Application of laboratory feed evaluation to identify methods of easing feed scarcity in N W India

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Final Technical Report

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Executive Summary

Dry season feed shortages are a widespread constraint in semi-arid regions. This project aimed at applying laboratory feed evaluation to identifying methods of alleviating feed scarcity in N W India. The project monitored livestock to obtain information on diet and grazing behaviour, and obtained feed samples for laboratory evaluation to augment literature information on nutritive value. Monitoring data enabled contrasts to be identified between the diets and management of goats belonging to commercial milk producers and subsistence tribal goat keepers in Udaipur District, and also comparisons to be made with milk producers in Bhilwara District. Lack of access to good quality feed was a constraint in the dry season, particularly for tribal goat owners. There were general similarities in goat management for milk producers in Udaipur and Bhilwara Districts, although differences were found in the make up of the goats' diets due to differences in feed availability. Specific recommendations based on the laboratory and monitoring data were identified. For Bhilwara District, protein-deficient cactus should be supplemented with protein-rich feed, such as tree pods. Parallel "cluster" project R6953 has researched pod storage and use as feed supplements in this District. *Acacia leucophloea* pod toxicity can cause the deaths of goats and inhibits the utilisation of this potentially very valuable feed. Toxicity was a problem for tribal goat keepers in Udaipur District and widely in Bhilwara District. A new project on alleviating *Acacia leucophloea* pod toxicity has been proposed, although at the time of writing a source of funding has yet to be identified. Shortage of good quality feed in the dry season, rather than feed shortage per se, is the major feed constraint to livestock production. Strategies for increasing feed availability include feed storage (although there are few traditional feeds available for storage) and increased fodder production. Project R6953 has reviewed case studies on increasing the availability of grazing and improving the management of communal grazing areas as an aid to future project development. Increasing the feed available from the often degraded communal grazing areas is one of the few options with the potential to greatly improve the feed supply for goats in this region.

Background

Seasonal scarcity of fodder

Seasonal variations in the quantity and quality of forages, and feed shortages during the dry season, have been identified as being critical problems in many semi-arid areas in Asia and Africa (Acharya and Bhattacharyya, 1992; Ndiritu, 1995). In NW India poor agro-pastoralists often obtain most of the feed for their livestock from grazing on common lands (Jodha, 1990). An Indo-Swiss project (Hocking et al, 1992) has shown that there tends to be a surplus of fodder at the end of the monsoon season and during the winter, followed by a shortage in the second half of the summer and the first half of the monsoon season (i.e. from April to July). During this period livestock tends to lose weight and the range tends to become overgrazed. Tree fodders are critical for goats during periods of shortage, however there is little published information about how locally available feeds are used nor their nutritive value.

Current knowledge on fodders used in NW India

Conroy and Matthewman (1996) have recently described the feeding practices for goats in the study region. Appreciable differences in fodder availability and utilisation were found between different villages, apparently reflecting the differences in local tree populations. For example, *Acacia nilotica* (Babul) leaves and pods, *Prosopsis cineraria* (Khejri) are particularly important in Bhilwara towards the end of the dry season when scarcity is most acute, while in Khakhad *A. nilotica* is only available in small quantities and hence is of minor importance. Table 1 taken from Conroy and Matthewman (1996) summarises the information on times of scarcity and main fodders available at these times. Table 2 lists the main fodder available to goats in the study region. The list includes several *Acacias*, *Prosopis* and many lesser known species.

Table 1 Characteristics of Villages (from Conroy and Matthewman, 1996)

	Village						
	Rampuriya	**Ghodasikheda**	**Patiyo Ka Khera**	**Khakhad**	**Gopir**	**Kirat**	**Jothana**
Times of Scarcity	June (Not clear whether scarcity is a problem)	None	June	February/ March	March to May/June	March to April & mid-April to mid-June (esp 2nd month)	March and April to June
Main dry season fodder species	Babul Ronjia Khejri Neem Ber Cactus (Thor)	Ronjia Babul Ber Bordi Neem Khejri Champeli Kamboi Methi	Arunjia Babul Neem Bordi Akadi Thor (dry/chopped) Methi (Concentrates also given in June)	Bor Neem Karanj Kalambi Kadwa Runjia Babul Chanbor	Babul Ber Chanbor Paba (Ardu) Ronjia Akadi Hetri Godala Neem Bans Khanni Negad	Kalambi Hetri Ber Khanni Kanja Mahua Ronjia Kimra Khalia	Babul Subabul Ronjia Andruk Chanbor Kambity Kankar Ber Kakaiya Bansd Tamat Hetri Dawada
Breeding season(s)				March-April (only tribals)	May	June-mid-July	May-July, peaking in July
Times of Kidding	September to October and ??	??	??	Tribals:September to December (?) Gayris: June/July & Nov/December	October to November	Late October and November	November to January (peaking in Jan)

Table 2 Feed resources for goats stated to be available for Goats in Bhilwara and Udaipur Districts (from Conroy and Matthewman, 1996)

		Village						
		Rampuriya	Ghodasi-kheda	Patiyo Ka Khera	Khakhad	Gopir	Kirat	Jothana
Species found in Bhilwara (mainly Hindi names)[2]								
Khejri	*Prosopis cineraria*	✓	✓					
Babul	*Acacia nilotica*	✓	✓	✓	✓	✓	✓	✓
Arunjia (t:Ronjia)	*A. leucophloea*	✓	✓	✓	✓	✓	✓	✓
Neem	*Azadirachta indica*	✓	✓	✓	✓	✓		
Ardu/Paba	*Ailanthus excelsa*				✓			✓
Jangal jalebi	*Pithecellobium dulce*							
Khakhra/Dhak	*Butea monosperma*				✓			
Siris (t:Kalio)	*Albezia lebbek*				✓			✓
Hingota	*Balanites aegyptica*							
Khair	*Capparis decidua*							✓
Kumta	*A. senegal*							
Israeli babool	*A. tortilis*							
Dhokra	*Anogeisus pendula*							
Champeli			✓					
Kamboi			✓					
Thor	Cactus	✓	✓	✓				✓
Akadi	Calotropus gigantea			✓		✓		
Mahua	Madhuca indica					✓	✓	
Ber	*Ziziphus mauritania*	✓	✓			✓	✓	✓
Bordi/Jharberi	*Z. nummularia*		✓	✓				
Neelgiri/Safeda	Eucalyptus tereticornis				✓			
Imli (t:Amali)	Tamarindus indica				✓			✓
Lucerne	*Trifolium alexandrium*							

		Rampuriya	Ghodasi-kheda	Patiyo Ka Khera	Khakhad	Gopir	Kirat	Jothana
Methi								✓
Dhaman grass (t:Lapna)	Garunga pinnata				✓			
Berseem	*Leucaena leucocephala*							
Subabul	Aegle marmelus							✓
Zadki								
Bans	Bamboo				✓	✓		✓
Udaipur Species (mainly Tribal names)								
Hetri	Bauhinia racemosa				✓	✓	✓	
Tamat	Garuga pinnata				✓	✓		✓
Kankar	Wrightia tintoria				✓	✓		✓
Khirani/Khanni	Vitex negundo				✓	✓	✓	
Negad	Derris indica					✓		
Karanj	Holorrena antidisentrica				✓	✓		
Kadwa/Kadwo						✓		
Timdi					✓			
Mujal	Melia azedarach?				✓			✓
Kalambi	Morus elba (Mulberry)				✓		✓	
Shehtoot (h:Shetrit)	Boswellia serrata				✓	✓		
Halar	Dichrostachys cynerea				✓	✓		
Amena	Prenna spp				✓			
Anni/Arni	Citrus medica				✓			
Limboo	Ricinus communis (Castor)				✓			
Arandia	Miliusa tomentosa				✓			

Published information on the nutritive value of these feeds is scarce. Bennison and Paterson (1993) reviewed data on the nutritive value of *Acacias* and noted their generally fairly high protein content but modest digestibility, also their variability in composition and the possible negative effects of tannins. Some feeding trials using growing calves and bullocks have indicated that A. *nilotica* pods are a potentially useful source of protein which could be incorporated at up to 45% in a concentrate mixture given to pasture fed cattle. *Prosopis cineraria* leaves are said to be well accepted but of low digestibility, although some studies have suggested that *Prosopis* leaves are generally unpalatable. The pods are widely used for both humans and livestock (reviewed by Clinch et al., 1993). However, for most of the feeds identified by Conroy and Matthewman (1996) there appears to be no published information on their composition, digestibility, anti-nutritive factors or perceived value as judged by farmers.

Strategies to alleviate seasonal feed scarcities

Given the variations found between villages, Conroy and Matthewman (1996) concluded that a range of interventions may be required, the appropriate ones depending on local circumstances. Such interventions will be aimed at:
(a) the better use of available feeds
(b) increasing the supply of feeds.

Improved feed combinations and strategic supplementation of nutrient deficient feeds could improve intake and digestibility, and hence animal performance, on existing poor quality feeds. Increasing feed supply could involve:
(a) planting fodder trees (indigenous and/or exotic species)
(b) drying and storage of fodders from the wet season for use in the dry season
(c) use of molasses blocks.

This project worked closely with ODA LPP project R6953 "Easing seasonal feed scarcity for small ruminants in semi-arid crop/livestock systems through the process of participatory research", which provided most of the background information described above during the formulation of this project.

Laboratory feed evaluation

The number and diversity of the feeds in use, coupled with what can be considerable variation in composition, means that laboratory evaluation is essential if objective indicators of nutritive value are to be obtained. The objective of laboratory feed evaluation is to provide information on which to base advice on selecting fodders to grow or store, and feeding strategies such as strategic supplementation. An earlier LPP project (R5180) recognised that conventional laboratory feed evaluation techniques have their limitations as (in particular) they do not take account of interactions between feeds nor the effects of anti-nutritive factors. An in vitro gas production technique has been shown to be sensitive to interactions between feeds (Prasad et al., 1994; Sampath et al., 1995) and inhibition by tannins (Wood and Plumb, 1995), hence appears to be suitable for investigating interventions of the type outlined above. While several research groups within the UK and elsewhere are now using in vitro gas production methods to evaluate feeds, NRI has pioneered its use in

the investigation of feed mixtures and unbalanced diets. This is because these are particularly important in LDCs whereas other groups are primarily concentrating on high quality balanced diets used in developed countries.

Demand for the project was initially identified in three ways.

1. BAIF regards research on feeds for small ruminants as important for development in NW India, hence their desire to collaborate on this project. BAIF is also expanding activities on small ruminants into several more districts in this region.

2. Directorates of Rural Development in Rajasthan and Madhya Pradesh are funding development work by BAIF on small ruminants, indicating the importance of this subject in these states.

3. Livestock specialists have identified the seasonal feed constraint as a high priority research issue in semi-arid regions generally.

The related farmer participatory methods project confirmed that seasonal feed constraints were a problem in many villages in the study area, and there was a general lack of information on the nutritive value of the feeds which were available.

Project Purpose

The DFID RNRRS has recognised that seasonal limitations on feed supplies to livestock is a constraint to increased production. This project will help evaluate improved feeding practices to help alleviate constraints in the target area. More widely, it will help develop the application of feed evaluation to service livestock keepers in less developed countries.

This project sought to study the quality of the feeds available to livestock keepers, particularly at times of feed shortages. The study was intended to generate advice on using the feed resources available to give a balanced diet, and also to identify feeds appropriate for correcting particular inbalances. The advice generated was aimed at optimising the use of the feeds available.

Research Activities

Publicity leaflet

A publicity leaflet, "Easing seasonal fodder scarcity for small ruminants in North West India" was drafted and produced at the start of the project.

Literature review on feeds and information gaps identified

The participatory research project listed 44 fodder species identified by farmers in Udaipur and Bhilwara Districts of Rajasthan as being important goat feeds. A literature review was conducted to extract existing information on the nutritive value of these feeds. The information available was found to be patchy, with no information on several important fodder species.

A larger information gap was the complete absence of any data on the make up of the goats' diet. Goat keepers had identified the most commonly used tree fodders, but there were few indications of their relative importance. Some priority was therefore given to obtaining data to fill this information gap, which had a large influence on the future direction of the project. A major component of the project became the monitoring of animals to investigate their grazing behaviour and define their diet in a semi-quantitative manner.

Sampling of feeds for chemical analysis

Dr Wood visited Udaipur and Bhilwara Districts of Rajasthan in February and May 1998 for familiarisation, to set up a goat monitoring study, and to take samples of the most important feeds. Visit reports are presented in Technical Annex 1. Khakad village was selected as the field site in Udaipur District, Rampuriya in Bhilwara District. In both villages there were close contacts with BAIF, goat keepers regarded dry season feed shortages as a constraint and were willing to collaborate. The sites were also visited in July 1998 (by Mr Badve, BAIF) to take further samples. Field observations indicated that in Khakad dried fallen leaves, selected by goats, were a significant component of the diet. Lopped cactus was used in Rampuriya. Hence the initial list of fodders was not comprehensive, however feed samples had to be taken and analysed before the monitoring data was available to complete the work within the original three year time frame.

The samples obtained during the three visits to Rajasthan are listed in Tables 3, 4 and 5 below, together with the types of analyses conducted.

Analysis of feeds

The samples taken were air dried in the shade and ground through a 1 mm sieve. They were analysed for chemical composition by conventional methods, total phenols (as an indicator of tannins) by the method of Price and Butler (1997), and in vitro digestibility by gas production (Theodorou et al., 1994) and Tilley and Terry (1963) methods.

Dryhurst and Wood (1998) demonstrated that the gas production method could be adapted to make is sensitive to nitrogen availability. Wood et al. (1998) described nitrogen-deficient incubation conditions and demonstrated the potential use of the method for providing information on the nitrogen-sufficiency of feeds. On an experimental basis, this project took this work a step further by the calculation of a Nitrogen Deficiency Index (NDI) and using this as an indicator of whether there was sufficient fermentable protein (nitrogen) in the feed to sustain the fermentation of its carbohydrate content. The NRI was calculated based on data obtained from gas production in nitrogen-rich (NR) and nitrogen-free (NF) media. The NDI was calculated after 48 and 96 h fermentation, and was defined as:

$100 \times (CG96_{N\text{-}rich} - CG96_{N\text{-}free})/CG96_{N\text{-}rich}$

where $CG96_{N\text{-}rich}$ = cumulative gas production after 96 h fermentation (CG96) in the feeds fermented in nitrogen-rich.

$CG96_{N\text{-}free}$ = cumulative gas production after 96 h fermentation (CG96) in the feeds fermented in nitrogen-free media

and similarly for NDI at 48h.

Nitrogen deficiency is indicated by a high positive NDI. It was used as a rapid qualitative tool to evaluate feeds, particularly tree fodders, as nitrogen sources.

Two bioassays were also used on an experimental basis to try to identify toxic factors in the feeds: TLC/fungal inhibition (by methods used at Wye College) and the brine shrimp assay (by the method of Panigrahi and Dallin, 1994). Mr Badve, BAIF, was trained in the in vitro gas production technique, bioassays and the total phenols assay during a 5 week visit to the UK in July/August 1998. A report on this visit in given in Technical Annex 1 and gives protocols of some of the methods used. A report on the TLC/fungal inhibition work conducted at Wye College by L. Goodenough is also given in the Technical Annex 1.

Laboratory methods and feeds review booklets

A booklet on laboratory methods of feed assessment was published during the project extension. The pamphlet is aimed at a generalist scientific audience rather than specialist ruminant nutritionists. The text is given in Technical Annex 2.

The literature review on the nutritive value of feeds was revised to incorporate the findings of the laboratory analyses where appropriate. This was also published by the project as a booklet, the text of which is also given in Technical Annex 2.

Table 3 Samples obtained in India, February 1998

Code	Description	Anti-nutritional factors	Gas production	Chemical analysis
	From Rampuriya			
IF1	A leucophloea pods, not toxic	x		
IF2	A leucophloea leaves from same branch as IF1	x		
1F3	Azadirachta indica (Neem) leaves	x	x	x
IF4	Ziziphus mauritiana leaves	x	x	x
IF5	Cotton pala	x	x	x
IF6	Ziziphus nummularia, dried leaves (bordi pala)	x	x	x
IF7	Ziziphus nummularia, dried leaves (bordi pala)	x	x	x
IF8	Azadirachta indica (Neem) leaves	x	x	x
IF9	A leucophloea pods, not toxic	x		
IF10	A leucophloea leaves from same branch as IF9	x		
IF11	as IF9 but from other branch of tree, pool with IF9 after weighing			
IF12	A leucophloea pods, said to be toxic (pods curled, reddy brown and look dry compared to non-toxic pods)	x		
IF13	barley grain, ex BAIF buck breeding programme		x	x
IF14	wheat grain, ex Patiyo Ka Khera		x	x
IF15	barley grain, ex Patiyo Ka Khera		x	x
	From Khakad			
IF16	A leucophloea pods, not toxic[a]			
IF17	A leucophloea pods, said to be toxic (blotches on pod surface, said to due to disease, and indicate toxicity)[a]			
IF18	wheat grain + sun hemp seed "concentrate" ex Mr. Sava Roopaji Vadera, Khakad		x	x
IF19	barley grain ex Khakad		x	x
IF20	neem leaves	x	x	x
IF21	A leucophloea pods, said to be toxic (had ball-like growths, galls, on twigs, said to be caused by insects and to indicate toxicity)	x		
IF22	wheat grain, ex Kirat		x	x
IF23	dried maize, ex Gopir		x	x
IF24	dried leaves of "kadwa" from hill slopes	x	x	x
IF25	dried leaves of "kadwa" from hill slopes	x	x	x
IF26	whole weed from wheat field (Chenopodium alba)		x	x (CP)

Note a Samples attacked by mould whilst in transit to UK and will not be evaluated.

Table 4 Samples collected in India, May 1998

Code	Description	Anti-nutritional factors	Gas production	Chemical analysis
	From Khakad			
IMy1	*Ziziphus mauritiana* (ber) leaves	x	x	x
IMy2	*Acacia leucophloea* (arunjia) new leaves	x	x	x
IMy3	*Acacia nilotica* (babul) pods	x		
IMy4	*Derris indica* (negad) leaves	x	x	x
IMy5	Dried leaves collected underneath karanj tree, upper valley (location code 2)	x	x	x
IMy6	Dried leaves collected underneath karanj tree, lower slopes (location code 3)	x	x	x
IMy7	*Vitex negundo* (Khanni), tops of green shoots pooled from 5 trees (only part eaten by goats)	x	x	x
IMy8	Dried leaves from below tamat trees, top of hills (location code 4)	x	x	x
IMy9	Second sample as per IMy8	x	x	x
IMy10	Dried leaves from below karanj trees (mainly), but also *Vitex negundo* (khanni) and *Holorrena antidisentrica* (kadwa) trees, top of hills (location code 4)	x	x	x
IMy11	Dried leaves from below mainly *Holorrena antidisentrica* (kadwa) trees, lower slopes (location code 3)	x	x	x
IMy12	*Acacia nilotica* (babul) leaves	x		
IMy13	*Acacia nilotica* (babul) pods	x		
	From Rampuriya			
IMy14	*Acacia nilotica* (babul) pods	x		
IMy15	Cactus, *Opuntia spp.*? (thor), dried	x	x	x
IMy16	*Prosopis juliflora* pods	x	x	x
IMy17	*Prosopis cineraria* (khejri) pods	x	x	x
IMy18	*Prosopis cineraria* (khejri) leaves	x	x	x
IMy19	*Ziziphus nummularia* (bordi) fresh leaves	x	x	x

Table 5 Samples of tree leaf fodders collected by Mr Badve, Rajasthan, July 1998

Samples of fresh leaves, dried and ground to 1 mm before analysis

Code	Description	Anti-nutritional factors	Gas production	Chemical analysis
IJy1	Ziziphus maritiana (ber)	x	x	x
IJy2	Mangitesa indica (mango)	x	x	x
IJy3	Bamboo	x	x	x
IJy4	Derris indica (negad)	x	x	x
IJy5	Holorrena antidisentrica (kadwa)	x	x	x
IJy6	Pongamia pinnata (karanj)	x	x	x
IJy7	Acacia leucophloea (runjiya)	x	x	x
IJy8	hitazi	x	x	x
IJy9	Ficus indica (pimpal)	x	x	x
IJy10	tamat	x	x	x
IJy11	khanni (all green leaves, not just shoots)	x	x	x
IJy12[a]	godla			x
IJy13	Acacia nilotica (babool)	x	x	x
IJy14	kalbi	x	x	x

Note a Samples attacked by mould whilst in transit to UK and was not evaluated.

Goat monitoring - Udaipur and Bhilwara Districts

Goat monitoring exercises were established at the two collaborating villages (Khakad and Rampuriya) used for sample collection. Goat monitoring was established in early May 1998 and continued until mid May 1999 at both sites, although monitoring periods were not completely synchronised. The primary objective was to obtain information on the diet consumed by the goats, although the study also produced information on grazing behaviour and animal management.

There are two major communities in Khakad who keep goats. Tribal farmers generally have small plots of land for subsistence agriculture and keep small herds of goats for milk and as a source of income. They may also work as hired labourers for part of the year. The Gayri community are specialist goat keepers, producing milk for local markets as well as selling animals for income. They generally have large herds, or manage goats belonging to the extended family in large herds. These herds were monitored separately to enable comparisons between the herds to be made. In Rampuriya there was a single community in the collaborating village.

The monitoring methodology was based on that used by Bennison et al. (1998). Monitors were recruited from both local goat keeping communities. Each monitor selected two female goats from within their own community herds. The goats selected were lactating at the time of selection. Monitors followed a single goat on each day of monitoring. Each monitoring period lasted for four consecutive days of monitoring where each goat was monitored for two days per monitoring period, the goat to be monitored on any particular day being chosen at random. Observations were taken every 5 minutes from before the goats left the homestead to after they returned in the evening, to include all of the grazing time. The goat activity, type of feed, the location of the goats and where possible the name of the feed were noted by monitors. Data were entered onto spreadsheets and transferred to a database, where the numbers of counts for each feed type and activity for individual goats for each day

of monitoring were extracted. Activity, feed type and location codes are given in Tables 6, 7 and 8 respectively. Statistical analysis (means and ANOVA) was performed using SPSS (Statistical Package for Social Scientists).

Table 6 Activity codes

Activity code	Activity
0	not defined
1	feeding
2	walking
3	resting
4	other

Table 7 Feed type codes

Feed type code	Feed type
0	not feeding
1	lopped tree fodder
2	not lopped tree fodder/grazing
3	dried leaves
4	concentrates
5	other

Table 8 Location codes (Khakad only)

Location code	Location description
1	Homestead area
2	Bottom of hills
3	Middle of hills
4	Top of hills

Location codes were not collected during monitoring period 1 in Khakad and not for Rampuriya where the grazing areas could not be so readily divided into different geographical zones.

Named feed codes were developed during the course of the monitoring and are given in the Project Outputs. Total counts per named feed for each monitoring period were extracted, and daily average counts for each period of monitoring calculated to identify the most frequently occurring named feed codes. Named feeds were not collected during monitoring periods 5, 6, 10 and 11 in Khakad.

Details of the monitoring periods are given in Table 9. The two monitoring exercises were mainly conducted at the same times, although in practice this was not always possible. There were also some problems in co-ordinating the monitoring effort in Rampuriya such that some monitors started a day later than planned, but continued for a four day period. In Khakad the monsoon rains started on 10 June 1998, between periods 3 and 4. In Rampuriya the 1998 rains were a little later, starting on 20 June

during monitoring period 4 In 1999 the rains started on 18 June in Khakad and 17 June in Rampuriya, after the monitoring had been completed.

Table 9 Periods of monitoring: data analysed to date

Monitoring period	Dates (Khakad)	Dates (Rampuriya)
1	2 to 5 May 1998	N/A
2	16 to 19 May 1998	16 to 19 May 1998
3	2 to 5 June 1998	2 to 6 June 1998[a]
4	16 to 19 June 1998	19 to 22 June 1998
5	2 to 5 July 1998	6 to 9 July 1998
6	16 to 19 July 1998	16 to 19 August 1998
7	2 to 5 September 1998	16 to 19 September 1998
8	17 to 20 November 1998	N/A
9	17 to 20 January 1999	17 to 21 January 1999[b]
10	17 to 20 March 1999	17 to 21 March 1999[b]
11	17 to 20 May 1999	17 to 21 May 1999[b]

N/A not available (data not collected)
[a]3 to 6 June 1998 on one data set only, other data sets 2 to 5 June 1998
[b] 3 monitors started on day 1 of the monitoring period, 3 monitors on day 2.

Livestock monitoring - Bhavnagar District

Conroy et al. (2000) describe how in the village of Khumbhan, near Bhavnagar in Gujurat, India, seasonal water scarcity is regarded by livestock keepers as the most important constraint to livestock keeping. The mean annual rainfall in Bhavnagar is about 500 mm, concentrated in the July to September monsoon season. During the hot dry summer season (March to June, inclusive) there is a lack of water at the main communal grazing area. This obliges the livestock keepers to bring their animals back to the village at mid day to water them, before returning to their grazing areas.

As a result, a water trough was constructed next to a well near to the summer season grazing area. As part of the evaluation of the impact of the introduction of the trough, cattle and goats were monitored to study their grazing behaviour and management. The design of the experiment was to monitor livestock before and after the introduction of the trough in the 1999 summer season and make comparisons between these periods.

The methodology was similar to that described for goat monitoring in Khakad and Rampuriya districts, with the introduction of activity code 6 = walking and feeding, and feed type code 6 = grazed grass. Location codes were used as shown in Table 10. The village secondary school was contacted with a view to recruiting school leavers as monitors. Eight school leavers were identified for this work, together with two adult monitors who were trained during the time of the visit.

Table 10 Location codes, Khumbhan

1	Homestead
2	In fields
3	Field borders/roadsides
4	Anida hills
5	Anida plains
6	At new water trough
7	Walking on road

Monitoring was conducted over four consecutive days, two days monitoring for both animals randomised over the four days. Monitoring was conducted every two weeks starting on 26 March and ending when the rains started and grazing patterns change as a result. (the monsoon rains normally start on about 15 June, but this is variable in Gujurat). The monitoring periods are given in Table 11.

Table 11 Monitoring periods, Khumbhan

Monitoring period	**Dates**
1	26 to 29 March 1999
2	9 to 12 April 1999
3	23 to 26 April 1999
4	7 to 10 May 1999
5	21 to 24 May 1999
6	4 to 7 June 1999
7	18 to 21 June 1999

The trough came into use in mid May, between periods 4 and 5. The monsoon rains started on 20 June 1999, half way through monitoring period 7.

Village dissemination meetings

Apart from meetings to obtain information, meetings were held in the collaborating villages in Udaipur and Bhilwara to present the findings of the project to the local goat keepers and to get their reactions to it. These meetings are reported on in the visit reports of Dr Wood for November 1998 and March/April 2000 in Technical Annex 1.

Modifications to proposed research activities

The research activities were extensively redesigned during the course of the project to adjust to the information gaps found (as noted in the project Annual Report 1998/99). The key information gap was in the details of the goats' diets, which the monitoring worked was designed to fill. This was a major new activity, so the feeding trial work anticipated in the Project Memorandum was not conducted due to lack of time and funding. In general, the goat keepers' options of what to feed to their goats were very

constrained by what was available, so some of the anticipated work on feed combinations was not appropriate. Additionally, project R6953 conducted farmer participatory feeding trials on the use of tree pods as supplements in Bhilwara district. This was also a major recommendation of this project based on the monitoring and laboratory work data. There was no need to replicate the feeding trials under this project. Otherwise, the planned inputs were achieved.

Outputs

Laboratory data on the nutritive value of feeds

This section starts with a presentation of the laboratory data which the project produced, followed by an overview of the properties of the different feed types. The data were used, together with existing literature information, in the preparation of a more user-friendly review of the nutritive value of dry season feeds in Southern Rajasthan. This gives a summary of the nutritive properties of the most important dry season goat feeds.

The chemical compositions of the samples from Khakad and Rampuriya analysed under this project is given in Table 12. Ash contents ranged from low levels in grains (8g per kg in maize) to relatively high levels in many of the dried leaf samples (up to 169 g per kg in sample IMy9, dried leaves collected from hills). There was also a wide range of crude protein contents, from 51 g per kg in cactus stems to 216 g per kg in green shoots of *Vitex negundo*. Ether extract values were generally low, the highest being 91 g per kg for a wheat grain plus sun hemp seed mixture (sample IF18). Some of the tree leaf samples had high fibre contents, which may have been due to the phenolic (tannin) fraction being included in some of the fibre fractions. For example sample IJy7 had a high NDF content (534.6 g per kg) and also a high total phenols content (86.5 g per kg gallic acid equivalent). Fibre contents ranged from lows for the grains (NDF for wheat grain 111 g per kg) to very high levels in bamboo leaves (NDF 802 g per kg). Total phenols ranged from trace levels in grains to high levels in some tree leaves and pods (up to 105 g per kg gallic acid equivalent in *Acacia nilotica* pods).

In vitro digestibility data are presented in Table 13. The extent of digestion is indicated by the fitted Gas Pool A, but perhaps in more familiar units by the dry matter disappearance (DMD). The rate of gas production is indicated by the rate constant b. It is unclear what, if any, physiological significance the rate constant c has. It is also unclear if the lag time T indicates a lag phase which would occur in a normal grazing goat. Therefore, indicators of the extent of digestion and the rate constant b were taken as the physiologically significant parameters. The Tilley and Terry in vitro dry matter digestibility is the extent of digestion at a single fixed point, which has proven to be a reliable indicator of the digestibility of good quality temperate pastures, but less reliable with tropical feeds. Gas Pools ranged from a low of 30 ml per g for *Prosopis cineraria* leaves to 300 ml per g for wheat grain, with corresponding DMDs of 0.30 and 0.96 respectively. Rate constant b ranged from a slow of 0.015 per h for Ziziphus maritiana leaves to a rapid 0.135 per h for wheat grain plus sun hemp seed.

Data on the experimental Nitrogen Deficiency Index (NDI) and in vitro protein degradation are presented in Table 14. A high positive NDI indicates that the feed is deficient in protein available to rumen microbes. This may be due to a low protein content, a low availability of the protein (perhaps due to tannins) or a particularly high amount of degradable carbohydrate which increases the need for a protein supply. NDI values vary with time of incubation and which times may be the most appropriate to use is unclear, but 48 h and 96 h were selected to give a concise representation of the data. The data indicated that particularly protein-deficient feeds

included *Derris indica* leaves, dried cactus stems, some samples of *Ziziphus maritiana* leaves, and dried maize grain. These feeds also had relatively low levels of crude protein disappearance when fermented in nitrogen-free medium, consistent with their NDI values. Low CPDnf values coupled with high CPDnr values may be an indicator of a good source of by-pass protein, that is protein which is not degraded in the rumen but is digestible lower in the gut. Leaves of *Ziziphus nummularia*, Z maritiana and Derris indica appeared to be particularly good sources of by-pass protein.

The approach needs more research to validate it, but it is a potentially rapid means of identifying which feeds should be supplemented with protein, and which can be used as supplements. Crude protein contents alone are inadequate particularly for tanniniferous tree fodders.

Table 12 Chemical composition of samples in g per kg dry matter (except where otherwise indicated)

Sample code	Description of sample	Ash	Crude protein	Ether extract	NDF	ADF	CF	Lignin	Total phenols[a]
IF3	*Azadirachta indica* (Neem) leaves	91	116	30	265	184	69	85	29
IF4	*Ziziphus mauritiana* leaves	78	139	18	333	217	120	50	14
IF5	Cotton pala	127	132	32	457	342	N/A	143	6
IF6	*Ziziphus nummularia*, dried leaves (bordi pala)	135	125	13	339	220	96	83	41
IF7	*Ziziphus nummularia*, dried leaves (bordi pala)	126	117	34	325	213	77	79	69
IF8	*Azadirachta indica* (Neem) leaves	73	156	56	287	179	65	89	19
IF13	barley grain, ex BAIF buck breeding programme	72	77	38	260	595	53	0.6	n/a
IF14	wheat grain, ex Patiyo Ka Khera	19	101	26	152	17	16	6	0
IF15	barley grain, ex Patiyo Ka Khera	26	73	20	134	25	20	3	2
IF18	wheat grain + sun hemp seed “concentrate” ex Mr. Sava Roopaji Vadera, Khakad	31	127	91	200	200	58	26	n/a
IF19	barley grain ex Khakad	36	89	23	219	342	38	7	n/a
IF20	neem leaves	116	124	35	231	178	69	90	52
IF22	wheat grain, ex Kirat	27	96	55	111	11	13	2	n/a
IF23	dried maize, ex Gopir	8	77	32	119	5	13	3	n/a
IF24	dried leaves of “kadwa” from hill slopes	107	66	47	317	315	147	118	13
IF25	dried leaves of “kadwa” from hill slopes	139	93	22	361	250	133	88	30
IMy1	*Ziziphus mauritiana* (ber) leaves	151	145	17	361	270	118	60	74
IMy2	*Acacia leucophloea* (arunjia) new leaves	79	169	17	358	281	168	86	54

Sample code	Description of sample	Ash	Crude protein	Ether extract	NDF	ADF	CF	Lignin	Total phenols[a]
IMy3	*Acacia nilotica* (babul) pods	52	133	21	332	278	169	81	96
IMy4	*Derris indica* (negad) leaves	62	128	34	346	260	145	112	31
IMy5	Dried leaves collected underneath karanj tree, upper valley (location code 2)	164	114	14	293	270	91	102	8
IMy6	Dried leaves collected underneath karanj tree, lower slopes (location code 3)	156	105	14	252	228	87	53	14
IMy7	*Vitex negundo* (Khanni), tops of green shoots pooled from 5 trees (only part eaten by goats)	71	216	57	205	150	122	40	42
IMy8	Dried leaves from below tamat trees, top of hills (location code 4)	169	68	11	313	334	106	70	13
IMy9	Second sample as per IMy8	164	74	11	310	380	106	87	12
IMy10	karanj trees (mainly),	157	98	22	308	272	108	84	15
IMy11	*Holorrena antidisentrica* (kadwa)	99	91	47	348	328	128	136	20
IMy12	*Acacia nilotica* (babul) leaves	94	143	44	273	151	104	74	93
IMy13	*Acacia nilotica* (babul) pods	40	136	20	272	250	156	74	105
IMy14	*Acacia nilotica* (babul) pods	47	137	19	271	218	154	61	104
IMy15	Cactus, *Opuntia* spp. (thor), dried	101	51	58	313	281	199	70	13
IMy16	*Prosopis juliflora* pods	43	115	14	382	214	189	39	18
IMy17	*Prosopis cineraria* (khejri) pods	40	164	15	325	213	136	44	n/a
IMy18	*Prosopis cineraria* (khejri) leaves	79	124	24	358	246	142	118	49
IMy19	*Ziziphus nummularia* (bordi) fresh leaves	57	185	21	292	196	129	64	94
IJy1	*Ziziphus maritiana* (ber)	112	131	23	415	269	140	95	37
IJy2	*Mangitesa indica* (mango)	157	69	38	425	371	196	104	64
IJy3	Bamboo	81	89	22	802	405	323	72	4

Sample code	Description of sample	Ash	Crude protein	Ether extract	NDF	ADF	CF	Lignin	Total phenols[a]
IJy4	*Derris indica* (negad)	63	96	45	410	285	196	155	16
IJy5	*Holorrena antidisentrica* (kadwa)	69	116	61	339	237	121	102	24
IJy6	karanj	145	150	20	268	180	108	37	9
IJy7	runjiya	71	116	47	535	384	265	161	87
IJy8	hitazi	92	92	27	548	441	246	137	44
IJy9	*Ficus indica* (pimpal)	141	123	30	430	358	215	81	10
IJy10	tamat	88	154	20	261	129	56	29	16
IJy11	khanni (all green leaves, not just shoots)	84	116	81	354	310	199	73	18
IJy12	godla	80	116	26	357	218	122	38	n/a
IJy13	*Acacia nilotica* (babool)	76	108	22	443	382	177	130	89
IJy14	kalbi	157	139	38	351	236	135	55	6

[a] Total phenols in g gallic acid equivalent per kg dry matter

Table 13 In vitro digestibility and gas production data on samples from Khakad and Rampuriya

Sample code	Description of sample	CG96[a]	Gas Pool A (ml g^{-1}DM)[b]	Rate Constant b (h^{-1})[b]	Rate Constant c ($h^{-0.5}$)[b]	Lag Time T (h)[b]	DMD (GP + acid pepsin)[c]	IVDMD[d]
IF3	Azadirachta indica (Neem) leaves	159	164	0.039	-0.018	0.5	0.66	0.73
IF4	Ziziphus mauritiana leaves	151	172	0.024	-0.014	0.8	0.63	0.66
IF5	Cotton pala	110	112	0.053	-0.108	3.5	0.52	n/a
IF6	Ziziphus nummularia, dried leaves (bordi pala)	67	71	0.03	-0.027	1.2	0.51	0.56
IF7	Ziziphus nummularia, dried leaves (bordi pala)	85	94	0.024	-0.013	1	0.51	0.61
IF8	Azadirachta indica (Neem) leaves	129	127	0.05	-0.041	1.3	0.67	0.73
IF13	barley grain, ex BAIF buck breeding programme	281	269	0.13	-0.207	2.6	0.9	n/a
IF14	wheat grain, ex Patiyo Ka Khera	310	300	0.132	-0.24	3.2	0.96	0.58
IF15	barley grain, ex Patiyo Ka Khera	296	287	0.114	-0.185	2.6	0.94	0.59
IF18	wheat grain + sun hemp seed “concentrate” ex Mr. Sava Roopaji Vadera, Khakad	224	217	0.135	-0.259	3.5	0.85	n/a
IF19	barley grain ex Khakad	291	280	0.124	-0.207	2.8	0.92	n/a
IF20	neem leaves	146	152	0.037	-0.022	0.5	0.62	0.71
IF22	wheat grain, ex Kirat	269	261	0.101	-0.182	3.1	0.98	n/a
IF23	dried maize, ex Gopir	330	322	0.085	-0.183	4.2	0.98	n/a
IF24	dried leaves of “kadwa” from hill slopes	126	130	0.046	-0.099	3.7	0.59	0.66
IF25	dried leaves of “kadwa” from hill slopes	121	124	0.048	-0.104	4.1	0.61	0.66
IMy1	Ziziphus mauritiana (ber) leaves	81	81	0.041	-0.065	2.7	0.46	0.64
IMy2	Acacia leucophloea (arunjia) new leaves	121	144	0.024	-0.043	2.6	0.47	0.54
IMy3	*Acacia nilotica* (babul) pods	n/a	n/a	n/a	n/a	n/a	n/a	0.61
IMy4	Derris indica (negad) leaves	177	185	0.045	-0.079	2.5	0.64	0.52
IMy5	Dried leaves collected underneath karanj tree, upper valley (location code 2)	106	107	0.054	-0.105	3.4	0.63	0.69
IMy6	Dried leaves collected underneath karanj tree, lower slopes (location code 3)	117	118	0.049	-0.087	2.7	0.61	0.75

Sample code	Description of sample	CG96[a]	Gas Pool A (ml g^{-1}DM)[b]	Rate Constant b (h^{-1})[b]	Rate Constant c ($h^{-0.5}$)[b]	Lag Time T-(h)[b]	DMD (GP + acid pepsin)[c]	IVDMD (%)[d]
IMy7	Vitex negundo (Khanni), tops of green shoots pooled from 5 trees (only part eaten by goats)	195	194	0.054	-0.08	2.5	0.82	0.83
IMy8	Dried leaves from below tamat trees, top of hills (location code 4)	106	116	0.029	-0.042	1.7	0.6	0.64
IMy9	Second sample as per IMy8	106	114	0.035	-0.065	2.8	0.59	0.62
IMy10	Dried leaves from below karanj trees (mainly), but also Vitex negundo (khanni) and Holorrena antidisentrica (kadwa) trees, top of hills (location code 4)	123	125	0.05	-0.089	2.9	0.61	0.67
IMy11	Dried leaves from below mainly Holorrena antidisentrica (kadwa) trees, lower slopes (location code 3)	119	123	0.046	-0.089	2.8	0.58	0.63
IMy12	*Acacia nilotica* (babul) leaves	n/a	n/a	n/a	n/a	n/a	n/a	0.61
IMy13	*Acacia nilotica* (babul) pods	n/a	n/a	n/a	n/a	n/a	n/a	0.63
IMy14	*Acacia nilotica* (babul) pods	n/a	n/a	n/a	n/a	n/a	n/a	0.62
IMy15	Cactus, Opuntia spp.? (thor), dried	229	228	0.064	-0.103	2.3	0.81	0.61
IMy16	Prosopis juliflora pods	212	216	0.034	0.044	0.1	0.81	0.75
IMy17	Prosopis cineraria (khejri) pods	235	236	0.051	-0.019	0.4	0.77	0.91
IMy18	Prosopis cineraria (khejri) leaves	29	30	0.042	-0.087	3	0.3	0.45
IMy19	Ziziphus nummularia (bordi) fresh leaves	128	150	0.022	-0.011	0.8	0.64	0.45
IJy1	Ziziphus maritiana (ber)	105	134	0.015	0.010	0.0	0.53	0.63
IJy2	Mangitesa indica (mango)	97	100	0.042	-0.022	0.3	0.50	0.65
IJy3	Bamboo	187	213	0.029	-0.056	2.2	0.70	0.58
IJy4	Derris indica (negad)	123	no fit	no fit	no fit	no fit	0.58	0.51
IJy5	Holorrena antidisentrica (kadwa)	150	153	0.048	-0.050	0.9	0.60	0.84
IJy6	karanj	153	149	0.075	-0.044	0.5	0.86	0.85
IJy7	runjiya	77	82	0.026	0.002	0.5	0.40	0.44

Sample code	Description of sample	CG96[a]	Gas Pool A (ml g^{-1}DM)[b]	Rate Constant b (h^{-1})[b]	Rate Constant c ($h^{-0.5}$)[b]	Lag Time T-(h)[b]	DMD (GP + acid pepsin)[c]	IVDMD (%)[d]
IJy8	hitazi	47	47	0.043	-0.044	1.2	0.38	0.45
IJy9	Ficus indica (pimpal)	134	131	0.068	-0.075	1.2	0.69	0.75
IJy10	tamat	109	no fit	no fit	no fit	no fit	0.70	0.68
IJy11	khanni (all green leaves, not just shoots)	167	162	0.065	-0.060	1.2	0.73	0.84
IJy12	godla	n/a	n/a	n/a	n/a	n/a	n/a	0.66
IJy13	Acacia nilotica (babool)	111	114	0.045	-0.063	1.8	0.60	0.38
IJy14	kalbi	180	174	0.069	-0.004	0.2	0.76	0.80

[a] CG96 = cummulative gas production after 96h incubation in nitrogen rich medium (ml per gDM)
[b] Parameters from the France et al. (1993) model to interpret gas production data
[c] Proportional dry matter disappearance following 96h gas production and acid pepsin treatment of residue
[d] Proportional in vitro dry matter digestibility by the method of Tilley and Terry (1963)
n/a = sample not analysed
no fit = France et al. (1973) model did not fit the data, hence parameters not estimated.

Table 14 In vitro protein degradation of samples from Udaipur and Bhilwara

Sample code	Description of sample	NDI48[a]	NDI96[b]	CPDnr[c]	CPDnf[d]
IF3	Azadirachta indica (Neem) leaves	24	10	88	66
IF4	Ziziphus mauritiana leaves	41	43	109	62
IF5	Cotton pala	1	-1	82	78
IF6	Ziziphus nummularia, dried leaves (bordi pala)	-4	2	73	44
IF7	Ziziphus nummularia, dried leaves (bordi pala)	17	27	68	33
IF8	Azadirachta indica (Neem) leaves	17	18	136	102
IF13	barley grain, ex BAIF buck breeding programme	-5	-11	99	98
IF14	wheat grain, ex Patiyo Ka Khera	-5	-7	125	125
IF15	barley grain, ex Patiyo Ka Khera	12	-9	n/a	n/a
IF18	wheat grain + sun hemp seed "concentrate" ex Mr. Sava Roopaji Vadera, Khakad	-20	-18	n/a	n/a
IF19	barley grain ex Khakad	-14	-16	n/a	n/a
IF20	neem leaves	18	6	84	63
IF22	wheat grain, ex Kirat	21	-6	n/a	n/a
IF23	dried maize, ex Gopir	46	14	n/a	n/a
IF24	dried leaves of "kadwa" from hill slopes	22	1	44	38
IF25	dried leaves of "kadwa" from hill slopes	6	-4	67	62
IMy1	Ziziphus mauritiana (ber) leaves	4	10	103	100
IMy2	Acacia leucophloea (arunjia) new leaves	17	8	134	90
IMy4	Derris indica (negad) leaves	68	67	97	48
IMy5	Dried leaves collected underneath karanj tree, upper valley (location code 2)	-6	-10	91	87
IMy6	Dried leaves collected underneath karanj tree, lower slopes (location code 3)	1	-3	83	79
IMy7	Vitex negundo (Khanni), tops of green shoots pooled from 5 trees (only part eaten by goats)	-21	-9	211	193
IMy8	Dried leaves from below tamat trees, top of hills (location code 4)	29	29	49	36
IMy9	Second sample as per IMy8	22	5	54	51
IMy10	Dried leaves from below karanj trees (mainly), but also Vitex negundo (khanni) and Holorrena antidisentrica (kadwa) trees, top of hills (location code 4)	6	1	73	n/a
IMy11	Dried leaves from below mainly Holorrena antidisentrica (kadwa) trees, lower slopes (location code 3)	17	2	66	61
IMy15	Cactus, Opuntia spp.? (thor), dried	38	13	48	46
IMy16	Prosopis juliflora pods	-1	-2	113	110
IMy17	Prosopis cineraria (khejri) pods	-1	1	157	146
IMy18	Prosopis cineraria (khejri) leaves	-3	-2	37	41
IMy19	Ziziphus nummularia (bordi) fresh leaves	11	22	118	74

Sample code	Description of sample	NDI48[a]	NDI96[b]	CPDnr[c]	CPDnf[d]
IJy1	Ziziphus maritiana (ber)	6	11	128	67
IJy2	Mangitesa indica (mango)	41	28	53	39
IJy3	Bamboo	1	2	46	43
IJy4	Derris indica (negad)	55	54	149	30
IJy5	Holorrena antidisentrica (kadwa)	15	4	132	120
IJy6	karanj	24	10	225	171
IJy7	runjiya	11	8	70	43
IJy8	hitazi	2	-2	66	44
IJy9	Ficus indica (pimpal)	4	3	54	42
IJy10	tamat	32	26	249	175
IJy11	khanni (all green leaves, not just shoots)	-3	-5	88	113
IJy13	Acacia nilotica (babool)	9	6	168	123
IJy14	kalbi	7	2	71	56

[a] Nitrogen Deficiency Index after 48h incubation
[b] Nitrogen Deficiency Index after 96h incubation
[c] Crude protein disappearance after gas production in nitrogen-rich medium plus acid pepsin treatment.
[d] Crude protein disappearance after gas production in nitrogen-free medium
n/a not analysed as grains left insufficient residue for analysis

Bioassays

The results of the bioassays are summarised in Table 16. Total Phenols content data are also included as it was considered that phenols could be active in the bioassays. Toxic factors were not detected in the majority of the tree fodder samples. Extracts of *Acacia leucophloea* pods (samples IF1, IF9, IF12, IF21) were toxic to brine shrimp but not to moulds under the conditions of the assays. Bordi pala (dried leaves of *Ziziphus nummularia*) gave inconsistent results with one sample (IF6) having toxic activity to both brine shrimp and moulds (DCM extract only), while the other sample (IF7) had no detectable activity in either assay. Mature *Acacia leucophloea* leaves were toxic to brine shrimp, but not mould (samples IF2, IF10, IJy7), but new leaves had not detectable toxicity (sample IMy2).

Table 15 Summary of brine shrimp and TLC/mould inhibition data, together with data on Total Phenols content

	brine shrimp assay	TLC/mould data		Total Phenols
		DCM extract	Aq extract	g/kg gallic acid equiv
Sample code[a]				
IF1	5.9	nd	nd	na
IF2	6	nd	nd	na
IF3	nd	nd	nd	29.2
IF4	4.4	nd	nd	14.4
IF5	nd	nd	nd	6.3
IF6	5.6	0.2	nd	41.3
IF7	nd	nd	nd	69.2
IF8	nd	nd	nd	18.7
IF9	5.9	nd	nd	na
IF10	13	nd	nd	na
IF11	nd	na	na	na
IF12	6	nd	nd	na
IF13	nd	na	na	na
IF14	nd	na	na	0
IF15	nd	na	na	1.4
IF16	nd	na	na	na
IF17	nd	na	na	na
IF18	nd	na	na	na
IF19	nd	na	na	na
IF20	6.6	nd	nd	52.2
IF21	10.3	nd	nd	na
IF22	nd	na	na	na
IF23	nd	na	na	na
IF24	nd	nd	nd	13
IF25	nd	0.57	nd	30
IF26	nd	na	na	na

IMy1	5.65	nd	nd	73.6
IMy2	nd	nd	nd	54.4
	brine shrimp assay	TLC/mould data		Total Phenols
		DCM extract	Aq extract	g/kg gallic acid equiv
Sample code[a]				
IMy3	6.8	nd	nd	95.8
IMy4	4.8	nd	nd	31.4
IMy5	nd	0.58	nd	7.6
IMy6	nd	0.25	nd	13.6
IMy7	5.4	0.38	0.4	42
IMy8	nd	nd	nd	13.1
IMy9	11	nd	nd	11.7
IMy10	nd	nd	nd	15.2
IMy11	nd	nd	nd	19.7
IMy12	8.6	nd	nd	93.1
IMy13	4.2	nd	nd	105
IMy14	4.8	nd	nd	104.1
IMy15	6.4	nd	nd	13.1
IMy16	5.4	nd	nd	18.3
IMy17	nd	nd	nd	na
IMy18	9.8	nd	nd	48.6
IMy19	4.9	na	na	94.3
IJy1	10.8	nd	nd	37
IJy2	5.2	nd	nd	63.7
IJy3	nd	nd	nd	4.2
IJy4	3	nd	nd	16.4
IJy5	nd	nd	nd	24
IJy6[b]	3.8	0.15	0.29[b], 0.26[b]	8.9
IJy7	7.3	nd	nd	86.5
IJy8	nd	nd	nd	44.2
IJy9	nd	nd	nd	9.5
IJy10	3.3	nd	nd	16
IJy11	3.7	0.41	0.52	18.3
IJy12	nd	na	na	na
IJy13	3.7	nd	nd	88.7
IJy14	7.6	nd	nd	6.3

Note a For key to sample codes see Tables 1, 2 and 3
Note b For sample IJy6 there were two spots on the TLC plates with the aqueous extract
nd = not detected
na = not analysed

Karanj leaves (IJy6) were toxic in both assays, with the Aqueous extract giving two areas of mould inhibition in the TLC/mould assay. Fallen, dry karanj leaves (IMy5 and 6) inhibited mould growth (DCM extract only), but had no detectable toxicity to brine shrimp. Khanni (*Vitex negundo*) (samples IMy7 and IJy11) were toxic in both assays.

A wide range of tree fodders had toxic activity towards brine shrimp, but no detectable activity in the TLC/mould bioassay. These fodders included *Ziziphus mauritiana* (IF4, IJy1), *Acacia nilotica* (IMy12, 13, 14 and IJy13), *Prosopis juliflora* pods (IMy16) and *Prosopis cineraria* leaves (IMy18, but not pods IMy17). Most of the dried leaf samples of material grazed from the ground did not contain toxins. Perhaps surprisingly cactus (IMy15) had some activity in the brine shrimp assay, but not in the TLC/mould assay. As expected bamboo (IJy3) had no toxic activity with either assay.

There were no apparent relationships between total phenol contents of the samples and their activities in either bioassay. 24 samples were active in the brine shrimp assay and had detectable levels of total phenols, but there was no significant ($P>0.05$) linear correlation found between these assays. All of the samples with mould inhibition activity had detectable total phenols, but of the 10 samples with high (>50 g kg^{-1} gallic acid equivalent) levels of total phenols which were also assayed for mould inhibition, none had any detectable activity with that assay.

A leucophloea pods did not appear to contain toxic factors according to the mould inhibition/TLC assay, even ones said to be toxic by farmers. This is consistent with earlier findings that cyanogenic glycosides are the main toxic agent as it is unlikely that these would survive the sample preparation procedure. However, it is said that stored pods are toxic, possible due to another toxin, but whatever the toxin the test used did not detect it.

Overview of laboratory data

To obtain an overview of the data, the feeds were grouped into four types: concentrates, dried leaves (stored or grazed), tree pods and tree leaves (fresh only; grazed or lopped). Table 16 summarises the most important properties of different feed types.

Table 16 Summary of most important laboratory characteristics of different types of feeds
(average ±standard deviation for all feed samples of the type analysed)
g per kg dry matter, unless otherwise shown

Feed type	Rate Constant b (h^{-1})	GP + acid pepsin[a]	Ash	Crude protein	Ether extract	NDF
concentrates	0.12±0.017	0.92±0.049	31±20.1	91±18.8	41±25.1	171±56.4
dried leaves	0.04±0.012	0.57±0.046	134±30.7	100±22.2	23±14.1	305±98.3
tree pods	0.04±0.008	0.79±0.028	42± 2.1	165±42.1	15± 0.7	354±40.3
fresh leaves	0.04±0.025	0.60±0.088	97±44.6	135±13.2	17± 3.0	166± 5.2

Note a Proportional dry matter disappearance following in vitro gas production (96 h) and treatment of the residue with acid pepsin

The various concentrate samples all yielded relatively high gas productions at all selected times, indicating a rapid and extensive fermentation (0.86 to 0.98 DMD). There were indications of a deficiency of fermentable protein in maize grain (high positive NDI48) but not with the other concentrates. The laboratory data indicated that, as expected, all of the concentrates are excellent energy sources. Maize grain may benefit from supplementation with a readily fermentable protein (or nitrogen) source.

Dried leaves

Ziziphus nummularia, dried leaves (bordi pala), was relatively poorly fermented (both slowly and to a low extent, 0.51 DMD). Bioassays indicated the presence of a toxic factor in *Ziziphus nummularia* which survives the drying process. Cotton pala fermentation was relatively quick but not extensive (0.52 DMD). Dry kadwa, karanj and tamat leaves were fermented fairly extensively (0.6 - 0.7 DMD). Dried karanj and some dried kadwa appeared to contain a toxic factor. They appeared to be quite reasonable energy sources. Bordi pala appeared deficient in fermentable protein, possibly also kadwa. However, the other samples appeared sufficient in fermentable protein.

Overall, the dried leaves grazed by goats in Udaipur district appear to be of reasonably high nutritive value based on the in vitro data. Cotton pala appeared to be of higher quality than bordi pala. Dried leaves could potentially be a useful feed for storage, to be fed when grazing is severely restricted.

Tree pods

Fermentation rates and extents were mid range (about 0.6 to 0.8 DMD), although this is quite good for tree fodders. The pods appear to be particularly useful as sources of fermentable protein. *Acacia* pods were found to be good protein supplements in earlier in vitro work. *Prosopis juliflora* pods have a lower protein content, but the protein appears highly fermentable.

The tree pods appear to be valuable protein supplements. They would be particularly useful for goats fed protein deficient diets, and/or for lactating or pregnant goats. There could be scope for storage of pods, or better management of their utilisation, in recognition of their high nutritive value.

Tree leaves (fresh)

19 different tree leaf fodders have been examined in the laboratory, and they were found to have widely ranging properties. Extents of DMD during gas production ranged from 0.38 to 0.86, rate constants from 0.022 to 0.075 h^{-1}. *Pongamia pinnata*, *Opuntia* sp. stems, *Vitex negundo* tops were highly fermentable(0.86, 0.81 and 0.73 respectively). However, fresh *P. pinnata* and *V. negundo* appeared to contain toxic factors. The popular feeds *A. leucophloea* and *Ziziphus mauritiana* leaves were both poorly fermented (0.40 and 0.54 respectively), as was hitazi (0.38). *A. leucophloea*

and *A. nilotica* leaves both had high contents of total phenols (>50 g kg^{-1} gallic acid equivalent). *Z. nummularia* (fresh leaves) was fermented slowly but reasonably extensively (0.64). This tends to support findings in Nepal that farmers do not appear to necessarily prefer the most digestible feeds for their animals (Thorne et al., 1999).

The green tops of khanni appeared to be a very good protein source. *P. cineraria* leaves also appeared useful. *D. indica* appeared to be very deficient in fermentable protein, but there were indications that it may be a source of by-pass protein. *Azadirachta indica*, *Z. mauritiana* and *A. leucophloea* leaves appeared to have a slight deficiency in fermentable protein, but again may be good sources of by-pass protein. *Mangitesa indica* leaves and tamat also appeared deficient in fermentable protein, but the data sets are incomplete. *M. indica* leaves had a high content of total phenols (>50g kg^{-1} gallic acid equivalent).

The nutritive characteristics of fresh tree leaves are very variable. The information from in vitro evaluation may suggest improved ways of managing feed resources.

Use of laboratory data

The project then sought to use the data produced, together with literature data, to produce messages on feed quality which could be transmitted to farmers and extension workers. The information was compiled into a review on the nutritive value of feeds. This is summarised below. The full review has been published by the project as a booklet. The full text of the booklet is given in Technical Annex 2. A more general description and discussion on laboratory methods is given in a second project booklet, the text of which is also given in Technical Annex 2.

Review on the nutritive value of feeds

The information on nutritive value was compiled into a draft review "A review of the nutritive value of dry season feeds for ruminants in Southern Rajasthan", which was added to and refined as the project progressed, and which constitutes one of the outputs of the project. A summary of the most important characteristics of the most important fodder species is given in Table 17.

The chief characteristics are a slightly subjective way of summarising complex data, sometimes from different sources and in different forms, in a way which can be presented to livestock keepers and extension workers.

Table 17 Summary of chief characteristics of nutritive value of most important fodders

Scientific name	Where found	Chief characteristics
Acacia leucophloea	Bhilwara, Udaipur	
Pods		Good protein source, potential toxicity problems
leaves		Moderate to poor energy and protein source
Acacia nilotica	Bhilwara, Udaipur	
Pods		Good protein source
leaves		Moderate energy and protein source
Azadirachta indica, leaves	Bhilwara	Good energy source
Balanites aegyptica, leaves	Bhilwara	Good energy source
Derris indica, leaves	Udaipur	Moderate to good energy source
Ficus indica, leaves		Good energy source
Garunga pinnata, leaves	Bhilwara, Udaipur	Moderate energy and protein source
Gossypium sp., leaves	Bhilwara	Moderate energy source
Holorrena antidisentrica, leaves	Udaipur	Moderate energy source
Opuntia spp.	Bhilwara	Good energy source
Pongamia pinnata	Udaipur	Moderate energy source
Prosopis cineraria	Bhilwara	
pods		Good protein and energy source
leaves		Poor energy source
Prosopis juliflora, pods only	Bhilwara	Good protein and energy source
Vitex negundo, leaves	Udaipur	Good protein source
Ziziphus mauritiana, leaves	Bhilwara	Good energy source, moderate protein source

Goat monitoring - Khakad, Udaipur District

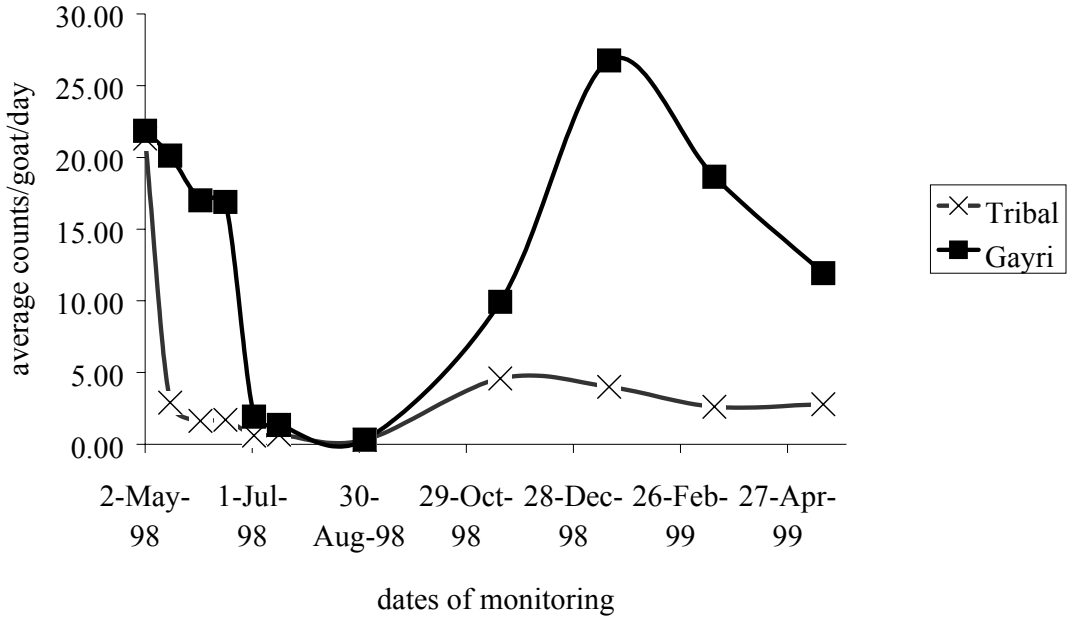
While the monitoring studies were conducted primarily to obtain information on the diets which the goats were consuming, data from Khakad enabled comparisons to be made between specialist goat keepers (Gayris) and poorer tribal caste goat keepers. It was found that, on average, tribal goats spent about twice as much time walking to look for feed, reflecting the distances of the different grazing areas used from the homesteads. Table 18 presents overall averages for the types of activities monitored.

Table 18 Activities of goats by ethnic group of goat keepers, average counts per goat per day over all monitoring periods ± standard error

Activity of goats	Tribal goat herds	Gayri goat herds
Feeding	67.8 ± 0.91	74.1 ± 0.93
Walking	34.1 ± 0.42	16.1 ± 0.46
Resting	17.5 ± 0.70	10.5 ± 0.29
Other	2.4 ± 0.20	11.6 ± 0.27

However, there were very marked seasonal differences in many of the parameters monitored. Overall differences can be misleading. Differences were most pronounced in the summer season when feed shortages are generally most acute. A major difference was in access to lopped tree fodder, which was relatively poor for tribal goat keepers. This is illustrated in Figure 1 below.

Figure 1 Access to lopped tree fodder by goats of the Tribal and Gayri communities



Tribal goat keepers were very much more dependant of grazing in the hill areas than the Gayris. The Gayris access to *A. nilotica*, a good quality tree fodder, was relatively high, but in an interesting contrast *A. leucophloea* was much more important to the poorer goat keepers. This was probably due to the ability of this species to prosper in poor land, such as the hill areas, and also the preference of goat keepers for other species due to the sporadic incidences of toxicity of *A. leucophloea* pods. The use of these two *Acacias* by the two groups of goat keepers is illustrated in Figures 2 and 3.

Figure 2 Use of *Acacia nilotica*

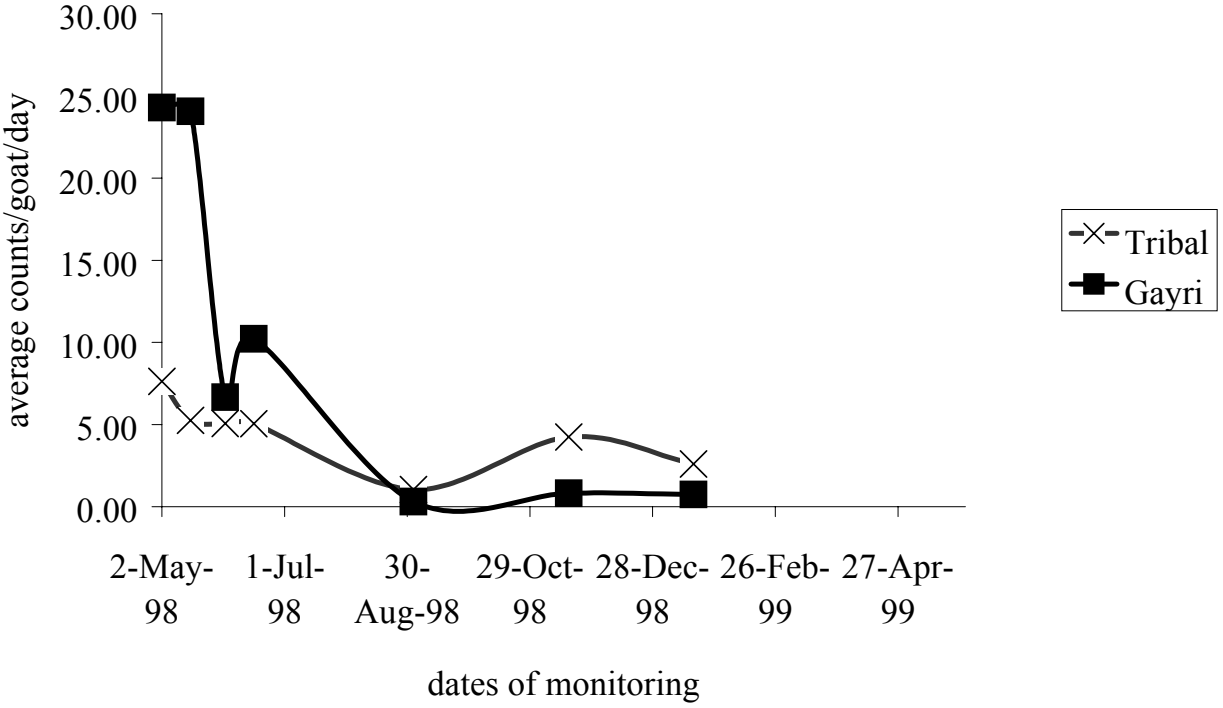
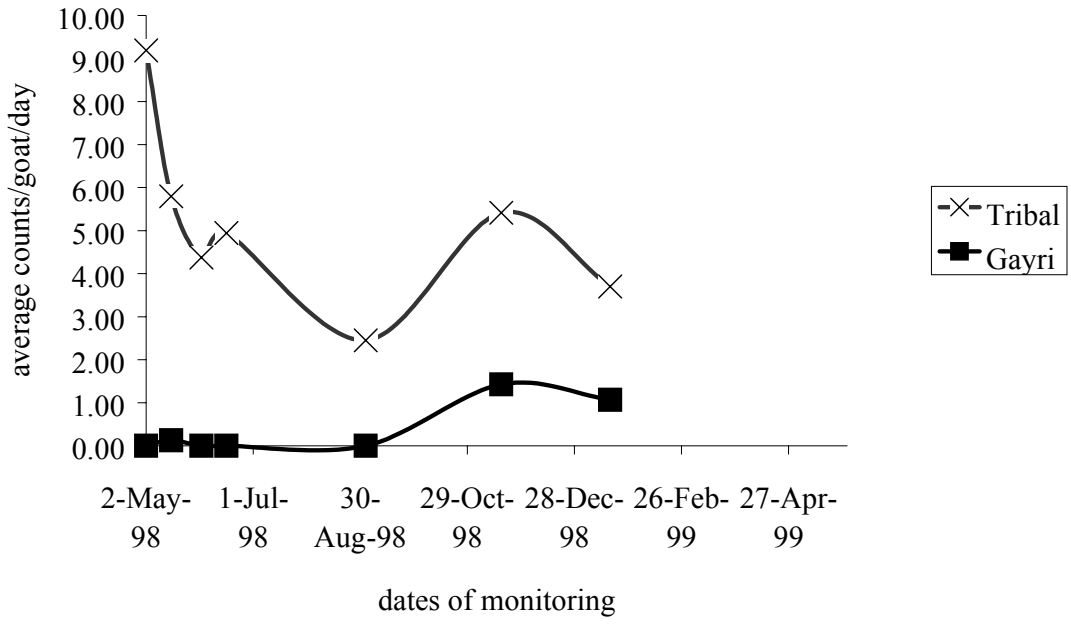


Figure 3 Use of *Acacia leucophloea* by period and ethnic group of goat owners



The most frequently occurring named feeds during the May - June period (summer and the start of the monsoon season) are given in Table 19. Of a total of 19,085 records, 12,407 records were of the goats feeding. Only named feeds with more than 248 records (2% of the total feeding codes) are listed.

Table 19 Named feeds consumed by grazing goats, May-June 1998 (Monitoring periods 1 to 4 inclusive)

Local name	Scientific name	No counts	% of total feeding counts
Runjiya leaves	*Acacia leucophloea*	460	3.7
Negad leaves	*Derris indica*	996	8.0
Kanje leaves		300	2.4
Dry grass and pods of shrubs		1392	11.2
Unknown shrub or tree leaves		275	2.2
Green grass		415	3.3
Mango tree leaves	*Mangifera indica*	491	4.0
Fallen ber leaves	*Ziziphus mauritiana*	1216	9.8
Desi babool leaves and pods	*Acacia nilotica*	1570	12.7
Rujadi twigs		494	4.0
Green dhobadi or hariyali		625	5.0
Aankada green leaves		305	2.5

The 12 named feeds in Table 19 accounted for 68.8% of all the feeding codes over this period. Excluding dry grass and pods of shrubs and unknown shrub or tree leaves, the 10 named feeds accounted for 55.4% of the total feeding counts. Thus it was only possible to define the diet in fairly broad terms due to its complexity and difficulty of identifying all its components.

The outputs of the work conducted in Udaipur are described in more detail, and with a more rigorous analysis of the data, in a draft scientific paper, given in Technical Annex 2 ("The monitoring of goats in Rajasthan, India: contrasts between goat herds owned by two ethnic groups" by C D Wood, V C Badve, D N Shindey and M A Conroy). As regards the technique itself, the study concluded that goat monitoring, using members of the goat-keeping communities as monitors, has been able to investigate the grazing behaviour and diet of goats. Key differences in the diets of goats from the two communities investigated have been identified together with differences in where the goats were grazed. The technique allows semi-quantitative estimates of differences to be made. It also enables a more detailed analysis of the diet to be made than could be achieved by interview and survey techniques, and usefully complements such techniques

Goat monitoring - Rampuriya village, Bhilwara District

Average daily counts per monitoring period for each activity are given in Table 20, and for each feed type in Table 21.

Table 20 Goat activities by monitoring period (average number of counts per goat per day)

	Goat activities			
Monitoring period	**1 grazing**	**2 walking**	**3 resting**	**4 other**
Period 1	78.3	17.3	25.6	23.9
Period 2	84.6	19.8	22.1	18.3
Period 3	85.2	16.8	24.1	18.7
Period 4	104.1	11.9	14.0	14.9
Period 5	82.4	20.7	25.9	16.0
Period 6	72.1	17.8	30.2	24.8
Period 7	65.0	15.4	28.0	36.7
Period 8	67.8	15.9	29.0	32.2
Period 9	74.0	17.3	31.7	35.1
All periods	78.4	16.9	25.9	25.3
P (differences between periods)	.000***	.014*	.000***	.000***

Differences in walking (code 2) were modest and did not follow a clear seasonal pattern. Grazing counts were highest in early July (104.1 counts/day). Otherwise grazing counts in other periods were in the range 65.0 to 85.2 counts/day, with the lowest number (<70) in periods 7 and 8 (mid January and mid March). High grazing counts in period 4 were also reflected in reduced walking, resting and other counts.

Table 21 Feed types by monitoring period (average number of counts per goat per day)

	Feed type (code and description)					
Monitoring period	**0 no feed**	**1 lopped tree fodder**	**2 grazed tree fodder and grass**	**3 dried leaves**	**4 concentrate**	**5 other**
Period 1	63.5	3.5	51.9	1.1	0.0	25.1
Period 2	60.7	4.9	54.3	1.5	0.0	23.6
Period 3	59.7	0.9	66.7	0.7	0.1	16.7
Period 4	40.7	0.0	99.9	0.4	0.1	3.8
Period 5	62.9	0.4	79.1	0.0	0.0	2.7
Period 6	72.8	0.9	69.2	0.1	0.3	1.8
Period 7	80.5	27.6	29.8	3.4	0	3.7
Period 8	77.2	19.0	38.0	4.5	0	6.3
Period 9	84.2	20.8	41.4	4.9	0	6.9
All periods	67.9	9.8	56.8	2.0	0.1	10.0
P (differences between periods)	.000***	.000***	.000***	.000***	.004**	.000*

For code 0 (as with the activities), the major differences were in period 4, due to a sharp decrease in the average number of counts when the goats were not feeding. Lopped tree counts reached a peak in period 7 (mid January), falling sharply by mid May. Lopped tree fodder virtually disappeared from the diet at the end of the dry season/start of the wet season (period 4, early July) and remained a very minor component of the diet at the end of the rains (periods 5 and 6, mid August and mid September). The largest category of feeding counts were for grazed tree fodder and grass during every monitoring period, although in period 7 (mid January) lopped tree fodder was nearly its equal. Grazed tree fodder and grass rose to a maximum in period 4 (early July) and fell to a minimum in period 7 (mid January). Dried leaves were a minor component of the diet for much of the dry season, from mid January to early July.

Named feed codes were developed in the course of the first six monitoring periods and are given in Table 22; the utilisation of the most common named feeds in Table 23. Field observations of grazing goats had indicated that *Ziziphus nummularia* (Bordi) was a very common feed although it had not featured at all as one of the named feeds in the monitoring. Discussions with the monitors revealed that this was because small shrubs were usually called "zhadi", and so it had been classified as an unnamed tree or shrub (code 13). The monitors estimated that the unnamed tree or shrub category consisted of about 70% *Ziziphus nummularia*, 10% jherjani (a small shrub), 2 to 3% *Trapa natans* (kareti, a small shrub), 5% Phang (a creeper), 4 to 5% *Clerodendrum phlomidis* (arani, a small shrub), 2% *Securinega leucopyros* (salepan, a small shrub), small quantities of *Solanum surattense* (kantali, a prickly shrub - not very common).

Table 22 Named feeds identified during monitoring periods 1 to 6
Most commonly occurring (>100 counts) named feed codes are shown in bold

feed code	Feed	counts	% of total	% of total feeding counts
0	**Not feeding**	**10626**	**45.5**	**N/A**
5	***Acacia leucophloea***	**1834**	**7.9**	**14.4**
7	**Derris indica**	19	0.1	0.1
13	**Small shrubs, (mainly *Ziziphus nummularia*)**	**3995**	**17.1**	**31.4**
17	**Green grass**	**2124**	**9.1**	**16.7**
31	*Ziziphus mauritiana*	68	0.3	0.5
35	***Acacia nilotica***	**1083**	**4.6**	**8.5**
47	Green dhobadi	27	0.1	0.2
64	Aankada	26	0.1	0.2
71	*Azadirachta indica*	24	0.1	0.2
201	***Opuntia* sp. (cactus)**	**2056**	**8.8**	**16.2**
202	**Hingoli**	**240**	**1.0**	**1.9**
203	Warwai	57	0.2	0.4
204	*Prosopis cineraria*	**516**	**2.2**	**4.1**
206	*Prosopis juliflora*	41	0.2	0.3
208	Gai	25	0.1	0.2
209	**Ker**	**145**	**0.6**	**1.1**
210	Jarjani	48	0.2	0.4
211	**Dab (a grass)**	**101**	**0.4**	**0.8**
212	Mustard straw	29	0.1	0.2
213	Sorghum	67	0.3	0.5
214	Kantala (a grass)	32	0.1	0.3
215	Maize	12	0.1	0.1
217	Gwar	16	0.1	0.1
218	Wheat	30	0.1	0.2
220	Cotton leaves (dry or green)	41	0.2	0.3
222	Pipal	12	0.1	0.1
223	Lemon tree leaves	13	0.1	0.1
	Total No counts	23,343		

Table 23 Average counts per goat per day of most common named feeds by monitoring period

Monitoring period	1	2	3	4	5	6	7	8	9
Named feed code									
0	65.8	60.2	59.5	40.9	62.8	72.9	80.8	77.3	84.3
5	7.0	14.6	6.1	4.8	10.8	12.9	23.6	8.7	9.5
13	34.8	26.7	21.1	29.3	18.6	19.2	27.6	21.5	22.5
17	2.2	2.3	13.8	44.5	36.8	11.4	.4	4	4.4
31	0.2	0.0	0.0	0.0	0.0	0.1	.7	1.8	2.0
35	9.3	5.5	2.5	1.9	6.6	7.7	2.9	15.8	17.2
201	19.6	23.5	26.4	13.2	4.7	7.2	3.3	6.8	7.4
202	1.2	2.0	5.5	0.6	0.6	0.7	.9	.7	0.8
204	3.3	8.4	3.1	3.4	3.3	5.8	0	0	0.0
209	0.7	1.0	1.1	0.9	0.3	1.1	1.1	1.0	1.1
211	0.0	0.1	1.1	1.6	0.1	0.0	.3	1.8	2.0
Average total counts per day	145.2	145.0	144.8	144.9	145.1	145.0	145.0	145.0	158.2
Average counts eating per day	81.7	84.3	85.1	104.2	82.2	72.2	64.5	67.8	74.0

Code 13 (small shrubs) constituted 43.9% of the feeding counts in Period 1, but fell to about 25% in Periods 3 to 6. Green grass (code 17) was a major component (>40%) of the counts in Periods 4 and 5, after the rains had started, but was of minor importance (2.7%) in Periods 1 and 2, before the rains. Code 201 (*Opuntia* sp., cactus) is clearly an important dry season component which is of lesser, but still appreciable, importance when green grass is available. Acacia fodder (*Acacia leucophloea*, code 5; *Acacia nilotica* code 35) was a major component. Only in Period 4 did the total *Acacia* sp. counts fall below 10% of the total feed counts. *Prosopis cineraria*, code 204, was another important fodder tree component of the diet.

One of the objectives of this study was to define the dry season diet of the goats to see if there were likely to be imbalances in the diet. Cactus was a major component of the diet with 23.5 of 84.3 (28%) feeding counts in Period 2. Small shrubs, mainly *Ziziphus nummularia*, accounted for 26.7 of 84.3 feeding counts in Period 2. Other important components of the diet were the tree fodders *Acacia leucophloea* (14.6 counts in Period 2), *Acacia nilotica* (5.5 counts in Period 2) and *Prosopis cineraria* (8.4 counts in Period 2). These five dietary components together accounted for 78.7 counts out of 84.3, 93% of the total feeding counts.

The goat monitoring in Khakad village, Udaipur District, found averages (in counts per day per goat) of 74.1 for feeding, 16.1 for walking, 10.5 for resting and 11.6 for other activities for goats owned by Gayri herdsmen. The grazing and walking counts are very similar to those found in Rampuriya, although resting and other counts were

higher in Rampuriya. Both the Gayri goat herds in Khakad and those monitored here were kept for commercial milk production and similarities in activities may reflect a general similarity in management style. Lower feeding counts (67.8 counts per goat per day) and much higher walking counts (34.1 counts per goat per day) for goats owned by subsistence Tribal farmers in Khakad, probably reflecting reduced access to feed and different management styles and objectives.

Discussions with goat keepers indicated that the decline in the use of lopped tree fodder in the summer season is a reflection of its poor availability and is clearly a constraint to the feed supply. "Other" feed types, of which lopped cactus stems formed a large part, were used to help fill the gap in the feed supply. Lopped tree fodder was of little importance during the monsoon season, when the availability of green grass meant that it was not required.

This study concluded that the monitoring had been able to provide a semi-quantitative description of the diet and had clearly detected seasonal changes in the goats' diets. The data provided an objective basis for looking at the importance of different feed components. There were similarities between the management of the goats in Rampuriya and the goats belonging to the Gayri herdmen in Khakad, although differences in the availability of different feeds gave rise to differences in the diets. *Opuntia* sp.(cactus), *Ziziphus nummularia*, *Acacia leucophloea*, *Acacia nilotica* and *Prosopis cineraria* were major components of the diet at the end of the dry season, the first two feeds being the most important quantitatively. A paper reviewing the goat monitoring studies at Rampuriya and Khakad was presented at the end of project workshop held at Udaipur, September 2000, the text of which is given in Technical Annex 2 (The monitoring of goats in Rajasthan, India by C D Wood and V C Badve). A draft scientific paper on the Rampuriya monitoring has been produced and is also given in Technical Annex 2 (Diets and behaviour of grazing goats in semi-arid India by C D Wood, V C Badve, M. S. Sharma and M A Conroy).

Livestock monitoring - Khumbhan, Bhavnagar District

This monitoring exercise was designed to investigate the impact of the introduction of a water trough (constructed under project R6953) rather than to define the diet as such, although the methodology was broadly the same that used for the Khakad and Rampuriya studies.

Average numbers of activity counts for each monitoring period for goats and cows are given in Table 24.

Table 24 Activities of monitored goats and cows by monitoring period
Data in average counts per day per animal

Monitoring period	1 Grazing	2 Walking	3 Resting	4 Other	5 Walking and feeding
Goats					
1	38.2	26.3	31.1	16.7	29.5
2	36.2	26.8	32.8	15.5	35.6
3	42.5	25.7	37.5	20.1	22.5
4	34.9	24.4	38	19.2	32.6
5	*37.5*	*28.5*	*45*	*16.5*	*25.7*
6	*39.5*	*23.8*	*42.7*	*15.2*	*31.9*
7	***21.4***	***8.5***	***15.4***	***8.4***	***19.2***
Cows					
1	48.4	33.6	34.3	13	18.3
2	56.8	25.8	26.3	30.2	16.3
3	48.2	26.7	26.3	27.9	22.8
4	44.3	26.8	28.1	26.3	27.3
5	*41.8*	*28.3*	*27.8*	*22.7*	*30.8*
6	*39.9*	*26.1*	*31.3*	*27.9*	*26*
7	***49.8***	***14.4***	***35.4***	***34.5***	*7*
Sig 1	*	***	ns	*	***
Sig 2	ns	ns	**	ns	ns

Sig 1= Statistical significance of parameter*period across goats and cows
Sig 2 = Statistical significance of parameter*with/without trough (monitoring periods 1 to 4/5 and 6 only)
Standard numbers = before trough in use
Italic numbers = after trough in use
Italic bold numbers = start of wet season

Across all seven monitoring periods, there were highly significant ($P<0.001$) differences in Activities 2 and 5, walking, and walking and feeding, respectively. This was due to the sharp reduction in both activities during Period 7, as animals were not taken out to graze when it was raining. The introduction of the trough appeared to lead to an increase in resting time of goats. Otherwise, the introduction of the trough did not appear to affect livestock activities.

Table 25 Feed types of monitored goats and cows by monitoring period
Data in average counts per day per animal

Monitoring period	0 no feed	1 Lopped tree fodder	2 Grazed tree fodder	3 Dried leaves	4 Concentrate	5 Other	6 Grass
Goats							
1	67.5	0.6	46	18.5	1.2	7.5	0.8
2	72.8	2.6	26	25.8	1.4	18	0.4
3	81.2	21.1	12.5	22.2	1	10.5	0
4	80.1	11.6	19.7	23.3	1.2	13.1	0.1
5	*88.4*	*13.5*	*12.3*	*22.5*	*1.1*	*15.3*	*0*
6	*80.5*	*14*	*17.7*	*20*	*1.1*	*19.2*	*0*
7	***75.3***	***0.8***	***58.3***	***2.3***	***1.5***	***8.8***	***0***
Cows							
1	76.1	0.7	35.2	13	2	8	12.7
2	77.8	0.3	16.1	27.4	2	15.2	16.6
3	77.3	0.9	5.9	23	1.9	10	33.2
4	77.9	0.6	5.9	22	2	8	36.2
5	*76*	*1.8*	*5.8*	*16.6*	*3.1*	*1.8*	*46.2*
6	*81.9*	*1*	*3.4*	*11.5*	*1.7*	*7.4*	*44.5*
7	***108***	***0***	***0.5***	***1***	***1.5***	***1.4***	***54***
Sig 1	**	***	***	***	ns	**	***
Sig 2	**	*	***	*	ns	ns	***

Notes as given for Table 24

Very large differences in feed types used were observed between monitoring periods, and between goat and cows. Lopped tree fodder was much more important for goats than for cows. However, even for goats it was little used in Periods 1 and 2, but from mid April to the onset of the rains (Periods 3 to 6) lopped tree fodder was an important component of the goats' diets. Conversely grazed tree fodder was more important for both goats and cows in Period 1 and declined sharply until Period 3, presumably reflecting the increasing shortage of supply of tree fodders for grazing over this period. Goats' access to grazed tree fodder increased markedly at the onset of the rains. Dried leaves were an important component of the diets of goats and cows until the onset of the rains. Grass was a very minor part of the goats' diets, but was of major importance for cows. Increasing consumption of grass by cows after Period 2 may have been due to the general lack of more palatable alternatives; the grass was dry during this period. Grass consumption by cows increased at the onset of the rains, probably due to a lack of alternative feed as the number of counts when cows were not feeding increased sharply. There would have been insufficient time for the new growth of grass stimulated by the rain to become available for grazing.

Table 26 Locations of monitored goats and cows by monitoring period
Data in average counts per day per animal

Monitoring period	1 Homestead	2 In fields	3 Borders	4 Anida hills	5 Anida plains	6 Water trough	7 On road
Goats							
1	6.3	90.4	20.2	0	1.6	5.3	17.7
2	16	74.3	34.2	0	0.6	3.3	18.5
3	13.8	60.3	50.5	4.1	2	3.1	14.5
4	18.8	57.5	37.7	1.2	12	6	16
5	*29.8*	*54.3*	*33.6*	*11.4*	*0.9*	*3.8*	*19.4*
6	*21.1*	*38.6*	*31*	*29.8*	*5.2*	*9.3*	*17.9*
7	***22.7***	***9.3***	***19.2***	***69.8***	***2.2***	***7.3***	***16.4***
Cows							
1	37.2	69.8	7.3	1.5	0.3	4.1	27
2	31.7	56.8	12.2	8.6	18.6	5.8	21.7
3	26.5	48.8	18.5	23.3	4.8	10.4	19.8
4	27.6	42.7	15.5	27	9.7	8.4	21.8
5	*36.7*	*32.5*	*14.5*	*26.5*	*8.9*	*7.5*	*24.6*
6	*51.7*	*21.7*	*21.6*	*19.5*	*8.5*	*8.1*	*20.1*
7	***105.3***	***2.1***	***3***	***14.6***	***0.8***	***2.4***	***12.9***
Sig 1	***	***	***	***	**	ns	***
Sig 2	***	***	ns	***	ns	ns	ns

Notes as given for Table 24

The locations used for grazing changed over the period of the study, and there were also differences between goats and cows. During Period 7 the goats stayed mainly in the hill area (Location 4) whereas the cattle stayed mainly in the homestead area (Location 1). It was quite clearly different from the other periods. Goats spent more time in the Anida hills (Location 4) immediately after the introduction of the trough.

Livestock keepers indicated that about 85% of the livestock went to the water trough for the mid-day watering during Periods 5 and 6. It was also said that the trough had attracted some non-traditional users to the watering facility.

An underlying assumption of the monitoring exercise was that any major changes in grazing behaviour between the periods before and after the introduction of the trough could be assumed to be due to the trough itself. In the event, there were clear trends during Periods 1 to 4 before the trough was introduced. The grazing area in Anida Hills became increasingly important for both goats and cows over this period, apparently because there was greater access to lopped tree fodder and grass (albeit dry) in this area. This trend was believed to be a response to declining feed availability from alternative sources. Therefore livestock monitoring was unable to distinguish between seasonal changes which coincided with the introduction of the trough and direct impacts of its introduction.

The changes in the use of Anida Hills appeared to have little impact on the overall pattern of activities, probably indicating that the strategy of using Anida Hills for

grazing at the end of the dry season was reasonably successful. Monitoring of milk production (BAIF, unpublished data) over this period indicated that production was maintained during what goat keepers perceived to be a period of feed scarcity. By helping livestock keepers to use Anida Hills as fully as possible the water trough contributes to this strategy, but given the large changes in grazing patterns over this period it was not possible to identify changes arising specifically due to the introduction of the trough. The largest change coinciding with trough introduction was the increased use of Anida Hills for goat grazing. This change was anticipated when the trough intervention was identified and was consistent with the trough enabling goat keepers to maximise the use of this grazing area, but this may have been due to a coincidental seasonal shift in grazing rather than a direct response to the trough.

The study concluded that livestock keepers appeared to be able to maintain the supply of grazed feed by using the Anida Hills and Plains areas towards the end of the dry season, when alternative sources of grazing become scarce. Livestock monitoring data indicated that there were large shifts in grazing patterns during the dry season making it difficult to detect changes due to the introduction of the water trough. The impact of the trough appeared to be that it helped livestock keepers maintain grazing during a time of feed constraint. The study is described in more detail in Technical Annex 2. **(**Report on livestock monitoring: Bhavnagar by C D Wood)

Village dissemination meetings

A summary of the outcome of village meeting held at Khakad in November 1998 is given below and is described in more detail in the relevant visit report in Technical Annex 1. Dr Wood gave an introduction to the meeting, with Mr Badve acting as interpreter, then Mr Badve gave an overview of the monitoring and feed analysis data obtained to date. This was illustrated by some flip charts depicting the main points in a pictorial style. The introduction indicated that there was a lot more work required to analyse the data and information obtained, and more information is still required to identify feed related problems and interventions. The importance of barley grain and tree pods as high quality feeds was clearly appreciated by goat keepers. There was awareness of the feeds which the goats preferred, which presumably relates to palatability. The lack of tree fodder in the hills due to degradation of the forests was seen as a major problem. Tree fodder from private wastelands in the valleys was of increasing importance due to the lack of good communal grazing. There was interest in the concept of storing tree pods as supplements. The goat keepers wanted a good quality feed supplement for the kidding season. There was little *Prosopis juliflora* here, while the toxicity problem of *A. leucophloea* was seen as preventing their storage. *A. nilotica* would be the only pods which might be stored, but it was unclear whether there would be enough available for this given that the pods are an important summer feed when fodder is generally in short supply.

Similarly, the outcome of village meeting held in Khakad in April 2000 is summarised below and is described in more detail in the relevant visit report in Technical Annex 1. A summary, in English, of the text of the flip chart diagrams used for the presentation is given in Appendix 2 of the visit report. The flip charts were prepared in Hindi using pictorial representations of seasons, numbers, feed types as appropriate. It was noted that while Gayri owned goats had access to lopped tree

fodder in the late summer, this had virtually disappeared as a component of the diet of the tribal owned goats by this time. Mr Badve then explained that feeds had two major nutrient components, protein and energy, both of which were required for milk production and growth. The contribution of the most common tree fodders to energy and protein supply was then described. Options for increasing milk production were presented to stimulate a discussion with the farmers. The options proposed were:
Purchase/produce more concentrate.
Store feeds for use in summer e.g. tree pods.
Have more trees e.g. more *A. nilotica*.
Goat keepers said that the factual content of the presentation was broadly in agreement with their perceptions. Goats which eat more dried leaves are observed to be more disease-prone. The goat keepers would like an *A. nilotica* plantation as they think that this would greatly help them feed their animals. However, the need for fodder and firewood, together with large families and increasing population has put pressure on resources. There is interest in the concept of nurseries to provide fodder tree saplings. The goat keepers said that they would need to think about where the saplings could be planted. Small quantities of feed are stored for use in the monsoon season (*A. nilotica* pods in particular, also some *Ziziphus nummularia* leaves but the supply is very restricted). These are for emergency use, e.g. for sick animals. The major constraints to feed storage are lack of feed available for storage and, for larger herds, the labour which would be required to store useful quantities of feed.

The outcome of village meeting held in Rampuriya in April 2000 is summarised below and is described in more detail in the relevant visit report in Technical Annex 1. The format and style of the presentation was very similar to that given at Khakad; English summaries of posters are given in Appendix 2 of the visit report. A summary of seasonal variations in feed types as shown by the goat monitoring data was presented, then a summary of goat activities. The decline of lopped trees in the diet in summer and the importance of lopped cactus was noted. As in Khakad, Mr Badve then explained that feeds had two major nutrient components, protein and energy, both of which were required for milk production and growth. The contribution of the most common tree fodders to energy and protein supply was then described. It was noted that both cactus stems and *Balanites aegyptica* are good sources of energy, but poor sources of protein. Options for increasing milk production were presented to stimulate a discussion with the farmers. The options proposed were:
Purchase/produce more concentrate.
Store feeds for use in summer e.g. tree pods.
Have more trees e.g. more *A. nilotica*.
Feeding energy rich cactus and *Balanites aegyptica* with protein rich tree pods

Goat keepers were interested in planting fodder trees. Rampuriya village has about 16 acres of common land and the villagers would like 5 acres of this to be used for tree planting. Villagers could provide labour. Goat keepers raised the issue of *Acacia leucophloea* pod toxicity as one farmer had lost four goats the previous week due to this problem. He had promptly cut down all the *A. leucophoea* trees on this bit of land to avoid future toxicity problems. There was some storage of feeds. *A. nilotica* and *Prosopis juliflora* pods are stored by some goat keepers for use in summer (May) to augment feed supply. Pods are collected in mid April. Any left over are kept to the next year. The pods are kept in sacks and kept in the house.

Achievement of anticipated outputs

The anticipated outputs were summarised in the original Project Memorandum logical framework as being:

1. Recommendations on improved feed combinations for seasonal feed shortages.
2. Recommendations on the field use of laboratory techniques.
3. Final report with draft scientific paper and extension pamphlet on laboratory methods.

A project extension was granted to publish the laboratory methods pamphlet/booklet, to similarly publish a review on the nutritive value of goat feeds and proceedings of the end of project workshop.

The timely revision of the project activities has meant that these outputs have been achieved, albeit not in the way originally anticipated, with the inclusion of the three monitoring studies. Output 1 is summarised in the section above, as they were presented to the participating farmers. The feeds review booklet is intended to help extension workers develop recommendations on feed combinations for other livestock keepers in the region. The project also serves as an illustration of how laboratory data can be converted to messages for extension workers and livestock keepers. The written project outputs have all been produced (workshop proceedings still to be printed at the time of writing).

Contribution of outputs

The Project Memorandum anticipated that the project would investigate and identify improved feeds and diets for collaborating farmers. BAIF in particular could use the information provided more widely. The project would study the application of laboratory methods to investigate feeds and diets, to help develop the methods and provide lessons on how to apply feed evaluation to service the needs of poor farmers. Project outputs, when published, will be suitable for a wider scientific and extension audience. BAIF was the only specific target institution, although other institutions with livestock interests in India were identified as targets for project outputs.

The publicity leaflet helped to increase awareness of this project and the related project R6953. The literature review on feeds was useful to the project in identifying existing information and information gaps. It was also a vehicle for the data produced by the project which was included in a redrafted review for the benefit of BAIF field staff and other livestock extension workers. An extension to the project was granted to cover the finalisation, reproduction and distribution of the review as a booklet. The booklet will be a reference source for extension workers to give advice to livestock keepers on the nutritive value of locally available feeds. The booklet on laboratory methods will similarly inform scientists and extension workers about methods in use and areas of ongoing method development. Again, an extension to the project was granted to cover the finalisation, reproduction and distribution of the methods review as a booklet

Project laboratory data identified that in Bhilwara District highly digestible but protein deficient cactus (in particular) was a major dietary component which should be supplemented with tree pods. Project R6953 conducted participatory trials on the

use of *Prosopis juliflora* pods as supplements in this District, confirming their beneficial effects.

Goat monitoring data from Khakad village, Udaipur District, indicated that access to lopped tree fodder was a problem for tribal goat keepers, particularly *Acacia nilotica*, a relatively good quality tree fodder in this district. The diets of the goats in the summer season were to a large extent driven by what feeds were available. Therefore the practical impact of information on the nutritive value of feeds is restricted by the underlying restrictions of choices of feeds available. The monitoring indicated that shortages of good quality feed were particularly acute for the relatively poor tribal goat keepers, who were most dependent on feed resources from communal lands.

Therefore, future work should concentrate on increasing the supply of feed during the summer season. An important area which may be soluble by new research was the toxicity of *Acacia leucophloea* pods. *A. leucophloea* is particularly prevalent on communal areas, and as such is particularly important to poorer goat keepers. A safe and reliable way of using *A. leucophloea* pods would help promote their wider use. Farmers would be less inclined to chop down potentially valuable "toxic" trees. The pods could be used more strategically, as supplements, after storage. Deaths of goats due to toxicity would be prevented. Beneficiaries of the work would be goat keepers in arid and semi-arid regions of India, particularly those dependent on common land grazing resources where *A. leucophloea* is a major resource e.g. landless goat keepers, small holder farmers/goat keepers, and pastoralists. A draft Concept Note, suitable for funding by the Livestock Production Programme, was prepared as given in Appendix 1 (but as yet not funded).

Other interventions could be aimed at feed storage, although the supply of feeds to store is limited, and increasing feed supply. There is scope to increase the supply of tree fodders by the planting of fodder trees and/or by encouraging the recovery of degraded grazing lands and their better long term management. Project R6953 has conduced a series of case histories on the management of communal grazing areas to review past experiences of projects of this type.

Written outputs:

Easing seasonal fodder scarcity for small ruminants in North West India (publicity leaflet) 12pp.

WOOD, C.D., MATTHEWMAN, R. and BADVE, V.C. (2001) A review of the nutritive value of dry season feeds for ruminants in Southern Rajasthan, India. Booklet. 500 copies. 26pp. BAIF Development Research Foundation, Pune, India and Natural Resources Institute, Chatham, Kent, UK. [Science] (Booklet)

WOOD, C.D. and BADVE, V.C. (2001) Recent developments in laboratory methods for the assessment of ruminant feeds. Booklet. 500 copies. 14pp. BAIF Development Research Foundation, Pune, India and Natural Resources Institute, Chatham, Kent, UK. [Science] (Booklet)

Proceedings of a Workshop on participatory research on goat feeding systems and silvi-pastoral development on common lands in North-West India, held Udaipur, India, 11 to 13 September 2000.

WOOD, C. D., BADVE, V. C., SHINDEY, D. N. and CONROY, M. A. (scientific paper in draft) Contrasts in grazing management and diet between goat herds owned by two ethnic groups in Rajasthan, India (submitted to Small Ruminant Research and currently under review)

WOOD, C. D., BADVE, V. C., SHARMA, M. S. and CONROY, M. A. (scientific paper in draft) Diets and behaviour of grazing goats in semi-arid India

Scientific papers to be finalised and submitted using University of Greenwich funding as time permits.

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