The use of alternative animal feeds to enhance food security and environmental protection in the Sudan (The case for Prosopis Juliflora)

By

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Research Partners

Pastoral and Environmental Network in the Horn of Africa (PENHA)

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Abstract

Prosopis juliflora (referred to in this paper as Prosopis or locally known to as ‘’Muskit’’) is a member of a fast growing, ever green and drought resistant shrub which grows in semi-arid areas all over the world, including Sudan and several arid and semiarid countries in Africa. The seed pods are palatable to local animals, particularly ruminants such as sheep and goat. The leaves are relatively unpalatable – due to both the tannin content and to their indigestibility. However, in Sudan and elsewhere, Prosopis has also caused considerable problems because of its rapid growth and damage to farmlands, pasture and especially the irrigated agricultural schemes. The shrub is dispersed in a number of ways, including distribution of seeds from the pods via the faeces of goats and sheep. A concerted but unsuccessful attempt at its removal has been made by the government.

There are differing perspective in Sudan among policy makers and academics and such views range from total physical eradication of Prosopis to seeking alternative uses for it.

This paper uses as its point of departure that Prosopis in underutilized resource and that it has great potential as an animal feed resources in the arid lands of Sudan and Africa.

During 2007, The Pastoral and Environmental Network in the Horn of Africa (PENHA) and the Animal Production Research Centre (APRC) within the Animal Resources Research Corporation within the Ministry of Science and Technology (MOST) have been engaged in some serious research to investigate the potential and more effective use of Prosopis as an animal feed. The results from the four month study which came to an end in late 2007 have clearly indicated that prosopis has indeed a great potential for use as animal feed in various forms if fed in appropriate quantities and made more palatable to the animals .Following the outcomes of the research led to a series of pilot training programmes were conducted with pastoral communities in Eastern Sudan and Eritrea.

The overall conclusion is that Prosopis can provide a significant input into the feed of small ruminants in the pastoral areas of Sudan as a well as other parts of Africa.

Zeremariam Fre (PhD).

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Chapter 1: Introduction

Prosopis juliflora Swartz (family Leguminosae, subfam. Mimosoideae) is a perennial, fast-growing, often ever-green and drought resistant shrub or tree that grows in semi-arid areas all over the world. It has also been planted successfully under desert like conditions where it is often used to halt shifting sand dune encroachment.

Native to Central and South America P. juliflora (hereafter also referred to as Prosopis) has been introduced globally over the last 200 years. Today, it can be found in various semi-arid and arid climate zones including further parts of Southern America, India and Pakistan, Australia and the Pacific, and several countries in Africa (e.g. Senegal, Sudan, Ethiopia, Kenya, and South Africa), the Arabic Peninsula (e.g. Yemen), and the Middle East. (Pasiecznik 2001, Wick and Thiessen et al, 2000; Igbal and Sharfiq 1997). The plant is also often referred to internationally as *mesquite* or *algaroba* (Al & Warrang 1998; Pasiecznik 2001) however in most countries local communities are using local names for it. Worldwide there are about 44 known Prosopis species which have been defined by Burkhart (1976).

Pasiecznik (2001) describes the process of taxonomical misidentification of P. juliflora (Sw.) DC as *P. chilensis* (Molina) Stuntz during the early century in Sudan. It has today been widely acknowledged in the Sudan that it is not *P.chilensis* but rather Prosopis juliflora, which is widely spread, but some experts still refer to the species as Prosopis chilensis (which also exists in the Sudan in small stands) (Pasiecznik 2001).

P. juliflora can establish itself in a wide range of rainfall zones ranging from less than 100 mm mean annual rainfall in dry coastal zones to more than 1000 mm. It has also been reported that it can occasionally even be found in areas with up to 1500mm of rainfall, for example in the Andean region where P.juliflora can be found at altitudes of up to 1,500 metres (Pasiecznik 2001; Duke 1983). According to Pasiecznik (2001) the species is not frost tolerant, which is the main reason that it rarely spreads into higher altitudes, although the species has been observed in slightly higher altitudes by some experts.

Prosopis grows as a shrub or tree and occasionally can reach up to 12 metres in height. P.juliflora usually has thorns with varying thorn size reaching up to 5 cm, but some stands have been reported to be thorn less. Prosopis thorns however vary a lot in appearance and can occur either paired or solitary, and even both on the same branch. Leaves are bipinnate, often with few pairs of opposite pinnae. The single leaflets of a leaf are many, generally small, mostly opposite, linear, oblong, fusiform and of the same colour on both sides. Roots of P.juliflora can develop rapidly following germination and can reach a depth of 40 cm in eight weeks. (Pasiecznik 2001; Sharma & Dakshini, 1998; Garg 1998). They are widely referred to as a tap root system, which is one of the characteristics that gives Prosopis the advantage over local plants, as it can access deeper groundwater levels.

Prosopis is a nitrogen-fixing species and is widely used as a source of fuel wood, animal fodder, timber for construction and furniture, as living fences and shelterbelts to halt the encroachment of sand dunes and occasionally even for human nutrition. Other products derived from Prosopis can be honey, gums, fibbers and medicines.

P. juliflora was globally introduced into many countries for the above mentioned benefits. Introduction into Africa is believed to have probably taken place two centuries ago. According to Pasiecznik (2001) the precise introduction history is not definite, but introductions into Senegal in 1822, South Africa around 1880 and Egypt around 1900 have been documented. Reports confirm that "*Prosopis* was introduced into Sudan by RE Massey from the Egyptian Department of Agriculture at Giza and from South Africa both in 1917 (Pasiecznik 2001). Prosopis was introduced into many semi-arid countries, as the drought resistant plant was seen as a valuable source for wood, fodder, shade and other in dry lands. Similarly Magid (2007) states that the purpose for introduction in Sudan was "to find exotic fast growing tree species resistant to drought and grazing" that are valuable "for conservation of ecological balance", and which can be used as a "source of fuel wood and fodder and other economical values". According to Laxen (2005) Prosopis was successfully introduced and used for sand dune stabilisation in northern Sudan. Today Prosopis is spreading fast in the Sudan. Laxen stated that "in the early 2000s prosopis had been introduced in about half of the total of 26 states which constitute Sudan" (Laxen 2005).

P. juliflora is salt tolerant and has been used successfully for the regeneration and afforestation of sodic wastelands (Garg 1999; Singh & Singh 1998)

P.juliflora is propagated through seed. The long pods are nutritious and high in sugar content. When animals eat the pods the seeds are excreted through their droppings. These seeds usually germinate in the animal droppings during the rainy season.

Map 1.1: Global Distribution of the *P. juliflora* - *P. pallida* complex and other Prosopis Species (Pasiecznik 2001)

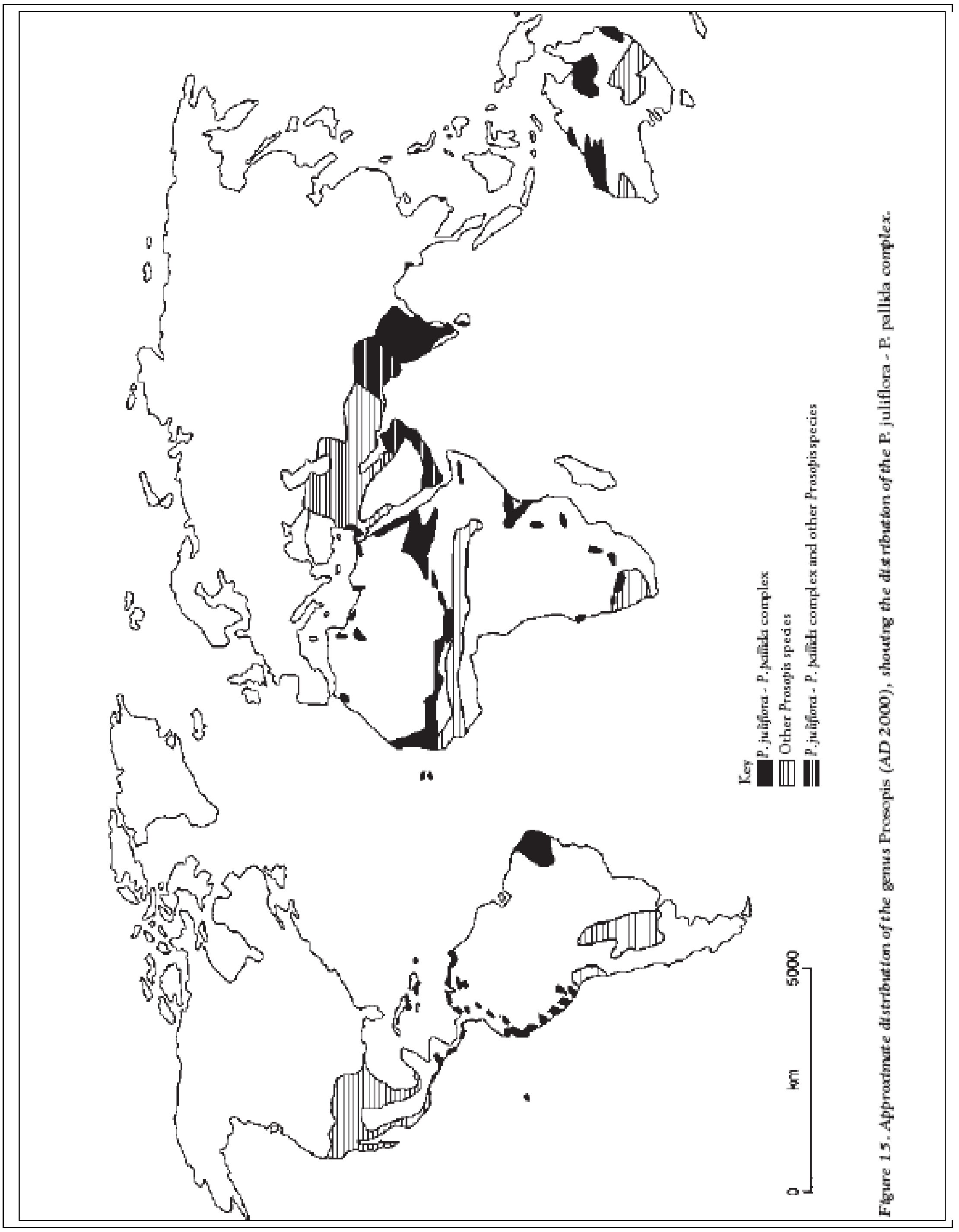

Figure 1.5. Approximate distribution of the genus Prosopis (AD 2000), *showing the distribution of the* P. juliflora - P. pallida *complex.*

The invasiveness of Prosopis has however become a problem in many parts of the world it has been introduced to, including areas in the Sudan. Globally, Prosopis is reported to “aggressively” invade all sorts of land areas including rainfed crops, irrigated agricultural schemes, pastoral rangelands, gardens and river sides. In some areas (for example in Eastern Ethiopia or in Northern Kenya) its invasiveness has become so severe that thousands of hectares have been “lost” to the species. Indigenous plant and grass species have disappeared and local communities of those semi-arid dry lands – although they widely use Prosopis as a source for fuel or fodder – have stated that their existence is under threat as they have lost valuable pastures and farmland to Prosopis. Where the species has widely (strongly?) established itself, it often forms a thorny thicket, which is inaccessible to humans or livestock. Furthermore, it flourishes in irrigated agricultural areas where it blocks wells and irrigation structures and competes with crops. Many communities and farmers have belatedly attempted to eradicate the plant. However, Prosopis – particularly when it is cut above ground – simply regenerates and it has almost become impossible to get rid of it.

In Sudan, Prosopis has caused a particular problem in the agricultural irrigation schemes of the country such as the Halfa Irrigation Scheme. During the early 1990s the Government of Sudan assessed the invasiveness of Prosopis and classified it as an aggressive invader that poses as threat to farmlands and pastures and especially to the irrigated agricultural schemes. As a result a presidential decree for its eradication was passed on 26th February 1995. The government has since invested millions in the application of heavy machinery in a quest to eradicate the resistant species once and for all. However local conditions, the continuous spread of the species’ seed through livestock and valid seed banks have proven a major challenge and in many parts eradication has been very costly but of limited success. In addition other areas and ecosystems such as the riverine forests along the Gash, rain fed crops and pastures are being continuously invaded.

At the same time many experts highlight the benefits of Prosopis, which were the reasons for its popular introduction worldwide. Laxen (2005), for example, points out that communities in Eastern and Northern Sudan highly depend on the productivity of Prosopis for household income. He has outlined that a substantial amount of the families’ income is based on Prosopis-based products such as fuel wood, fodder or simply the income made by weeding someone's crop. This is particularly the case for the landless or the poorer households. Yet others have suggested that Prosopis – although it partly provides valuable resources to some –causes a degradation of the local environment over a wide area and is a hazard to many rural communities in the Sudan, Eastern Africa and other countries.

The Sudan Vision Daily (1st March 2008) states: "Mesquite is currently still spreading, and complete eradication of the tree in Sudan is considered by UNEP and others in the forestry and environmental management field to be physically impossible, economically unviable and more importantly, not warranted. The recommended alternative is control, with elimination in high-value irrigated land only".

In a similar new approach of 'control' a "popular committee for the development of Matama" was set up in Matama, Nile State, in collaboration with the Forests National Corporation (FNC) of Sudan, the Forest Research Centre, the University of Khartoum, and the Ministry of Agriculture of Nile State and "a group of artists" to develop a model for the economic exploitation of Prosopis. The production of wooden furniture and handicrafts was suggested as a means to exploit Prosopis (Magid 2007). The production of livestock fodder based on Prosopis follows the principle that seeks to exploit Prosopis to the benefit of local people while at the same time ecological and social control measures need to be applied to halt the spread.

1.1 Prosopis as a fodder resource

"Prosopis pods are used in Sudan mainly for livestock fodder, which is normally browsed directly from the trees. In the Tokar Delta of Red Sea Province prosopis pods have been collected on a large scale and ground in a mill for livestock feed. Individual households everywhere in Sudan where prosopis is growing also collect the pods, which are directly given to fenced-in livestock as fodder" (ELSIDDIG et al. 1998). Prosopis is globally used a source for free browsing animals. While the pods are highly palatable leaves have been reported to be relatively unpalatable but are being eaten by livestock when nothing else is available.

As Pasiecznik et al. (2001) say "Prosopis pods in Sudan have a low sugar content of only 13 to 20% comparison with many South and North American varieties used in the food industry which contain from 35% up to even 59% sucrose (cf. Estévez et al. 2004). The unripe pods in Sudan are bitter and not preferred as fodder. Pods mature between December and June and provide therefore needed fodder during the peak dry season (Siddig 1986; Bristow 1996; Felker 2003). Shiferaw et al. (2004) reported from Ethiopia that one kg of goat and cattle droppings contained, on average, 760 and 2,833 prosopis seeds, respectively, thus suggesting that cattle are the primary pod-eaters and thus dispersers of prosopis seeds."(Laxen 2005).

According to Laxen a significant increase in livestock numbers in few households that had "specific commercial interests in livestock rearing" was noted in the livestock population statistics for 2000 – 2002 compiled by the Federal Ministry for Range Management in Khartoum. There it was stated that in the River Nile State an increase by about 2 – 4% per year had occurred, which Laxen links directly to the locally growing Prosopis stands.

However, although Prosopis is globally propagated as a valuable source of fodder for livestock, especially during times of drought, it is also widely reported that if animals feed on nothing else they can fall very ill and in fact even die. Death among animals has been reported by local communities and experts alike (although little research has been done on this). It was assumed that death was caused by "the regression of rumen bacterial cellulase activity, due to the high sugar content of the pods" (source: Alder (1949) in Pasiecznik 2001) others believe that the hard coat of the pods is partly indigestible which causes accumulation and compaction of the residues in the digestive tract causing the death. However, illness, paralysation, injury and tooth decay among livestock have been reported by various communities throughout Eastern Africa as a consequence of feeding on both pods and leaves. Pasiezcnik et al (2001) suggests that palatability of Prosopis leaves was better for goats followed by sheep, less compatible with camels and unpalatable to horses, but that leaf debris after being cut off a tree was potentially a good fodder, as the toxic substances such as tannin would diminish a few days after drying.

It is therefore important to see Prosopis as a fodder supplement, which needs to be mixed with other fodder in order to be beneficial to livestock. Prosopis can be a valuable fodder source especially during times of drought, however communities will need to be aware of the amounts that can be fed safely and which can lead to healthy weight gain and increased milk production. Furthermore the grinding of Prosopis pods is not only an important part of the process of fodder supplement production (mixing it with various local ingredients), but will also be a vital control step as it will prevent the seeds being dispersed through animal droppings – a major cause of the spread of Prosopis.

This research paper seeks to present Prosopis based feeding and to advocate it as a valuable activity to rural communities in Sudan and elsewhere. However it is crucial that such advocacy and related community training takes and integrated approach in which awareness is raised about the impact of free browsing on Prosopis (which can harm animals and when Prosopis is overfed, as well as communities and the environment as it propagates further spread of the species). Moreover it is crucial that the impact of Prosopis is assessed locally and in close cooperation with local communities. Where the species is found to be of major concern, fodder production activities need to be carried out as a means of exploitation to the socio-economic benefit of the people alongside concrete control measures (such as regular weeding of new seedlings, enclosure of Prosopis thickets to avoid animals browsing, cutting of the stem below ground etc) that contribute to the halting of excessive spread of the shrub.

Chapter 2: The Scientific Research on Prosopis Juliflora

The context to the research

In the Sudan nomadic pastoralists, agro-pastoralists and sedentary livestock owners represent almost 60% of the total population and posses almost 90% of the total livestock population in the country. The pastoralist livestock sector contributes greatly to national and local food security. Off- take from livestock production systems still contributes almost 25-30% of the national income in the country.

One of the key constraints for livestock owners both sedentary and nomadic during the long dry is lack of fodder for their animals. The other key challenge is the inappropriate use of whatever crop fodder which may be available to them. In some cases the scarcity of fodder has led to conflict between sedentary farmers and pastoralists in their search for meagre fodder and water resources. In the Sudan providing adequate and diversified feed resources for the livestock population is one of the national priorities within the Federal and State governance.

Prosopis Juliflora (muskit) an evergreen desert plant widely distributed in the Sudan, Eritrea, Ethiopia, Somalia and Northern Kenya could offer an alternative animal feed source if utilized properly. During 2007, PENHA and the Animal Production Research Centre (APRC) have been engaged in some serious research to investigate the potential and more effective use of Prosopis as an animal feed. The results from the six month study which came to an end in early 2008, have clearly indicated that prosopis has indeed a great potential for use as animal feed in various forms if fed in appropriate quantities and made more palatable to the animals.

Having completed the research trial successfully, PENHA and APRC have developed and tested a pilot training using the outcomes of the research for pastoralists and livestock extension workers in Kassala state, Eastern Sudan. The focus of the training was on Training of Trainers (ToT), drawing trainees from among relevant line ministries, the pastoralist union and local NGOs which are associated with pastoralists in one way or another. In this way the project will have a much wider impact among pastoralists because the training has equipped the relevant local line ministries and pastoralist representatives.

Over the last 20 years PENHA has organized a series of short training courses (one to four weeks) on range land management, land use planning, pastoral production systems and project planning in five countries, namely: Ethiopia, Eritrea, Uganda, Somaliland and the Sudan. A total of over 1,000 trainees benefited from these programs. The participants ranged from lower level to senior level officials involved in pastoral policy development in all the countries mentioned above. Partners in the training programmers included line ministries, local NGO_S and community leaders.

The National Agricultural Bi-products Project (NABP) is a national programme which has been specially set up by a special directive from the Minister of Science and Technology during 2004 in order to devise alternative feed resources in the Sudan. Managed by a national coordinator, the program has implemented a series of training of trainers (ToT) in more than seven States in the Sudan. The national coordinator reports directly to the Ministry.

There is a vigorous debate among academics and politicians for and against Prosopis. However, the fact remains that Prosopis is in the region is here to stay to and is expanding at a much faster rate than any one has imagined. Some favour the eradication route, which seems to be an impossible task. However in the case of the Sudan (at policy level), it seems that the eradication route is more favoured.

The other side of the argument is no one in the Region had properly empirically investigated the potential use of prosopis as an animal feed. Other countries like India and the US (Arizona State) have shown diversity of usage for prosopis. There is a great deal of positive experiences to learn from other arid land countries and the sensible thing would be to draw positive experiences from elsewhere with the view of replicating them in the Greater Horn.

Our two organizations see prosopis as having a great potential in redressing the animal feed deficit in the arid/semi-arid pastoralist areas of the Horn where Prosopis is seriously underutilized despite its abundance. The outcome from recent PENHA/APRC study in Sudan has proved without any doubt that prosopis if properly exploited has a great potential as animal feed. The research outcomes have also shown the multiple use of crop fodder use in the form of /mash/feed block/silage with or without Prosopis. Participants will be trained in better use of such widely available but underutilized feed resources.

2.1 Location and description

The research was conducted at the Animal Production Research Centre APRC at Hilat Kuku near Khartoum from July 2007-to December 2007.The teams were led by Dr.Talal Mirghani Abdelnoor from APRC side and Dr.Zeremariam Fre from PENHA side.

The APRC availed its staff and all the facilities for experimentation and participated fully in the whole process.

2.2 Materials and methods

Experiment 1: Laboratory evaluation of Prosopis juliflora pods and Prosopis juliflora leaves-silage as a ruminant feed

Silage making:

Mesquite (Prosopis juliflora) leaves were collected manually from trees around Animal Production research Centre, Kuku, Khartoum North during autumn (June-July 2007) by labourers. Then the freshly collected leaves were used for silage making after mixing with additions of ground sorghum grains (feterita) and molasses at the rate of 5% and 10% respectively. Three replicates of each mixture were prepared. After that the mixtures were mixed manually and filled into double layered of plastic bags. Then after expelling air, tied tightly and put into plastic barrels. The plastic barrels were then sealed and kept in the dark for one month. The three silage barrels were opened on successive days.

Collection of Prosopis Juliflora leaves at the APRC Centre at Hilat Kuku, Sudan.

Mesquite pods:

Dry pods of mesquite (Prosopis juliflora) were collected manually during autumn (June-July 2007). The pods were ground using hummer mill to pass 2.5 mm sieve.

The opened silage was immediately tested for pH using laboratory bench pH meter (Hanna instrument). The silage was also tested for their proximate components according to AOAC (1990) methods for dry matter, ash, crude protein and crude fibre. Proximate analysis was also carried out on the pods following the same methods of AOAC (1990). The in vitro digestibility of dry matter and organic matter of the tested samples were performed using Tilley and Terry methods (1963).

The rumen fistulised bulls used in *in vitro* digestibility study. Standing on the right Dr.Nuha Hamid one of the APRC researchers, APRC.

Experiment 2: The use of Prosopis julifloria as an emergency diet for small ruminants in the dry season

That study was conducted at the farm of Animal Production Research Centre during the period from August 2007 to March 2008 which corresponds to end of autumn to winter season in Sudan.

Animals and management:

Eight adult non castrated sheep and eight milking goats of local type (33 ± 5.7 and 25 ± 6.5 kg respectively) born and reared at Animal Production Research Centre (APRC) in Sudan were used in those experiments. Animals were dosed with prophilactive dose of antibiotic followed by Ivomec injection for ecto and endo parasites control. They were also individually housed with free access to clean water and mineral blocks. The experiment was lasted for 7 weeks with the first week was considered as an adaptation period.

Experimental sheep and Dr.Talal Mirghani research coordinator from APRC side standing in the middle row.

Feeds:

Mesquite leaves silage

Mesquite leaves silage was prepared by picking up leaves manually from mesquite trees around Animal Production Research Centre. The picked leaves were collected in plastic bags, weighed and then spread on plastic sheets at lots of 100 kg of fresh leaves each time. The crushed sorghum grains were spread over leaves at the rate of 5 % on fresh basis. Then mixed thoroughly and filled back into the plastic bags, tied and kept in an underground pit (2*3*1.5 m). The silage was left for one month at least before opening for animal feeding.

Mesquite leaves as silage combined with other ingredients.

Four concentrate diets were prepared were mesquite-leaves silage substitute 0 % (control), 5 %, 10 % and 15% of the concentrate diet (Table 1), mesquite pods were grounded and added to all concentrate diets containing mesquite-leaves silage at the rate of 10%. All of the four concentrate diets were prepared to be identical in crude protein percentage and metabolizable energy (MJ/kg DM) contents. Groundnut hay was also used as a source of roughage. The animals were offered feed at 4% of their body weight, 60% compromise the concentrate part and 40% compromise the roughage source on dry matter basis.

Experimental measurements:

Daily feed intakes were determined, feed offered and refusal for each animal was weighed daily. Animals were also weighed weekly. Milk production for goats was measured daily.

Chemical analysis:

All feeds used in this study were analyzed for their proximate components of dry matter (DM) and crude protein (CP) using AOAC (1990) standard methods. Metabolizable energy (ME) as MJ/kg DM was calculated from different ingredients according to their diet inclusion rate.

Experiment 3: The use of mash diet as an emergency diet for ruminants in the dry season

That study was conducted at the farm of Animal Production Research Centre during the period from August 2007 to March 2008 which corresponds to end of autumn to winter season in Sudan.

Animals and management:

Eight adult non castrated sheep and eight milking goats of local type (30 ± 5.2 and 28 ± 7.2 kg respectively) born and reared at Animal Production Research Centre (APRC) in Sudan were used in those experiments. Animals were dosed with prophilactive dose of antibiotic followed by Ivomec injection for ecto and endo parasites control. They were also individually housed with free access to clean water and mineral blocks. The experiment was lasted for 7 weeks with the first week was considered as an adaptation period.

Feeds:

Feeds used in this experiment are mostly agro and industrial by-products as shown in Table 2. Four concentrate diets were prepared; control diet and the other three diets were performed by substitution of the control diet by the mash diet at the rate of 30%, 70% and 100%. Groundnut hay was also used as a source of roughage. The animals were offered feed at 4% of their body weight, 60% compromise the concentrate part and 40% compromise the roughage source on dry matter basis.

Experimental measurements:

Daily feed intakes were determined, feed offered and refusal for each animal was weighed daily. Animals were also weighed weekly. Milk production for goats was measured daily.

Chemical analysis:

All feeds used in this study were analyzed to their proximate components of dry matter (DM), crude protein (CP), Ash, ether extract (EE), acid detergent fibre (ADF) using AOAC (1990) standard methods. Metabolizable energy (ME) as MJ/kg DM was calculated from different ingredients according to their diet inclusion rate.

Chapter 3: Results

Experiment 1:

The resultant silage in general was bright green to yellowish colour of good odour. Fungal growth was noticed only in silages with sorghum grains in very restricted areas. pH and proximate analysis of mesquite leaves silage and pods are presented in table (3). The crude protein content (g/kg) of silages ranged between (188- 241) g/kg. There was reduction in crude protein contents in silages containing sorghum grains or molasses additives. Crude fibre contents were ranged between (210-288) g/kg seemed not to be affected by different silages. The same was true for ash contents (93.6-110) g/kg. Mesquite pods (Prosopis juliflora) reported low values for crude protein and ash contents (172, 65) g/kg respectively compared with leaves silages.

Table 4 shows that silaging increased the dry matter digestibility (DMD) and organic matter digestibility (OMD) of unprocessed mesquite leaves (381.1, 246.8) g/kg by almost 25% and 80% respectively over the silages (444.3-541.9 and 401.9-484.7 g/kg) respectively. That increase was more pronounced at 5% addition rate of the sorghum grains or molasses.

The dry matter and organic matter digestibility of mesquite (Prosopis juliflora) pods was higher than that of unprocessed leaves (487.9, 381.1 DMD; 438.8, 246.8 OMD) respectively.

Experiment 2:

The diet ingredients and groundnut hay and their chemical composition of used in this study are shown in Table1. Table 5 shows growth performance, daily dry matter intake and milk production of sheep and goats fed control concentrate diet or partially replaced mesquite-leaves diets. Feeding mesquite-leaves silage and pods to sheep and goats in this experiment did not appear to affect their health and no disease problems were encountered throughout this study. From table 5 it was clear that inclusion of mesquite-leaves silage in sheep diet resulted in slight increase in body weight compared to control diet (without mesquite inclusion). Concerning dry matter intake as g/day or $g/kg^{0.75}$ or as % live weight, it was higher in control diet compared with other diets containing mesquite. The same table (Table5) showed that goats fed the control diet gained the most body weight (59 g/d). Whereas those fed 15% mesquite-leaves silage lost weight during the experiment. Furthermore the daily dry matter intake and milk production of goats reported in this study was presented in Table 5. The highest daily dry matter intake was recorded by goats fed on control diet. There was also a consistent drop in intake as the inclusion rate of mesquite-leaves silage increased. Milk produced by goats as g/animal/day in this study did not follow a common trend but fluctuated between different diets.

Experiment 3:

The diet ingredients and groundnut hay and their chemical composition used in this study are shown in Table 2. Table 6 shows growth performance, daily dry matter intake and milk production of sheep and goats fed control concentrate diet or partially replaced mash diets. No health or disease problems were encountered throughout this study. Table 6 shows that sheep fed the experimental diets gained weights and grown at rate of 161-190 g/day. Of course sheep fed the control diet grown faster than others (190 g/day) followed the sheep fed 100% mash diet (185 g/day). Dry matter intake as g/animal/day follow the same trend where the highest dry matter intake was recorded by sheep fed control diet (1452.9 g/day) followed by the sheep fed 100% mash diet (1303.1 g/day). However, dry matter intake as g/kg $W^{0.75}$ or as a proportion of body weight did not follow a consistent trend but still sheep fed the control diet recorded the highest intakes.

Goats fed the control and mash diets tends to maintain body weight. In the other diets, they lose weight. Dry matter intakes by goats fed mash diet or partially replaced mash diet recorded higher values (968-1086 g/day) than those fed the control diet (868.7 g/day). A similar pattern occurred when feed intake was expressed as g/kg $W^{0.75}$ or as a proportion of body weight. Milk produced by goats recorded in this study ranged between 535-975 g/animal/day with the lowest values reported by goats fed on control diet.

Chapter 4: Discussion

Experiment 1:

The chemical composition of P. juliflora leaves in this study was higher than that reported by others. Boyns (1947) reported that P. juliflora leaves contain 190 g/kg CP, 216 g/kg CF. The same is true concerning P. juliflora pods. Mahjoub et. al. (2005) conducted similar work in Oman and they recorded that mesquite pods contain 120 g/kg CP, 317 g/kg CF. The above mentioned results could be attributed to different ecological region where mesquite grown. Furthermore there are at least four species of Prosopis beside hybrids those differ in their chemical composition (Rogers, 2000). The results of in vitro digestibility experiment were presented in table (4). Comparing mesquite leaves digestibility before and after silaging, it was very clear that silaging doubled the digestibility. That increase in digestibility of that leguminous forage after silaging could be attributed to the fact that the added ingredients are mainly energy sources (Pitt and Shover, 1990; Sibanda et al., 1997). Another possible explanation is that as mesquite leaves are known for their high tannin contents of more than 5% (Simpson, 1977) and silaging is believed to degrade tannins (Oliveira et al., 2007), this made the feed ingredients more susceptible to digestion by rumen microbes.

Experiment 2:

Sheep:

Sheep fed control diet gained weight more than those fed diets containing various levels of Prosopis juliflora leaves. The growth rate of sheep fed the control diet in this study (185 g/day) is comparable to that recorded for local breeds. Monsour et al. (1993) reported a growth rate for Sudan desert sheep of 188-200 g/day. Furthermore, El Karim and Owen (1987) some time ago also reported a growth rate of 166-191 g/day for local Sudanese sheep types. However, those reported growth rates for Sudanese sheep are still higher than that reported for many tropical and subtropical sheep (Gatenby, 1986). The above findings could be explained by the fact that the data reported for local Sudanese sheep types depended on experimental results for sheep fed indoors in optimum management conditions. It is also suggested good potential of Sudanese sheep types for growth. Increasing levels of Prosopis juliflora leaves in the diet caused a linear reduction in sheep body weight which is a common feature when feeding mesquite.

Dry matter intake of control diet in term of g/day reported in this study is in line with the data reported by Mansour et al. (1993) of 1.45-1.4 kg/day. However, there was a drop in feed intake as inclusion rate of Prosopis juliflora in diet increased suggesting a decrease in palatability. Furthermore the reported daily feed intake reported in this study was in accordance with the nutrient requirements of sheep adopted by NRC (1985).

Goats:

Goats fed experimental diets gained weight only for those fed the control diet. For other diets there was a marginal increase in body weight (5% Prosopis juliflora-leaves silage) or even body weight loss (10% and 15% Prosopis juliflora-leaves silage). The growth rate reported in this study (12-59 g/day) was in accordance with that reported by Mahjoub et al. (2005) raising Omani goats on mesquite containing diets.

Dry matter intake as g/day reported in this study was in accordance with that reported earlier by Khalid (2002) raising the same local type breed. He recorded a daily feed intake of 0.85-1.10 kg/day. However NRC (1981) recorded lower values (283.5 g/day). Those lower values could be explained by the fact that NRC (1981) usually adopts high quality rations to efficient animals. Again there was an observable drop in feed intake of goats as long as inclusion rate of Prosopis juliflora increased suggesting its close relationship with feed palatability.

The milk produced by goats in this study was not consistent with the addition of increasing level of Prosopis juliflora in the experimental diets. Generally the milk produced in g/day in this study was consistent with that reported by Khalid (2002) raising the same local type goats towards the end of lactation.

Experiment 3:

Sheep:

The daily growth rate of sheep reported in this study was in line with other scientists raising local Sudanese breed types on conventional or non conventional diets. The high sheep growth rate reported in this study was not unexpected since the experimental diets where prepared to be of high quality as adopted by NRC (1985). El-Karim and Owen (1987) reported a growth rate ranged between 166-191 g/day for local sheep fed conventional diet. More recent work of El-khidir et al. (1988) where sheep grown on sorghum or molasses based diets reported a growth rate of 161-196 g/day. The daily dry matter intake in grams reported in this study is consistent with what was reported earlier by others (Mansour et al., 1993 of 1.45-1.4 kg/day and El-khidir et al., 1988 of 1415-1624 g/day).

Goats:

Goats fed on experimental diets in this study barely maintain their body weights. The inconsistent body weight change reported in this study may be attributed to the fact that body weight loss after parturition is affected by many factors. Khalid (2002) reported that the maximum weight loss attained after parturition in local goat types was between 2-8 weeks after parturition. Dry matter intake of goats reported in this study falls within the normal range reported by native scientist Khalid (2002) raising local breeds towards the end of lactation. However, the current reported intakes were well above those proposed by NRC (1981). The last result may be due to the fact that animals and diets used to set up NRC tables are both of high quality. The daily milk produced by local goats reported in this study was in line with what reported by Khalid (2002) raising local breeds on conventional diet.

Chapter 5: Conclusion

Experiment 1:

Making silage with mesquite leaves and durra or molasses at the rate of 5% and 10% on fresh basis gave good silage and improved the organic matter digestibility over the unprocessed leaves by more than 50%. Even though, it is still of low nutritive value even for maintaining ruminants. It was recommended to supplement those silages with different sources of energy and to dilute its toxic effect so it could be safely used as an emergency feed ingredient.

Experiment 2:

The conclusion drawn up from this study was that Prosopis juliflora-leaves silage could be safely incorporated in sheep concentrate diets up to 15% inclusion rate for growth purposes specially during the dry season where there is a great shortage of green fodder. That was economically feasible since it will reduce the feed cost.

As for the milking goats the same feeds could be used at the rate of 5% Prosopis juliflora-leaves silage inclusion rate for moderate milk production and body weight maintenance.

Experiment 3:

The conclusion of this study was that mash diet could effectively be used as an emergency diet for growing sheep and maintaining goats both of local breed types.

The overall conclusion therefore is that Prosopis pod and leaf can be used appropriately if prepared (such as grinding of the pods and as silage) in a mixture with other regular feeds for sheep and goats as a cheap feed source for maintenance during dry season.

ANNEX

Table1: The chemical composition (g/kg DM) and pH values of mesquite pods and mesquite leaves before and after silage with either dura or molasses at 5% and 10 % addition rate.

Analysis	Prosopis pod	Prosopis leaf (unprocessed)	Prosopis leaf silages			
			5 % Dura	10 % Dura	5 % Molasses	10 % Molasses
Fresh Dry Matter	931	390	469	476.	552	552
Secondary Dry Matter	953	950	983	918	984	979
pH	-	-	5	4.7	4.3	4.2
Crude Protein	172	256	237	188	241	196.
Crude Fibre	228	273	267	288	210	246
Ash	65	105	96	110	99	93

Table 2: The *in vitro* dry matter digestibility (DMD) and organic matter digestibility (OMD) of Mesquite (M) pods and M- leaves (g/kg DM) before and after silage with either sorghum grains or molasses at 5% and 10 % addition rate.

Analysis	Prosopis pod	Prosopis leaf (unprocessed)	M. leave silages			
			5 % Sorghum grains	10 % Sorghum grains	5 % Molasses	10 % Molasses
DMD	488	381	541	508	541	444
OMD	439	247	485	402	478	440

Table 3: Ingredients and chemical composition of the diets fed to sheep and goats in mesquite (Prosopis juliflora) diet experiment (DM basis).

Parameters	**Mesquite-leave silage inclusion**				**Groundnut hay**
	0 %	5 %	10 %	15 %	
Diet composition (%)					
Sorghum grains	50	47	42	47	
Groundnut cake	17	15	15	13	
Wheat bran	30	20	20	12	
Mesquite pods	0	10	10	10	
Mesquite leaves silage	0	5	10	15	
Lime stone	2	2	2	2	
Salt	1	1	1	1	
Total	100	100	100	100	
Chemical composition (g/kg)					
DM (%)	916	893	869	875	948
CP (%)	210	200	206	212	81
Calculated ME (MJ/kg DM)	12.3	11.4	11.1	11. 3	[1]7.8

[1]The ME for groundnut hay was 7.80 MJ/kg DM as reported by Suleiman and Mabruk, (1999).

Table 4: Ingredients and chemical composition of the diets fed to sheep and goats in mash diet experiment (DM basis).

Parameters	Concentrate diet		Groundnut hay
	Control	Mash	
Diet composition (%)			
Sorghum grains	50	39	-
Groundnut cake	20	28	-
Wheat bran	27	17	-
Groundnut Hulls	0	13	-
Lime stone	2	2	-
Salt	1	1	-
Total	100	100	-
Chemical composition (g/kg DM)			
DM	929	958	948
Ash	72	101	109
CP	242	255	81
EE	32	46	4
CF	75	102	333
ME (MJ/kg)	11. 4[1]	11. 4[1]	7.8[2]

[1]ME of concentrate diet was calculated according to the equation

ME (MJ/kg DM) = 0.012 CP + 0.031 EE + 0.014 NFE + 0.005 CF (MAFF *et al*., 1975).

[2]The ME for groundnut hay was 7.80 MJ/kg DM as reported by Sulieman and Mabruk, (1999).

Table 5: Dry matter intake and milk production of small ruminants fed control diet and partially replaced mesquite leaves-silage diets

Parameter	**Control**	**Mesquite-leaves silage replacement**		
		5 %	10 %	15 %
Sheep				
Initial body weight (kg)	36.3	38.0	35.3	34.0
Final body weight (kg)	44.0	43.8	38.3	35.5
Mean live weight (kg)	40.1	40.9	36.8	34.8
Live body weight change (kg)	7.8	5.8	3	1.5
Growth rate (g/day)	186	128	71	36
Dry matter intake (g/day)	1406.9	1402.8	1090.3	1028.2
Dry matter intake (g/kg $W^{0.75}$)	91.9	88.8	73.4	71.8
Dry matter intake (% body weight)	3.7	3.6	3	3
Goats				
Initial body weight (kg)	21.5	22.3	21.3	19.5
Final body weight (kg)	24.0	22.8	21.3	18.8
Mean live weight (kg)	22.8	22.5	21.3	19.1
Live body weight change (kg)	2.5	0.5	0.0	-0.7
Growth rate (g/day)	59	12	-	-
Dry matter intake (g/day)	933.1	788.6	737.5	479.1
Dry matter intake (g/kg $W^{0.75}$)	89.7	76.5	74.6	52.4
Dry matter intake (% body weight)	4.1	3.5	3.5	2.5
Milk produced (g/animal/day)	535	975	598	702

Table 6: Dry matter intake and milk production of small ruminants fed control diet and partially replaced mash diet

Parameter	Control	30% Mash	70% Mash	100% Mash
Sheep				
Initial body weight (kg)	31.3	31	33	32.8
Final body weight (kg)	39.3	37.8	40.3	39
Mean live weight (kg)	35.3	34.4	36.6	35.9
Live body weight change (kg)	8.0	6.8	7.3	7.8
Growth rate (g/day)	190	161	173	185
Dry matter intake (g/day)	1452.9	1297.4	1225.1	1303.1
Dry matter intake (g/kg $W^{0.75}$)	100.8	92.0	82.3	88.9
Dry matter intake (% body weight)	4.1	3.8	3.3	3.6
Goats				
Initial body weight (kg)	32.5	26.5	25.8	28.0
Final body weight (kg)	33.5	25.8	25.3	28.3
Mean live weight (kg)	33	26.1	25.5	28.1
Live body weight change (kg)	1.0	-0.7	-0.5	0.3
Growth rate (g/day)	23	-	-	7
Dry matter intake (g/day)	868.7	1059.0	968.1	1086.7
Dry matter intake (g/kg $W^{0.75}$)	64.3	92.1	85.7	89.1
Dry matter intake (% body weight)	2.6	4.1	3.8	3.9
Milk produced (g/animal/day)	535	975	598	702

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