morocco, with nearly 24% of the land planted in alley cropping. On average, adopters assigned nearly 27% of their farmland to Atriplex alley cropping but this varied considerably across farms. Overall, the area planted increased by 6% annually since 1999. Farm size, compensation provided by a development project, and flock size of small ruminants were the main factors explaining the expansion in the Atriplex plantations. Area in alley cropping increased with the increases in farm size, flock size, and the availability of the subsidy. The ex-post impact of the alley cropping on barley production is to increase barley grain yield by 17% compared to barley/fallow system. The technology contributed to the increase in flock size of small ruminants by 25% among technology adopters compared to non-adopters due to the increase in feed supply. Likewise, the adoption of this technology resulted in changes in the consumption and mix of alternative feed resources, and consequently of feeding cost. On average, the feeding cost of small ruminants decreased by 33% due to the adoption of the Atriplex technology. This cost reduction was due to the substitution of costly and purchased feed resources, such as wheat bran and sugar-beet pulp, by Atriplex biomass and barley straw. To estimate the impact of alley cropping, the Internal Rate of Return (IRR) was estimated for the 1992-2015 period, taking into account research and extension costs, as well as the subsidy provided by the development project, and all other costs. The estimated IRR was 29%. Results support the economic feasibility of research investment in Atriplex technology. This technology has been sustained in Tunisia and Morocco as a result of the incorporation of the establishment and management of the Atriplex shrubs into their National Strategies for rangeland rehabilitation.

In some of Ethiopia's CPR zones that are prone to drought and salinity, some halophytes, for example *Atriplex,* may be a promising intervention. Various species belong to the Atriplex family and are distinguishable by their different morphology, biological cycle and ecological adaptations (Le Houerou, 1992). Because of their high crude protein content, and tolerance to drought and salinity, most species of Atriplex are excellent livestock fodder in arid and semi-arid areas. *Atriplex halimus, Atriplex lentiformis and Atriplex nummularia* are examples. The Box (above) summarizes experiences using Atriplex for small ruminants in Tunisia and Morocco (Shideed et. al, 2005).

Improving the quantity and quality of crop residues: In Ethiopia's agro-pastoral and crop-livestock systems (Table 1) the area for crop production is increasing and grazing areas are being reduced (Yayneshet, 2010; Firew et al, 2010). Increasingly, therefore, crop residues form a major portion of the diets of large and small ruminants. Improving these cereal and grain legume residues through selecting varieties that yield more total biomass with better quality is a promising approach being applied to sorghum and other cereal crops in India (Blummel, 2010; see text Box below). In West

Africa improved dual-purpose cowpeas (Tarawali et al, 2005) and in India groundnuts (Teufel et al., 2011) have improved the feed resource base for large and small ruminants. Gender-differentiated decision-making is expected to play an important part in adoption rates (Saghir et al., 2012) and should be integral to the participatory approach to identifying and testing promising technologies.

Genetic improvement of the food-feed yields of staple crops

To address the challenge of how to improve the feed as well as the food yields of smallholder staple crops, cost-effective phenotyping to screen large entries of cultivars for relevant fodder traits has been developed (Blümmel et al., 2010). The screening of a wide range of cultivars of rice, wheat, maize, sorghum, pearl millet, cowpea, groundnut, pigeon pea and chickpea has shown that differences of 3-5% units in fodder digestibility can be exploited without detriment to grain yield (Blümmel et al., 2009). Conventional and molecular breeding techniques for improving the food and feed traits simultaneously are more expensive but have higher impact potential because full genetic crop variability can be explored and utilized (Blümmel, 2010). Impact pathways for seeds from superior food-feed cultivars are short compared to, e.g., planted forage technologies, and where competitive private seed industries exist to deliver the cultivar types.

Successful implementation will require, first, NARES capacity to use the phenotyping to identify cultivars for specific crop-livestock contexts and to support innovation systems principles that would embed the research in the development process, and, second, an enabling environment for the private sector, particularly seed and fodder market agents. Therefore, to deliver increased and more efficient feed production from the major staple crops by resource-poor households through improved food-feed crop varieties will require policy support and coordinated capacity building across the crop/livestock, development/ research and public/private sector divides.

Exploring these opportunities for improvements in total yield (human food, crop by-products and residues) through food-feed crop selection within the major cereal and grain legume crops in Ethiopia should be an important component of national efforts to achieve better feeding for meat production from small and large ruminants. Along with any genetic improvement of the food-feed crops it is expected that population pressure and market forces will lead to increased fertilizer use and to other agronomic practices that will contribute significantly to increased crop biomass yields per ha and per unit of labour.

To be successful the genetic improvement of staple cereal and root/tuber crops and grain legumes for food-feed characteristics and increasing biomass yields of these improved crops through agronomic practices (especially fertilizer use) will require substantial investment in systematic R&D. Gaining support for this will require field-based evidence to substantiate the expectation of significant returns through increased crop and livestock productivity and smallholder livelihoods.

Planted forages: For many years efforts to promote the adoption of planted forages by smallholder livestock keepers in Ethiopia as a means of increasing feed availability, have borne scant return.

However, if R&D agencies use the participatory approaches illustrated by the CIAT SE Asia programme (cited above: Horne and Stür, 2003; Gabunada et al, 2007) and target the interventions at locations in which SR systems are, or have the potential to be, market-oriented, significant adoption of planted forages seems likely.

Farmers participating in the ELF field studies ranked planted forages, either as living fences or on soil conservation structures, as promising technologies for increasing feed biomass yield and quality (see http://elfproject.wikispaces.com). A recent report, summarized in the Box below, suggests that *Sesbania sesban,* for example, can fit well in highland crop-livestock systems with small ruminants (Oosting et al., 2011).

Utilization of Sesbania in smallholder farmers in the Ethiopian Highlands depends on the farming system

Sesbania sesban is one of the exotic multipurpose forage trees introduced in the Ethiopian highlands for livestock feed and soil conservation. Sesbania supplementation is appreciated across annual (wheat-based, teff-based) and perennial (coffee-based) livestock systems for its feeding value for sheep. With an average of 6.9 years of experience using sesbania as a cut-and-carry supplementary feed, sheep farmers in the highlands who were interviewed perceived feeding of sesbania to result in increased lamb birth weight, increased body weight gain, earlier onset of puberty, improved pregnancy rate of ewes and rams' libido. Those in coffee-based systems, however, have a less positive perception of sesbania feeding for improved performance and reproduction. They feed less quantity of sesbania less frequently to sheep compared to farmers in the wheat and teff cropping systems. This is due to relatively better availability of good quality feeds in their system. The majority of farmers in wheat systems (87%) and teff systems (85%) supplement sesbania during feed shortage seasons whereas most farmers in coffee systems (67%) have no specific season for supplementation and supplement according to availability. In all farming systems, farmers gave lowest priority to goats for sesbania feeding compared to sheep and cattle. Highest priority is given to sheep in the teff systems. Farmers follow two forms of feeding: wilted or freshly cut. They mention that wilted sesbania removes insects or fungi that might cause bloating or diarrhea when ingested and increases retention time of the feed in the animal. Farmers feeding freshly cut sesbania say they do this to increase intake of Sesbania and crop residues fed along with it.

Establishment and utilization of some planted forages, e.g. multi-purpose trees like Sesbania, is knowledge intensive. For this reason, as shown elsewhere, careful evaluation of agro-ecological suitability and then participatory assessment of farm niches and participatory development of establishment and harvesting management practices, are required if planted forages are to achieve a significant role in improved SR feeding practices.

Smart feeding: Natural grazing, crop residues and various by-products (including traditional brewers' grains) form the major feed components in SR production systems in Ethiopia (Solomon Gizaw et al, 2010). Seasonal variation in feed quantity and quality is a continuing challenge to smallholders' efforts to achieve a better return from their sheep and goats. Water scarcity may also sometimes limit animal performance. Changing the mix of feeds on offer has the potential to significantly improve productivity and profitability but it requires having estimates of the relative nutritive values and prices of available feeds, whether produced by the smallholder or available for purchase, and the prices of the target livestock products. Adugna Tolera (2007, 2008) describes the theory and gives practical examples for Ethiopia. A key objective for SR would be to explore improving live-weight gain by sheep and goats being prepared for sale to meet the demand at religious festivals, and another, to achieve the finish required by specific domestic and export markets.

Smart feeding through better matching the use of feed resources to SR production objectives will be attainable if the systematic participatory analysis of value chains proposed in ELF, are applied. Capturing current prices of SR products and feeds and making that locally-relevant dataset easily accessible to public and private sector livestock advisers will be essential for the approach to work. It requires putting in place a system to routinely collect and collate the data (building upon the dataset compiled by ELF), and making it accessible through, for example, the electronic national market information system. Capacity building of livestock advisers in ration formulation, probably at zonal level, will also be important. In turn the zonal specialists would train the woreda/district staff and their private sector counterparts. Given the important role of traders in SR marketing, their participation in providing advice on feeding practices should be explored.

Two other aspects of smart feeding merit attention. Healthy SR perform better than unhealthy SR. Therefore, improved feeding strategies (e.g. better finishing rations) should address any disease that will limit responses to the better feeding. In SR gastro-intestinal parasites are the obvious example (Gray and Wagner, 2008). Others may be important and assessing the impact of possible disease x nutrition interactions should be integral to efforts to improve SR feeding strategies.

In the same way area-specific mineral deficiencies may limit SR performance and, if addressed, can significantly improve flock productivity (Shinde and Sankhyan, 2011). Assessing the importance of any mineral deficiencies should be part of the SR smart feeding regime.

Conclusions

Experiences with R&D elsewhere that sought to develop improved small ruminant feeding strategies show that a farmer participatory, action-research based approach and drawing on a good understanding of the product value-chain, will be much more likely to succeed than previous efforts. Applying that approach in Ethiopia to address improvements to common property resources, crop residues, planted forages and ration formulation (smart feeding) has the potential to significantly improve SR meat production through better feeding.

Given the major contribution of crop residues and by-products to SR feeding, productive inter-institutional collaboration, e.g. between the crop and livestock sectors will be important. In the same way productive collaboration between public and private sector actors, e.g. traders in SR and feed, and public R&D staff, will be critical to success.

The challenges are substantial but with demand for SR meat rising, satisfying that demand represents an excellent opportunity for improving smallholder livelihoods in Ethiopia through more efficient SR production.

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Appendix: Selected examples of research publications on improving feed resources for small ruminant meat production

Supplements

No.	Species	Where done	Experiment			Experimental Design	Effect on growth/fattening
			Feed tested	Technology option	Basal diet		
1	Highland sheep (males; weight 17 Kg)	Mekelle Agricultural Research Center, Ethiopia	Spineless Cactus (Opuntia ficus-indica)	Supplementation	Tef (*Eragrostis tef*) straw and noug (*Gouzotia abyssinica*) seed cake	Animals were offered 610 g tef straw DM and 57.6 g DM noug. Tef straw was replaced with one fourth, half and three fourths of cactus	Highest ADG (53g/day) with 50% replacement of tef straw with cactu with no digestibility disturbances. Lowest weight gain (23g/day) with no cactus replacement.
2	Highland sheep (males yearlings; weight 19.5 Kg)	Mekelle University, Ethiopia	Wild spiny cactus pear (Opuntia ficus-indica)	Supplementation	pasture hay	Sheep given 50g/kg BW. Cactus pear replaced 0%, 20%, 40%, 60% and 80% of pasture hay DM	Highest ADG (53g/day) with 50% replacement of tef straw with cactu with no digestibility disturbances. Lowest weight gain (23g/day) with no cactus replacement.
3	Comisana breed male lambs weighing 13 kg at weaning (40 days)	Italy	Wild spiny cactus pear (Opuntia ficus-indica)	Supplementation with agro-industrial products	pasture hay	Wheat middlings totally replacing corn, partially replacing (by 100g/d) soybean, partially (by 100g/d) wheatbran Both were TMR pelleted rations	Final live weight (21.9 vs 23.5kg) and ADG (174g/d vs199g/d) as well as feed conversion ratio (4.29 vs 3.74 gDM/g gain) were improved by wheat middlings (P=0.035).

No	Species	Where done	Experiment			Experimental Design	Effect on growth/fattening
			Feed tested	Technology option	Basal diet		
4	Highland sheep (19.5 kg); 14 months old	ILRI, Debre Zeit, Ethiopia.	Air-dried leaves of *L. leucocephala*, *L. pallida*, *C. palmensis* and *S. sesban*	Supplementation with tree & shrub leaves	teff straw (*Eragrostis tef*) fed adlib	leaves supplemented at graded levels of 15, 30, 45, 60 % of ration dry matter intake.	• Animals fed the control diet lost weight (-24.4 g/d, supplemented ones gained weight in the range of 6.5–65.2 g/d. The maximum ADG was 65.2 g/d was observed in sheep fed a diet with 60% L. pallida. • The optimum levels of browse supplementation in terms of live weight gain per g supplement were 45, 45, 30, 30% DM of total ration for L. leucocephala, L. pallida, C. palmensis and S. sesban, respectively.
5	Barbarine lambs	National Institute of Agricultural Research of Tunisia (INRAT) in Tunis	defatted Moringa oleifera seedmeal	Supplementation with oilseed cakes	oat-vetch hay adlib and 100g Soyabean meal	hay and soyabean meal mixed with 0 (Control), 2 (Low), 4 (Medium) or 6 (High) g DM of defatted moringa seed meal per day	Lambs grew at rates of 63.8, 88.5, 97.0 and 76.6 g/day, when fed 1, 2, 4, 6 g/d of moringa respectively (P=0.076)
6	yearling male sheep 21 kg	Maichew Agricultural Technical Vocational Education andTraining College	peanut cakemeal, cottonseed cake, noug cake	Supplementation with oilseed cakes	adlibitum teff; 172g DM cactus pear	supplementation with peanut cake (PNC) 149g, cottonseed cake (CSC) 145g, 195g noug (NSC) cake per head/day	• The ratio of CP intake from protein supplements to the mean ADG was 0.9, 1.78 and 1.10, respectively for CSC, NSCand PNC. • Control had 19.8 g ADG, CSC 69.1, NSC 35.2, PNC 56.7; ADG for CSC and PNC was significantly higher than control.
7	weaned male Nellore lambs and local kids (3-4 months old)	Hyderabad, India	cage layer droppings (CLD) /poultry litter (PL)	Supplementation with poultry litter	chopped sorghum straw adlib	Three low cost feed supplements containing (1)30% CLD; (2) 22.5% CLD and 7.5% PL; (3) 15% CLD and 15% PL and processed into pellets (97-98°C, 30-40 S).	30% CLD had 12.87% and 16.86% higher (ns) ADG than rations with 22.5% and 15% CLD respectively, indicating that CLD was more efficiently utilized than PL.
8	Farta yearling male lambs weighing 17.4kg	South Gondar Zone, Farta Woreda, Amhara Region, Ethiopia	Acacia saligna leaves	Supplementation with leaves from farm trees	grass hay	700 g grass hay (dry matter basis), feeding of lambs with grass hay and grass hay supplemented with700 g of either fresh, wilted, or dried A. saligna leaves	Dried form A. saligna leaves resulted in improved (P<0.05) ADG than feeding fresh A. saligna leaves.

No	Species	Where done	Experiment			Experimental Design	Effect on growth/fattening
			Feed tested	Technology option	Basal diet		
9	Barbarine yearling lambs- 4 months old 22 kg	OEP farm in Jebinina, Central Tunisia	barley, cactus, Atriplex nummularia	Supplementation with leaves from farm trees	Acacia cyanophylla foliage and twigs	acacia adlib supplemented with either barley alone, cactus alone, with barley and atriplex, with cactus and atriplex	• In the presence or absence of Atriplex, replacing barley with cactus significantly reduced growth rate of sheep• Cactus as a sole supplement of acacia resulted in a weight loss of sheep. Providing Atriplex as a source of N is necessary to improve growth.
10	Oudah bicolour male lambs of 27 kg; 12 months old	Regional Centre for Agricultural Research (CERRA) of Maradi, in the Central South of Niger	groundnut haulms, millet bran and wheat bran	Supplementation with agro-industrial by-products and xxx by-products	millet stover	millet stover supplemented with four levels of Groundnut haulms-GH (0, 200, 400, and 600 g) or (600 g GH + 100 g Millet bran) or (600 g GH + 75 g Wheat bran)	• GH also had a positive linear effect (P<0.001) on LW gain and feed conversion efficiency • The maximum ADG (80.5 g/d) was with Gnut haulms + wheat bran followed by Gnut haulms + milletbran (68 g/d). Sheep fed no gnut haulms lost BW (19.1 g/d).
11	4-month-old Barbarine male lambs,18.5 kg	National Instituteof Agricultural Research of Tunisia (INRAT)	tomato pulp; olive cake feed blocks (other ingredients in the blocks included: wheat bran, rapeseed meal, wheat flour residue, quicklime, salt, urea, minerals and vitamins)	Supplementation with agro-industrial by-products	wheat straw adlib	Wheat straw was fed ad libitum and supplemented with (1) 500 g concentrate (2) 250 g C and Tomato pulp feed block (TP-FB + 0.5C); (3) 250 g C and olive cake feed block (OC-FB + 0.5C); (4) 125 g C and TP-FB (TP-FB + 0.25C); or (5) 125 g C and OC-FB (OC-FB + 0.25C) Except control-animals, lambs had free access to feed blocks.	• The response of lambs was in general better with diets containing olive cake-feed blocks than those supplemented with tomato pulp-feed blocks. • The highest daily gain was obtained in lambs given 250 g/day of concentrate and Olive cake feed blocks

No.	Species	Other Effects	Duration of experiment	Conclusion/comments	References	
					Title	Author/s
1	Highland sheep (males; weight 17 Kg)	• Cactus was readily consumed and the animals preferred cactus to tef straw • water intake was negatively correlated (r =−0.88) with cactus intake. • The digestibility coefficients for CP, NDF and ADF reduced as the cactus level increased in the diet.	118 days	Cactus can optimally substitute tef straw with up to 50%	Effect of different levels of cactus (*Opuntia ficus-indica*) inclusion on feed intake, digestibility and body weight gain in tef straw-based feeding of sheep	Tikabo Gebremariam, Solomon Melaku ,Alemu Yami; Animal Feed Science and Technology 131 (2006) 42–51
2	Highland sheep (males yearlings; weight 19.5 Kg)	• The highest DM intake (92 g/kg $W^{0.75}$) was recorded with 60% replacement •Sheep on the control diet drank the highest amount of water (1226 ml/day), while supplemented sheep drunk negligible amount of water.	90 days	Cactus pear can optimally substitute pasture hay up to 60%	Study on the optimal level of cactus pear supplementation to sheep and its contribution as source of water	Firew Tegegne, C. Kijora, K.J. Peters; Small Ruminant Nutrition, 72:157-164
3	Comisana breed male lambs weighing 13 kg at weaning (40 days)	• Wheat middlings had no effect on lamb carcass traits. • Feed intake was similar (745 vs 743g/d)	50 days	Wheat middlings are 50% the cost of corn	Feeding of wheat middlings in lamb total mixed rations: Effects on growth performance and carcass traits	V. Tufarelli, R.U. Khan, V. Laudadioa; Animal Feed Science and Technology (2011): 130-135
4	Highland sheep (19.5 kg); 14 months old	• S. sesban and C. palmensis had higher rates of degradation than the Leucaena species	90 days	• The differences in substitution rates among the browses may be related to relative rates of degradation of these supplements from the rumen • Browses low in tannin S. sesban, C. palmensis. increased animal performance by enhancing DM intake while high tannin species L. pallida and L. leucocephala. increased live weight gain by increasing the efficiency of utilization of the nutrients. • This study indicate an optimum level of leaves at 30 to 45% of the ration DM	Effect of feeding graded levels of *Leucaena leucocephala*, *Leucaena pallida*, *Sesbania sesban* and *Chamaecytisus palmensis* supplements to teff straw given to Ethiopian highland sheep	R.J. Kaitho, N.N. Umunna, I.V. Nsahlai, S. Tamminga, J. Van Bruchem; Animal Feed Science and Technology 72 1998. 355–366
5	Barbarine lambs	Reduction of ADG at feeding level of 6 g/day could possibly be due to the presence of glucosinolates.	45 days	• Increase in ADG wit increasing moringa possibly due the trend to an increase in the microbial N supply (P=0.109) and the trend (P=0.086) to higher N retention with higher levels of moringa in the diet • 2-4g/day of moringa recommended when hay-soyabean meal is fed	Defatted Moringa oleifera seed meal as a feed additive for sheep	H. Ben Salema, H.P.S. Makkar; Animal Feed Science and Technology 150 (2009) 27–33
6	yearling male sheep 21 kg	• CSC and PNC resulted in higher (P<0.001) BW change	90 days	NSC and PNC also resulted in higher (P<0.01) apparent digestibility of DM and OM compared to the control	Supplementation of isonitrogenous oil seed cakesin cactus (Opuntia ficus-indica)–tef straw(Eragrostis tef) based feeding ofTigray Highland sheep	Amare Degu, Solomon Melaku, Gebreyohannes Berhane; Animal Feed Science and Technology148 (2009) 214–226

No.	Species	Other Effects	Duration of experiment	Conclusion/comments	References	
					Title	Author/s
7	weaned male Nellore lambs and local kids (3-4 months old)	The ADG was higher (P < 0.01)in lambs compared with kids, indicating that the lambs were more efficient in utilizing nutrients from these rations compared to kids. Kids required 14.6% more DM per kg gain than lambs.		Inclusion of cage layer droppings up to 30% in feed supplements had no adverse effects on growth, feed efficiency and nutrient utilization by lambs and kids.	Utilization of cage layer droppings and poultry litter as feed supplements for lambs and kids	Murthy et al., 1995
8	Farta yearling male lambs weighing 17.4kg	• Leaves improved the daily intake of DM by 8–9% and that of OM and CP by 7 and 38%, respectively compared to the control, replaced the intake of the grass hay by 26–27% of the total diet • A. saligna leaves increased (P<0.05) the final bodyweight and average daily weight gain (ADWG) (P<0.01) compared to the control, but no significant difference in final body weight was observed between the different forms of A. saligna leaves • fresh and wilted forms of A. saligna leaves showed higher levels ADF, ADL and condensed tannins, indicating their inferiority to be used as a supplement compared to the dried form, since feeds with higher fibre contents limit feed intake and digestibility		Inclusion of different forms of A. saligna leaves resulted in improved body weight gain and body measurements due to improved CP and OM intakes, and reduced the NDFom intake.	Effects of different forms of Acacia saligna leaves inclusion on feed intake, digestibility and body weight gain in lambs fed grass hay basal diet	Berhan Tamira,Getachew Asefab; Animal Feed Science and Technology 153:39-47
9	Barbarine yearling lambs- 4 months old 22 kg	• Cactus alone was not able to replace barley as supplement to acacia. It should be offered in combination with a nitrogen -rich supplement such as Atriplex to ensure normal microflora activity in the rumen.	70 days	DM intake of acacia was low, in the range of 26.3 - 38.3g/Kg $W^{0.75}$. Cactus provided alone or with atriplex reduced DM intake of acacia significantly.	Supplementation of Acacia cyanophylla based foliage diets with barley or shrubs from arid areas (cactus and Atripex nummularia) on growth and didgestibility of lambs	H. Ben Salem, A. Nefzaoui, L. Ben Salem; 2002; Animal Feed Science and Technology 96:15-30
10	Oudah bicolour male lambs of 27 kg; 12 months old	• Increasing level of GH caused a linear reduction (P<0.001) of millet stover intake	66 days	In the dry season, it is practical to supplement sheep with low levels (i.e., 200 g) of GH to support moderate LW gain or with 600 g GH + 75 g WB to support high LWgain.	Effects of groundnut haulms supplementation on millet stover intake, digestibility and growth performance of lambs	N. Abdoua, I.V. Nsahlaia, M. Chimonyoa; Animal Feed Science and Technology 169 (2011) 176–184
11	4-month-old Barbarine male lambs,18.5 kg	• Partial replacement of concentrate with the feed blocks had no effect on straw intake. • Tomato pulp is higher in CP than olive cake (201 g/kgDM vs. 65 g/kg DM, respectively) there was no need to include urea, rapeseed meal and wheat flour residue in the formula of TP-FB. The absence of urea and rapeseed meal in TP-FB could be among the reasons why sheep responded better to OC-FB.	75 days	OC-FB are cost-effective alternative supplements and allow farmers to reduce by 0.75 the amount oflocal concentrate used, while TP-FB allow a 0.5 reduction	Partial replacement of concentrate with tomato pulp and olive cake-based feed blocks as supplements for lambs fed wheat straw	H. Ben Salem, I.-A. Znaidi; Animal Feed Science and Technology 147 (2008) 206–222

Feeds from cropping systems

No.	Species	Where done	Experiment			Experimental Design	Effect on growth/fattening
			Feed tested	Technology option	Basal diet		
1	one year old local male sheep (17.3 kg)	Ethiopia (not very clear)	Leaves of enset	Feeds from cropping systems	Wheat (Triticum aestivum) straw untreated and treated with urea and CaO treatments	Three levels of chopped fresh enset leaf: low (215 g), medium (417 g) and high (594 g dry matter [DM] per day).	At low level of enset leaf supplementation, sheep lost weight in untreated and treated wheat straw (2.4 and 1.8 g/d, respectively). The highest ADG (29.8 g/d) was observed in sheep fed a basal diet of untreated straw at high level of enset leaf supplementation The highest enset leaf DM intake was at medium level of supplementation
2	one year old local male sheep (20.2 kg)	Ethiopia (not very clear)	Enset	Feeds from cropping systems	Wheat straw and desmodium hay (legume)	Ddifferent parts of enset (a) enset pseudostem, b) enset corm & c) enset mixture (containing equal amounts of pseudostem, corm and enset leaf on a DM basis)	• No differences in gain/day in sheep fed diets with pseudostem (29.3 g), corm (27.0 g) and enset mixture (36.5 g).
3	West African Dwarf goats	Small Ruminant Experimental Unit, College of Animal Science and Livestock Production, University of Agriculture, Abeokuta, Nigeria.	Dried cassava leaves	Feeds from cropping systems	Guinea grass (*Panicum maximum*)	Feeding dried cassava leaves at inclusion levels of 0, 20, 40 and 60% of DM respectively, using guinea grass as a basal feed. Other ingredients in the diets were dried brewers' grains, wheat bran, molasses, sulphur, salt and vitamin/mineral premix	ADG of supplemented animals was significantly ($P<0.05$) higher than in the control group. The highest gain was recorded in goats with 60% of dried cassava leaves in the diet (52.9 g/d) and lowest for the unsupplemented (control) (33.8 g/d)

No.	Species	Other Effects	Duration of experiment	Conclusion/comments	References	
					Title	Author/s
1	one year old local male sheep (17.3 kg)	• DM intake tended to be higher ($p<0.1$) at medium and high levels of enset than at the low level. • No major beneficial effect beyond medium level of enset leaf supplementation in both treated and untreated straw. Enset has tannins & lignin	76 days	For efficient utilization of enset leaf, sources of fermentable energy are necessary. Urea- and CaO-treated straw was poorly utilized probably due to the lack of energy to maximize nutrient utilization as enset leaf is poorly digestible.	Effect of enset (*Ensete ventricosum*) leaf supplementation on feed intake, digestibility, nitrogen utilization and body weight gain of sheep fed untreated or urea and calcium oxide-treated wheat straw	Ajebu Nurfeta, Adugna Tolera, Lars O. Eik, Frik Sundstøl;Livestock Science 122 (2009) 134–142
2	one year old local male sheep (20.2 kg)	no difference in DM or OM intake	71 days	enset fractions can be fed equally	The supplementary value of different parts of enset (*Ensete ventricosum*) to sheep fed wheat straw and *Desmodium intortum* hay	Ajebu Nurfeta, Adugna Tolera, Lars O. Eik, Frik Sundstøl; Livestock Science 119 (2008) 22–30
3	West African Dwarf goats	The total DM intakes were 482, 526, 537 and 528 g/d for the 0, 20, 40 and 60% of dried cassava leaves in the diet, respectively.	112 days	The lowest feed cost/unit weight gain was at the 60% inclusion level of dried cassava leaves, and the costs were higher with lower inclusion levels.	Effects of feeding different levels of dried cassava leaves (*Manihot esculenta, Crantz*) based concentrates with Panicum maximum basal on the performance of growing West African Dwarf goats	A.O. Oni, O.M. Arigbede, O.O. Oni, C.F.I. Onwuka, U.Y. Anele, B.O. Oduguwa, K.O. Yusuf; Livestock Science 129 (2010) 24–30

Improved forages

No.	Species	Where done	Experiment			Experimental Design	Effect on growth/fattening
			Feed tested	Technology option	Basal diet		
1	Menz male sheep 18.3kg	Holetta Research Centre	tagasaste forage	improved forages - fodder trees	natural pasture hay	• supplementing effect of tagasaste forage as a substitute for a concentrate supplement (wheat bran–noug seed cake) • iso-nitrogenous supplements of 100% concentrate offered at 200 g DM/sheep/day, 67% concentrate +33% tagasaste, 33% concentrate +67% tagasaste and 100% tagasaste	Average daily weight gain of sheep in the different treatments did not differ significantly, sheep fed 100% conc had a higher daily weight gain while in the other three treatments daily weight gain declined with increased level of tagasaste inclusion.
2	yearling castrated male Ethiopian Menz sheep; weight 22.3 kg	Ethiopia (where.. Not mentioned)	dolichos lablab (*Lablab purpureus)* hay, leaves of sesbania (*Sesbunia sesbun*) or tagasaste (*Chamaecyfisus palmensis*); wheat middlings	improved forages - fodder trees	oats hay; oats straw	Oats hay was given ad libitum (1.4 times the expected intake) either alone or supplemented with 250 g (air dry weight) of either dolichos lablab (50% flowering at harvest) hay, wheat middlings, sesbania leaves or tagasaste leaves. A further treatment was oat straw given ad libitum and supplemented with lablab. Middlings were a positive control	• Sheep on the hay-lablab diet, compared with the straw-lablab diet, had higher intake (774 vs. 7 11 g/day; P < O.OI), growth rate (28 vs. 18 g/day; P<O.I), digestibilities of DM (576 vs. 531 g/kg; P<O.O5) • Sesbania and wheat middlings, as compared with tagasaste and lablab, promoted higher body weight (BW) gain (35 and 41 vs. 25 and 28 g day-'; P<O.O5)
3	local male goats; 22 kg	Research Institute for Animal Production, Ciawi, Bogor, Indonesia	Leaves of *Acacia villosa*	Treatment by soaking in water, chemicals	sugarcane tops	Unsoaked leaves dried at 60 ◦C; Leaves soaked in water for 24 h, drained for 1 h and dried at 60 ◦C; Leaves soaked in 20 g/l calcium hydroxide solution for 24 h, drained for 1 h and dried at 60 ◦C; 100g/day cassava flour	ADG on a diet containing water soaked Acacia (44.7 g/day) was higher than on unsoaked Acacia (38.9 g/day) but the difference was not significant. When cassava flour was included in the ration, the ADG was significantly higher at 71 g/day (P < 0.05). flour, respectively.
4	Castrated kids Boer × Spanish crossbreds; 135 days ole; 18.7 kg	Texas A&M University-Kingsville (TAMUK) agriculture farm	*Medicago sativa, Dolichos lablab, Leucaena leucocephala* and *Desmanthus bicornutus*	improved forages - forage legumes	sudan grass (*Sorghum bicolor*)	Four dietary treatments were composed of sudangrass (60% of diet offered) supplemented with one of four forage legumes (40% of diet offered) and corn (0.2 kg/day)	• leucaena had better (P < 0.05) gain efficiency (ADG/total feed intake) compared to goats fed desmanthus. • Goats fed leucaena had the numerically greater ADG (93.9 g/day compared with 82.3, 76.5 and 60.9 g/day for alfalfa, lablab and desmanthus, respectively) and tended to gain more weight (33.5 g/day; P < 0.10) compared with goats fed desmanthus.

No	Species	Where done	Experiment			Experimental Design	Effect on growth/fattening
			Feed tested	Technology option	Basal diet		
5	East African goats; 6 months old; 9 kg	Kilifi Institute of Agriculture, Coast province, Kenya	Madras thorn (*Pithecellobium dulce*)	improved forages - forage legumes	napier grass (*Pennisetum purpureum*)	Napier grass was either offered alone (control) or supplemented with 7.5, 15, 22.5 and 30 g DM/kg $W^{0.75}$ of Madras thorn.	Goats fed the control diet lost a mean of 8 g BW/day while those supplemented with 7.5, 15, 22.5 and 30 g DM/kg$W^{0.75}$ gained 8, 23, 43 and 44 g/day, respectively.
6	Small East African male goats; 14.kg; 7-9 months	Meatu district ICRAF research sub-station, Tanzania	*A. nilotica; A. polyacantha*, and *L. leucocephala* leaf meals	improved forages - forage legumes	native pasture hay	pasture hay fed without browse supplementation, which was used as a negative control; pasture hay supplemented with 115.3 g A.nilotica, 125.9 g A. polyacantha and 124.1 g leucaena	ADG of 157.1 g/day with leucaena than the animals fed on A. nilotica (114.3 g/day) and A. polyacantha (42.9 g/day), and even to those fed on pasture hay alone (control), which lost weight (−71.4 g/day).

No	Species	Other Effects	Duration of experiment	Conclusion/comments	References	
					Title	Author/s
1	Menz male sheep 18.3kg	• Increasing inclusion of tagasaste forage, significantly decreased the total DM intake of the basal diet	90 days	• It has higher degradability and rate of degradation than wheat bran–noug seed cake concentrate. • It has low digestibility and ME energy content relative to the concentrate. There is need to adjust the level of ME and minimize the effect of anti-nutritional compounds, which reduce its efficiency of utilization.	Evaluation of tagasaste (Chamaecytisus palmensis) forage as a substitute for concentrate in diets of sheep	Getnet Assefa, C. Kijora, A. Kehaliew, S. Bediye, K.J. Peters; Livestock Science 114 (2008) 296–304
2	yearling castrated male Ethiopian Menz sheep; weight 22.3 kg	• Intake of oats hay tended to be depressed by supplementation, but the depression was more pronounced with lablab and tagasaste. • Sesbania and wheat middlings, as compared with tagasaste and lablab, promoted higher intake of DM (815 and 812 vs. 758 and 774 g day-'; P<O.O5)but not microbial N supply.	80 days	• Oat hay is a better feed than oat straw • Variation in the performance of animals given leguminous supplements may partly be ascribed to how quickly the supplement disappears from the rumen.	Effect of supplementing oat hay with lablab, sesbania, tagasaste or wheat middlings on voluntary intake, N utilization and weight gain of Ethiopian Menz sheep	N.N. Umunna, P.O. Osuji, I.V. Nsahlai, H. Khalilib, M.A. Mohamed-Saleem; Small Ruminant Research 18 (1995) 113-120
3	local male goats; 22 kg	Feed conversion ratio was reduced by 10 and 41% due to soaking and addition of cassava	70 days growth trial	A. villosa can contain nutritionally limiting amounts of tannins but significant proportions could be removed by soaking the forage leaves in water or dilute acid for 24 h. Soaking in calcium hydroxide solution reduced the extractable tannins in the recovered leaves. Soaking in water improved dry matter and organic matter consumption and also improved digestibility. However, feeding of Acacia as a protein supplement to ruminants on poor quality roughage diets should be combined with an energy source to obtain better microbial growth and to improve feed efficiency and animal production. Cassava flour is shown to be a suitable energy source	Effects of chopping, and soaking in water, hydrochloric acidic and calcium hydroxide solutions on the nutritional value of Acacia villosa for goats	E. Wina, B. Tangendjaja, I.W.R. Susana; Animal Feed Science and Technology 122 (2005) 79–92
4	Castrated kids Boer × Spanish crossbreds; 135 days ole; 18.7 kg	Intake of leucaena compared to desmanthus forage was higher by 97 g/day (P < 0.001), demonstrating relatively poorer acceptability of desmanthus.	135 days	Even though L. leucocephala appeared to have relatively high feeding potential in this study with growing goats, its use is to some extent limited by the presence of the toxic non-protein amino acid, mimosine.	Evaluation of tropical forage legumes (*Medicago sativa*, *Dolichos lablab*, *Leucaena leucocephala* and *Desmanthus bicornutus*) for growing goats	J. Kanani, S.D. Lukefahr, R.L. Stanko; Small Ruminant Research 65 (2006) 1–7
5	East African goats; 6 months old; 9 kg	Supplementing with Madras thorn up to 22.5 g DM/kg$W^{0.75}$ had no (P > 0.05) significant effect on the intake of the basal diet, however there was a 29% depression in the intake of the basal diet at 30 g DM/kg$W^{0.75}$ level of supplementation	49 days	The use of Madras thorn forage as a protein supplement for goats could be an affordable fed resource,	Effect of supplementing Napier grass (*Pennisetum purpureum*) with Madras thorn (*Pithecellobium dulce*) on intake, digestibility and live weight gains of growing goats	R.K. Kahindi, S.A. Abdulrazak, R.W. Muingab; Small Ruminant Research 69 (2007) 83–87

No	Species	Other Effects	Duration of experiment	Conclusion/comments	References	
					Title	Author/s
6	Small East African male goats; 14.kg; 7-9 months	• Supplementation with sun-dried browse leaves resulted to higher ($P < 0.05$) total DMI than the control animals on pasture hay alone • Animals on leucaena consumed slightly more basal diet than those on browse supplements	84 days	Higher ADG due to Leucaena and A. nilotica supplementation suggest optimised weight gains due to browse supplementation (20% of expected DMI); while lower weight gains from supplementation with A. polyacantha indicate the possible utilisation of A. polyacantha leaves to overcome weight losses especially during dry seasons	Effects of *Acacia nilotica, A. polyacantha* and *Leucaena leucocephal*a leaf meal supplementation on performance of Small East African goats fed native pasture hay basal forages`	C.D.K. Rubanza, M.N. Shem, S.S. Bakengesa, T. Ichinohe, T. Fujihara; Small Ruminant Research 70 (2007) 165–173

Feed conservation

No.	Species	Where done	Experiment			Experimental Design	Effect on growth/fattening
			Feed tested	Technology option	Basal diet		
1	male highland sheep (Arsi type) - 16 to 17.2 kg	Debre Zeit Research Centre, Ethiopia	Leucaena leucocephala leaf hay	Fodder tree leaf meal	chickpea haulm	chickpea haulm supplemented with 100, 200 or 300 g/head per day of sun dried leucaena leaf hay or 300g/d of concentrate (wheat bran, noug cake, molasses, formulated to supply about 200 g/kg CP) protein of dry matter.	• Live weight of sheep was found to have increased by 68, 88, 94 and 74% as a result of supplementation of 100, 200 and 300 g/head per day of sun dried leucaena leaves and 300 g/head/day of concentrate mixture, respectively.
2	Bachthao × Barbary or Jamnapary, breed; body weight of 13.6kg and 108 days old	Goat and Rabbit Research Centre Sontay, Hatay province, Hanoi (Vietnam).	cassava hay	Feed conservation - hay	guinea grass and dried cassava	cassava hay compared with a commercial grain and protein meal based concentrate in diets based on guinea grass and dried cassava root. Concentrate was replaced by cassava hay at five levels: 0, 250, 500, 750 and 1000 g/kg on a dry matter (DM) basis	• Growth rates at the five levels of inclusion were 53, 69, 62, 49 and 39 g/d and feed conversion ratios were 10.2, 7.6, 8.6, 10.2 and 13.0 kg DM/kg body weight gain. • The highest BWG and the lowest FCR of DM and CP occurred with 250 g/kg cassava hay replacement (i.e., when the cassava hay was 90 g/kg of total DM intake) but high BWG and low feed conversion ratio (FCR) was achieved within the range of 0–220 g/kg of cassava hay of DM intake
3	intact male lambs (18 kg)	Awassa, Southern Ethiopia	Desmodium hay (green leaf)	Improvements of crop residues or low quality roughages	root.	desmodium supplemented at 4 levels (0, 150, 300 and 450 g on as fed basis per head per day) which, on average, constituted 0, 16, 30 and 46%, respectively, of total feed offered).	• Body weight gain showed a significant increase ($p<0.05$) with increasing level of supplementation whereas all sheep without supplement lost body weight.

No.	Species	Other Effects	Duration of experiment	Conclusion/comments	References	
					Title	Author/s
1	Male highland sheep (Arsi type) - 16 to 17.2 kg	• Leucaena supplementation significantly increased total DM intake without marked effect on intake of the basal diet.	105 days	Weight gain of sheep supplemented with 300 g/day concentrate was comparable to that obtained by supplementing 100 g/day of leucaena but lower than the gain achieved with 200 and 300 g/day of leucaena suggesting that sheep could gain even better quantity of concentrate mixture.	Growth rates and testicular characteristics of Ethiopian highland sheep offered chickpea haulm supplemented with incremental levels of Leucaena leucocephala leaf hay	Negussie Danaa ,Teshome Shenkorua, Azage Tegegneb; Livestock Production Science 65 (2000) 209–217
2	Bachthao × Barbary or Jamnapary, breed; body weight of 13.6kg and 108 days old	The intake of cassava hay optimal for growth rates, feed conversion ratio and feed cost ranged from 0 to 220 g/kg of total DM intake.	90 days	Cassava hay can replace up to 750 g/kg of the concentrate (i.e., 233 g/kg ofDMintake) in the diet for growing goats fed a basal diet of guinea grass and cassava root meal with similar body weight gain and feed conversion, but lower feed costs.	Effect of replacing a commercial concentrate with cassava hay (Manihot esculenta Crantz) on the performance of growing goats	Ngo Tien Dunga, Nguyen Thi Muib, Inger Ledin; Animal Feed Science and Technology 119 (2005) 271–281
3	Intact male lambs (18 kg)	• There was a substitution of about 12, 21 and 37% of the stover by the desmodium hay at 150, 300 and 450 g of supplementation, respectively. • Considering DM intake and digestibility 300 g of desmodium hay appears to be an optimum level of supplementation	63 days	• If the availability & cost of desmodium hay is not a limiting factor, the level of supplementation could be increased up to 450 g per day to further enhance animal performance (body weight gain). • Crude protein (CP) content of the stovers showed a decreasing trend whereas the fibre contents showed an increase from stages 1 to 3.	Supplementation of graded levels of Desmodium intortum hay to sheep feeding on maize stover harvested at three stages of maturity 1. Feed intake, digestibility and body weight change	Adugna Toleraa, Frik Sundstùl; Animal Feed Science and Technology 85 (2000) 239±257

Improving residues and roughages

No.	Species	Where done	Experiment			Experimental Design	Effect on growth/fattening
			Feed	Technology option	Basal diet		
1	Awassi weaner lambs (17.9 kg) - aged 65 days	Agriculture Center for Research and Production at the Jordan University of Science and Technology.	wheat straw	Crop residue	concentrate	varying levels of wheat straw (0, 5, 10 and 15%) in high concentrate isonitrogenous (16% CP) diets	Average daily gain was higher ($P < 0.05$) for the 10 and 15% wheat straw diets (avg. 247 g/d) compared with the 5% wheat straw diet (185 g/d) and 0% wheat straw diet (161 g/d).
2	West African dwarf sheep; 8.9 kg; 10 months	Teaching and Research Farm, University of Agriculture, Abeokuta, Ogun State, Nigeria	milled cowpea haulms from the six dual purpose varieties, 3 improved varieties ITA2, ITA6, ITA8 and 3 commercial varieties Oloyin, Peu and Sokoto	Crop residue - home grown legume residues	*Pennisetum purpureum*	450 g/day (dry matter (DM) basis) of the supplements, based on 50 g/(kg BW×day); Approximately 1 kg of fresh P. purpureum fed to each sheep daily	Commercial haulm diets tended to higher ADG (32.5, 34.5 , 35.9 g/day) compared to improved haulms (30, 28.7, 31.9)
3	Small East African breed; 13.8 kg BW; 12–18 months of age	Magadu Research Farm, Sokoine University of Agriculture	Wheat straw	Treatment of crop residues	None	The dietary treatments were either ad libitum amount of untreated wheat straw, wheat straw treated with urea and lime, untreated wheat straw with hay or treated wheat straw with hay. In addition, each animal received 220 g/day (on as fed basis) of a concentrate diet	Daily body weight gain for goats fed treated straw was nearly two-fold higher than for those fed untreated straw. Meanwhile, goats fed treated straw with hay were more ($P<0.05$) efficient in converting feeds to body tissue as they required 9 kg less feed for one kg body weight gain compared to those fed treated straw without hay.

No.	Species	Other Effects	Duration of experiment	Conclusion/comments	References	
					Title	Author/s
1	Awassi weaner lambs (17.9 kg) - aged 65 days	Dry matter intake was similar ($P < 0.05$) for lambs consuming the 10 and 15% wheat straw diets (avg. = 1052 g/d) and significantly ($P < 0.05$) higher than lambs consuming the 0 and 5% wheat straw diets.	58 days	high concentrate diets for Awassi lambs should contain at least 10% wheat straw for good growth performance	Growth performance of lambs fed on diets varying in concentrate and wheat straw	S.G. Haddad, M.A. Ata; Small Ruminant Research 81 (2009) 96–99
2	West African dwarf sheep; 8.9 kg; 10 months	• Sheep fed commercial haulm diets gaining more BW and lower FCR than those on improved haulm diets (P=0.007) • N balance values, which were all positive	106 days	• Cowpea haulms have potential to facilitate N utilization • Cowpea haulms can be used to sustain animal growth during the dry season.	Effects of processed cowpea (Vigna unguiculata L. Walp) haulms as a feed supplement on voluntary intake, utilization and blood profile of West African dwarf sheep fed a basal diet of Pennisetum purpureum in the dry season	U.Y. Anelea, O.M. Arigbedeb, K.-H. Südekuma, K.A. Ikeb, A.O. Onic, J.A. Olaniteb, G.A. Amoleb, P.A. Deleb, A.O. Jolaoshob; Animal Feed Science and Technology 159 (2010) 10–17
3	Small East African breed; 13.8 kg BW; 12–18 months of age	Grass hay complemented the effects of chemical treatment in increased intake and growth performance of goats.	84 days	Goats on diets including hay produced carcasses with higher proportion of fat than those without access to hay. chemical treatment not only sustains goat production in the dry season, but also supports at least a minimum level of fattening.	Growth, carcass and meat quality characteristics of Small East African goats fed straw based diets	J. Safari, D.E. Mushi, L.A. Mtenga, G.C. Kifaro, L.O. Eik; Livestock Science (2011), 168-176

Balancing feeds

No	Species	Where done	Experiment			Experimental Design	Effect on growth/fattening
			Feed	Technology option	Basal diet		
1	Boer goat (BG) kids (26.2 kg)and South African Mutton Merino lambs (32.7 kg); castrated and weaned	Maitland, S.Africa	low (9.89 MJ kg−1 DM) or a high (12.11 MJ kg−1 DM) metabolisable energy level diets	Balancing feeds	none	Two pelleted diets with either a low or a high metabolisable energy level fed individually ad lib, for either 28 or 56 days.	• Mutton merino had significantly higher average daily gains (ADG) than Boer Goats. • The average daily gain of the merino on the low energy-diet for 28 days was significantly lower than for those on the high energy-diet (0.236 kg per day versus 0.330 kg per day. However, there was no significant difference between the ADG of Boer goat on the high or low energy diets.

No	Species	Other Effects	Duration of experiment	Conclusion/comments	References	
					Title	Author/s
1	Boer goat (BG) kids (26.2 kg)and South African Mutton Merino lambs (32.7 kg); castrated and weaned	feed conversion efficiency of the High energy diet merino was more efficient than that of those on the Low energy-diet (28 days: 5.56 kg feed versus 8.73 kg feed; 56 days: 6.47 kg feed kg BW per gain versus 9.40 kg feed kg BW per gain), regardless of time spent in the feedlot.	28 days; 56 days	Boer goats may be finished on a diet with a lower Metabolizable energy-value than is usually formulated for sheep, without a reduction in performance.	Production efficiency of South African Mutton Merino lambs and Boer goat kids receiving either a low or a high energy feedlot diet	R. Sheridan, A.V. Ferreira, L.C. Hoffman; Small Ruminant Research 50 (2003) 75–82

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