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Mathenge (*Prosopis juliflora*): An Underutilized Livestock Feed Resource in Kenya

[1]A.M. King'ori, [2]J.A. Odero-Waitituh and [1]A.Y. Guliye
[1]Department of Animal Sciences, Egerton University, P.O. Box 536-20115, Egerton, Kenya
[2]Ministry of Livestock Development, P.O. Box 44-20100, Nakuru, Kenya

Abstract: *Prosopis juliflora* is an invasive multipurpose dry land tree or shrub native to South America, Central America and the Caribbean. It was introduced to Eastern Africa in the 1970s through collaborative projects involving local governments and outside agencies. Prosopis species grow in arrays of environments and are not restricted by soil type, pH, salinity or fertility and are therefore used as rehabilitation of deserts and saline lands for shelter belts and sand dune stabilization. The use of agricultural and agro-industrial by products for livestock feed formulation results in fluctuation in quantity, quality and prices of the manufactured feeds. There has been much interest over recent years to explore alternative feedstuffs because of rising costs for conventional feed ingredients. The large resources of non-conventional agro-forestry trees are not efficiently utilized due to lack of information of their nutritive value and levels of inclusion in feeds. Among the non-conventional agro forestry feed resources is *Prosopis juliflora*. Prosopis pods are high in sugar and protein content and are a rich food source for livestock like sheep, goats, cattle, pigs and poultry. Rations containing prosopis pods have been recommended for lactating animals and have been said to increase milk production with increasing proportion of pod flour. No effects on milk flavour were noted at <50% pods in the ration, though as a sole feed some taste change has been reported. Faster growth rates on animals fed prosopis pods have been reported. In Brazil, *P. juliflora* bran (whole pod) replaced 100% wheat flour in chicken diets. The replacement of up to 35% of maize by prosopis flour in lactating sow rations in the North-East of Brazil has been reported. A maximum inclusion level of 20% prosopis pods in broiler, layer and fish diets has been reported. In Kenya, indigenous knowledge of prosopis management has lacked in the areas where it was introduced and spread and it has remained under-utilized and unmanaged. The local people were not advised on the management practices to fully exploit prosopis. In the countries where prosopis was introduced from, there are natural forests or plantations which harnessed for timber, charcoal, honey, gums, human and animal feeds. Similar benefits can be reaped by the Kenyan communities in the ASALs with prosopis. Therefore, technologies and management strategies for sustainable utilization of prosopis should be developed and employed. This will lead to economic empowerment and income diversification of these communities.

Key words: *Prosopis juliflora*, mathenge, leaves, pods, feed, livestock, tannins, Kenya

INTRODUCTION

The use of agricultural and agro-industrial by products for livestock feed formulation results in fluctuation in quantity, quality and prices of the manufactured feeds (Ngunyen and Preston, 1997; Radull, 2000; Nyaga, 2007). The supply of agricultural and agro-industrial by products depends on rainfall which is not always reliable. There has been much interest over recent years to explore alternative non-conventional feedstuffs because of rising costs for conventional feed ingredients. The large resources of non-conventional agro-forestry trees are not efficiently utilized due to lack of information of their nutritive value and levels of inclusion in feeds (Sawe *et al*., 1998; Donkoh and Attoh-Kotoku, 2009). In other parts of the world, *Prosopis juliflora* is one of the hardy nitrogen fixer plants used for rations for cattle, goats, sheep, camels, horses and poultry. *Prosopis juliflora* has a Crude Protein (CP) content of 16-22% depending on environmental conditions (Anttila *et al*., 1993; Abdulrazak *et al*., 1997) which is higher than maize carbohydrate content of 69% (Choge *et al*., 2007).

In Nigeria, use of prosopis pods resulted in lower prices of commercial poultry feeds (Yusuf *et al*., 2008). It can therefore be used as a feed supplement in the manufacture poultry feeds; significantly lowering the poultry feed cost, therefore impacting positively on the economic status of poultry farmers. This is also expected to save the country the foreign exchange spent in importing agro-industrial by products for manufacturing livestock feeds and increase export earnings

Corresponding Author: A.M. King'ori, Department of Animal Sciences, Egerton University, P.O. Box 536-20115, Egerton, Kenya

(Bakewell-Stone, 2006). Increased utilization of prosopis pods is also expected to increase returns to households with prosopis and subsequently control its spread in the Arid Semi-Arid Land (ASAL) areas (Aboud *et al*., 2005; Choge *et al*., 2007). Prosopis pods and leaves have anti-nutritive factors such as tannins (Abdulrazak *et al*., 1997) that could hinder the digestion and utilization and high sugar content (South TV progamme, 2009) that make it hygroscopic rendering milling and incorporation into feeds a challenge. Indigenous knowledge of prosopis management has lacked in the areas where it was introduced and spread and it has remained under-utilized and unmanaged. Local people were not advised on the management practices to fully exploit prosopis. In Kenya, indigenous knowledge of prosopis management has lacked in the areas where it was introduced and spread and it has remained under-utilized and unmanaged. The local people were not advised on the management practices to fully exploit prosopis. In other developing countries economic value has been added to some types of prosopis products, product certification and marketing (Admasu, 2008). Therefore, in Kenya studies on prosopis products, product certification and marketing should be undertaken to make use of prosopis as a valuable resource for national development.

***Prosopis juliflora* in the world:** *Prosopis juliflora* is native to Argentina, Belize, Bolivia, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Peru and United States of America. It has been introduced to Australia, Bahamas, Barbados, Brazil, Brunei, Cambodia, Cuba, Dominica, Dominican Republic, Grenada, Haiti, India, Indonesia, Iran, Jamaica, Kenya, Laos, Malaysia, Myanmar, Pakistan, Papua New Guinea, Philippines, Puerto Rico, Senegal, South Africa, Sri Lanka, St. Lucia, St. Vincent and the Grenadines, Sudan, Tanzania, Thailand, Trinidad and Tobago, Uganda and Vietnam (World Agroforestry Centre, 2012). Prosopis is known by the following English names: algarroba, honey mesquite, mesquite, mesquite bean (World Agroforestry Centre, 2012). It is an invasive multipurpose dry land tree or shrub. *Prosopis juliflora* is an evergreen tree with a large crown and an open canopy, growing to a height of 5-10 m and the root system includes a deep taproot. It has dark green compound leaves and the inflorescence is small, green-yellowish spikes without any particular fragrance or attractiveness, though relished by bees. Flowering begins at the age of 3-4 years. The bisexual, pea like flowers are cross-pollinated by wind and insects. The seed is disseminated and pretreated by the agency of animals that feed on the pods. The fruit is a non-dehiscent pod with ovoid, hard, dark brown seeds, with mucilaginous endosperm surrounding the embryo.

Prosopis juliflora is xerophytic and is adapted to many soil types under a wide range of moisture conditions. It has root nodules that can absorb nitrogen from the atmosphere thus the species may supplement soil fertility in some instances (Aboud *et al*., 2005; Bhojvaid and Timmer, 1998). The value of the tree lies in its exceptional tolerance of drought and marginal soils. It tolerates strongly saline soils and seasonal waterlogging. *P. juliflora* has been planted successfully on soils with acid to alkaline reaction. It is sometimes said to dry out the soil and compete with grasses, particularly in dry areas hence in some areas it is considered a weed.

It grows at an altitude of 0-1500 m, mean annual temperature: 14-34°C, mean annual rainfall: 50-1200 mm. It can grow on a variety of soils including rocky hills, saline flats, on shifting sand dunes and coastal sand although, it attains its best size in localities protected from wind and having the water table not far below the surface (World Agroforestry Centre, 2012). Although, prosopis is known for its merits in its natural range, it can become serious invading weeds when introduced into areas without proper management (Shiferaw *et al*., 2004).

***Prosopis juliflora* in Kenya:** Prosopis was introduced to Eastern Africa in the 1970s through collaborative projects involving local governments and outside agencies (Aboud *et al*., 2005). Prosopis tree, commonly known as mathenge, is found in the arid and semi-arid lands of Kenya in Baringo and Tana River counties. Studies have shown that Prosopis is an invasive plant species and can directly or indirectly affect the food security of local residents. In areas where they spread, it has destroyed natural pasture, displaced native trees reduced grazing potential of rangelands (Admasu, 2008). They compete for and reduce productivity of croplands (Anderson, 2005). The invasion of prosopis has caused considerable declines in livestock production and productivity due to the loss of dry season grazing areas to prosopis plants. Palatable indigenous pasture species have all reduced (Admasu, 2008; Mwangi and Swallow, 2005).

Little transference of the technologies of commercial utilization in its native range has led to the under-utilization of prosopis. Indigenous knowledge of prosopis management has lacked in the areas where it was introduced and spread and it has remained under-utilized and unmanaged (Mwangi and Swallow, 2008). Local people were not advised on the management practices to fully exploit prosopis. Therefore, management strategies should be developed to make use of prosopis as a valuable resource to support rural livelihoods in the dry lands (Mwangi and Swallow, 2005). Facial contortions, rumen compaction and constipation in livestock, disfiguration of livestock gums and tooth decay have

been reported (Mwangi and Swallow, 2005). These problems can be reduced by proper processing and incorporation in livestock feeds.

Uses of prosopis: Uses of prosopis include timber (building materials, floor tiles, furniture, handicrafts), charcoal, fire wood, human food (toasted seeds, beverage and processed food), animal feed (fodder, bee forage-flowers are good for honey production) gum production, tannin extraction, possible medicinal values and wind breaks of agricultural crops (Pasiecznik *et al*., 2001; Aboud *et al*., 2005; Mwangi and Swallow 2005; Perera *et al*., 2005; Choge *et al*., 2007). Fruit pods are high in sugar and protein content and are a rich food source for livestock like sheep, goats and cattle. Prosopis pods are palatable feeds and good sources of energy for ruminants due to their digestible carbohydrate content. They can replace part of the diet grains (Sawal *et al*., 2004). In many areas, cattle, sheep and goats browse the pods in the fields before they drop or picking up the dry ones from the ground. The pods can also be collected and fed to stalled livestock whole or processed, alone or as part of a ration and fresh or after storage. Processed pods are more digestible and ground pods have a better nutritive value. Processing involves the pounding, grinding or milling of pods, either as a single process producing a whole pod extract or with some separation of pod parts and further processing of each fraction. Processing usually involves milling of whole pods into a homogeneous, coarse flour although, in some cases exocarp and mesocarp (pulp) are separated from the endocarp and seed (Pasiecznik *et al*., 2001). Increase in milk production and faster growth rates on animals fed prosopis pods have been reported (Anttila *et al*., 1993; Admasu, 2008). Complete eradication of established prosopis is virtually impossible therefore, better ways of utilizing and managing prosopis will control its spread (Aboud *et al*., 2005; Perera *et al*., 2005; Choge *et al*., 2007). This includes development, promotion and utilization of prosopis products. In other developing countries economic value has been added to some types of prosopis products which involves comprehensive efforts incorporating product certification and marketing (Admasu, 2008).

Nutritional value of prosopis: Prosopis pods are high in sugars, carbohydrates (Choge *et al*., 2007) and protein (Anttila *et al*., 1993). Chemical composition has been reported as CP 16.2%, CF 22%, EE 3.4%, Ash 4.5% and NFE 54.1%. Pods from the species of *Algarobia* genus which includes the common weedy species in Africa contain 7-22% protein but fruits of *P. juliflora* contain 15.95% CP, 30-75% carbohydrates, 11-35% crude fibre, 1-6% fat and 3-6% ash. The variation in the proximate composition of the part of the plant analyzed (Table 1) being attributed to season and the environment (Oduol *et al*., 1986). The protein contains nearly all the essential amino acids (Talpada, 1985) with higher content of polyunsaturated fatty acids at (1.06/100 g DM) as compared to saturated of (0.56/100 g DM) (Choge *et al*., 2007). Care should be taken in interpreting food value data of prosopis from literature as these may be given for whole pods or only the pulp (mesocarp) or seed fractions (Choge *et al*., 2007). Despite the good nutritional value highlighted (Table 1-3) it is rarely utilized for food security and income generation in ASALs.

Table 1: Proximate composition of prosopis leaves and pods from different locations

Location/Part of plant	DM	CP	CF	NDF	ADF	Ash	EE	NFE	References
Kenya (seedpod meal)	88.4	18.5	-	51.8	29.8	5.2	-	-	Koech *et al.* (2010)
Kenya (pods)	-	16.3	-	44.8	36.2	-	-	-	Abdulrazak *et al.* (1997)
Kenya (pods)	-	16.2	22	-	-	4.5	-	-	Anttila *et al.* (1993)
Kenya (pods)		15.95	11-35	-	-	3-6	-	-	Oduol *et al.* (1986)
Kenya (pod flour)	93.6	16.2	47.8	-	-	6.0	-	-	Choge *et al.* (2007)
Kenya (pods flour)	89.2	59	1.7	-	-	4.9	-	-	Baiao *et al.* (1987)
Ethiopia (pods)	94.0	19.15	-	30.93	16.99	3.53	-	-	Farm Africa (2008)
Seed	88.4	35.8	6.1	-	-	3.7	-	-	Baiao *et al.* (1987)
Nigeria (prosopis seed meal-raw)	96.1	22.6	6.9	-	-	4.0	-	-	Yusuf *et al.* (2008)
Nigeria (prosopis seed meal-decorticated) fermented)	94.3	42.5	4.9	-	-	8.1	-	-	Yusuf *et al.* (2008)
Kenya (leaves)	-	18.5	-	27.1	18.2	-	-	-	Abdulrazak *et al.* (1997)
Location/Part of plant	DM	CP	CF	NDF	ADF	Ash	EE	NFE	-
Peru (pods)	82	9.1	13.6	-	-	5.8	0.4	65.3	Diaz Celis (1995)
Brazil (pods)	87.4	7.1	12.3	-	-	3.3	1.1	63.6	Galera *et al.* (1992)
India (pods)	88.5	12.3	28	-	-	1.4	1.3	46.3	Anon (1943)
Mexico (pods)	90.1	16.2	23.4	-	-	6	3.5	50.9	Diaz Celis (1995)
South Africa (pods)	-	13.9	27.7	-	-	4.8	3	50.6	Gohl (1981)

Table 2: Composition of flour from whole pods of *P. juliflora* from Baringo district, Kenya

Component	DM	Protein	Total sugars	Carbohydrate	Energy value (kJ) kcal	Dietary fibre	Fat	Ash
100 g DM	93.6	16.2	13.0	69.0	1530 3657	47.8	2.12	6.0

Choge *et al.* (2007)

Table 3: Amino acid composition of *Prosopis juliflora* flour, soya bean meal and cotton seed meal

Amino acid (g/kg/DM)	*Prosopis juliflora*[a]	Soya bean meal[b]	Cotton seed meal[b]
Arginine	48.2	42.1	41.8
Histidine	19.9	13.6	10.7
Isoleucine	32.6	25.5	11.9
Leucine	79.4	46.3	23.0
Lysine	42.6	31.9	19.0
Methionine	5.7	7.7	4.8
Phenlalanine	29.8	28.5	19.9
Trptophan	8.9	-	-
Tyrosine	28.4	21.0	10.9
Valine	78.0	27.0	20.9

[a]Choge *et al.* (2007), [b]Donkoh and Attoh-Kotoku (2009)

Table 4: Phenolic and tannin composition of Kenyan *Prosopis juliflora* leaves and pods

Part of plant	Total extractable phenolics	Total extractable tannins	Condensed tannins
	----------mg g^{-1} DM----------		
Pods	37.6	25.5	1.2
Leaves	16.2	13.3	15.4

Abdulrazak *et al.* (1997)

Limitations of use of *Prosopis juliflora* as a livestock feed: Abdulrazak *et al.* (1997) reported condensed tannins to have a depression effect on gas production (Table 4). This is due to depression on degradability hence reduction on the bio-availability of the nutrients present in prosopis. A tannin is any phenolic compound of sufficiently high molecular weight containing sufficient hydroxyls and other suitable groups (i.e., carboxyls) to form effectively strong complexes with protein and other macromolecules under the particular environmental conditions being studied. Bhatta *et al.* (2005) found that effects of tannins in prosopis can be reduced by treatment with Poly Ethylene Glycol (PEG) to improve performance in kids.

Intake in animal diets rich in tannins can be increased by using a compound with a high affinity for tannins like PEG (Poly Ethylene Glycol). PEG has a higher affinity to tannins than do proteins. PEG can be sprayed on the forages or added in the diet and is fairly inexpensive. PEG utilization can increase feed palatability and digestibility and result in higher animal productivity (Hagerman and Klucher, 1986). Intake of feed containing large amounts of condensed tannins is low (Barry and Duncan, 1984). Barry and Duncan (1984) recorded an increase in both Metabolisable Energy Intake (MEI) and Digestible Organic Matter Intake (DOMI) in sheep fed high-polyphenolic lotus. This was in response to decreased condensed tannin content when Polyethylene Glycol (PEG) was used to bind them (Barry and Forss, 1983). Digestibilities of OM, cellulose, hemicellulose and nitrogen also increased. Yusuf *et al.* (2008) and Mahgoub *et al.* (2005) suggested a 20% inclusion level for broilers and goats respectively, to be the optimum for improvement in performance. South TV progamme (2009) reported high sugar content, up to 35% that could render it hygroscopic making milling and incorporation into the feed a challenge. However, this property could improve the pelletting qualities of feed preparation with prosopis. The high CF/NDF content of both leaves and pods of prosopis depresses their utilization by non-ruminant and pre-ruminant stages of ruminant livestock.

Effects of tannins on feed degradation: Tannins negatively affect an animal's feed intake, feed digestibility efficiency of production. These effects vary depending on the content and type of tannin ingested and on the animal's tolerance. The effect on the animal is in turn dependent on characteristics such as type of digestive tract, feeding behavior, body size detoxification mechanisms. Condensed tannins rather than total extractable phenolics have a depressing effect on gas production especially in leaves (Abdulrazak *et al.*, 1997). This could be due to inability of rumen micro-organisms to attach to condensed tannins for degradation. Therefore, there is need for further research in incorporation of tree leaves in livestock feeds. However, Makkar (2003) found that tannins have beneficial properties in livestock feeding. Up to 4% tannins is beneficial because it promotes rumen bypass thus allowing high quality protein to be digested in the small intestines. One mechanism postulated is that tannins complex proteins at the pH of the rumen (5-7) and protect them from microbial enzymes. Subsequently, these complexes dissociate in contact with gastric (pH 2.5-3.5) and pancreatic (pH 8) secretions. High quality dietary proteins would be protected, at least in part, from degradation in the rumen and would then be digested more effectively in the intestine. However, even when released, tannins are still biologically active and can react with digestive enzymes or other proteins (Hagerman and Klucher, 1986). Indeed, in non-ruminants, tannins decrease intestinal absorption of amino acids (especially methionine) and reduce growth. Tannin-protein complexes that are strong enough to survive the environment of the rumen may not be broken down and digested in the lower tract. Studies by Ambula *et al.* (2003) showed that feeding laying hens sorghum with high level tannin did not affect their performance. A group of peptides present in human and monkey saliva have been demonstrated to acts as defense against dietary tannins (Barry *et al.*, 1986; Naurato *et al.*, 1999). This group of peptides might be present in poultry, explaining their ability to utilize the high tannin sorghum feed. This finding suggests the possibility of incorporating prosopis leaves and pods in poultry feeds.

FEEDING TRIALS WITH PROSOPIS

Ruminants: Prosopis pods contain cytotoxic alkaloids that may cause intoxications to cattle, horses, sheep and goats in diets containing high levels of pods (>50%). Problems have been reported in the USA, Peru and Brazil (Vilar da Silva *et al*., 2002; Tabosa *et al*., 2006; Camara *et al*., 2009). Poisonings were also recorded from pods eaten after exposure to rain (Gohl, 1981). Goats and cattle fed with diets containing 60-90 and 50-75% prosopis pods, respectively suffered mandibular tremors during chewing due to toxicity to neurons of certain cranial nerve nuclei (Tabosa *et al*., 2000, 2006). Neuronal lesions result in difficulties in prehending and chewing, it subsequently causes feed wastes and animal death (Tabosa *et al*., 2006). In India, goats offered dry prosopis pods as sole feed during 4 days suffered from partial anorexia, depression, salivation, twitching, dehydration and bloody diarrhoea. Histopathological studies revealed necrotic lesions in the liver, degenerative changes in renal tubules and rarefaction of lymphoid tissue (Misri *et al*., 2003). Nomads and pastoralists in Yemen as in many other countries, regularly feed their animals on *P. juliflora* pods which have a high nutritional value, being rich in sugars and protein. The importance of pods as fodder supply increases as natural conditions become harsher and seasonal (FAO, 2012). In Latin America and India the pods are processed to obtain excellent feed for ruminants. Pods have for long been used as feed for cattle, horses, sheep and goats. Ripe pods contain 12-14% crude protein (Orwa *et al*., 2009). Only ripe pods should be fed as the green pods are bitter and have little feed value. The foliage is good-quality fodder but its use is not widespread. Direct browsing of the foliage has been used but may limit tree development and it is not particularly palatable.

In a feeding trial in Ethiopia, goats supplemented with crushed prosopis pods had higher body weight gains than those on grazing only. In Oman, a diet containing 20% pods improved feed intake, feed conversion and body weight gain without compromising carcass yield or quality. However, intake and gain dropped sharply when pods where included at 30%. In the dry lands of India, up to 35% prosopis pod flour included in the diet of goats in late lactation maintained weight gain, blood parameters and milk yield. In India, does were supplemented during late pregnancy (4-6 weeks before kidding) and the 1st month after kidding. One group was given a mixture of horse gram and sorghum while the other was given *Prosopis juliflora* pods. The mean birth weight of kids in the group given prosopis pods was higher than that of kids in the group given sorghum and horse gram mixture and the control group. The weight gain (during the 1st month) of kids born to does in the two treatment groups was similar was higher than kids belonging to control group animals. Therefore, both treatments were beneficial; particularly the *Prosopis juliflora* pods. Prosopis pod meal can be used as goats feed up to 200 g/goat/day giving good weight gains and no negative effects on feed intakes and digestibility (Koech *et al*., 2010).

Rations containing Prosopis pods have been recommended for lactating animals and have been said to increase milk production with increasing proportion of pod flour. No effects on milk flavour were noted at <50% pods in the ration though as a sole feed some taste change has been suggested (Pasiecznik *et al*., 2001). In Colombia, the use of prosopis pods increased the weight in dual-purpose cows (Roncallo, 2002). In India, inclusion of up to 30% pods in the diet maintained dairy performance (Talpada and Shukla, 1988). Studies in Brazil showed that *P. juliflora* pod flour could replace up to 60% of wheat flour in rations for lactating cows and that DM intake, weight gain and milk production. In Brazil, total replacement of wheat bran by ground pods was found favourable for beef cattle (Silva, 1988). In Peru, Chile, Argentina and Uruguay, the pods are used in concentrate rations for dairy cows at a ratio of 40-60% (Habit and Saavedra, 1988; World Agroforestry Centre, 2012). Trials in India have shown that the inclusion of *Prosopis juliflora* pods could sustain cattle growth, diets containing up to 45% *Prosopis juliflora* pods (1.5% of body weight) gave acceptable live weight gains (Shukla *et al*., 1984). *Prosopis juliflora* pods can be fed to 9 months crossbred heifers up to 20% in the diet (replacing rice polishings) without adverse effect on growth and reproductive performances (Pandya *et al*., 2005). Similar results were obtained at 20% level in growing crossbred calves (Talpada *et al*., 2002). In Mexico, trials with sheep showed that replacement of sorghum flour with *Prosopis juliflora* pod flour increased live weight gain up to 45% but not at 60% (Habit and Saavedra, 1988).

In Brazil, replacement of sugarcane molasses with *Prosopis juliflora* pods at 0, 15, 30, 45 and 60% was most effective in terms of live weight gain at the 30 and 45% levels. It was found that intake by sheep was not influenced by grinding or heating but ground pods fed with elephant grass (*Pennisetum purpureum*) were eaten in greater volume than the whole pods. In South Africa, prosopis pods are fed unmixed to sheep (Orwa *et al*., 2009).

Non-ruminants: In Brazil, experiments with chickens showed that wheat flour could be replaced 100% by *P. juliflora* bran (whole pod). The prosopis fruits have been used as a supplement to balanced rabbit feed,

replacing up to 60% of the protein in the basic diet. Rabbit growth remained unchanged even when the feed contained up to 29.4% of the dried prosopis fruits. As human food, delicious flour can be made from pulverized pods from which seeds have been removed. Cotyledons and embryos when pulverized yield flour that is rich in protein and sugar appropriate for diabetic people. Sugars and sweeteners can be produced from the pods. There are reports that *P. juliflora* pods are used in preparing bread, sweets, syrup and coffee. However, the pods must be processed to improve the flavour. The short-fibred parts are also suitable for pigs and poultry. Prosopis flowers are good bee forage and their nectar yields a superior honey (World Agroforestry Centre, 2012).

P. juliflora is a major honey source in Bolivia, Jamaica, Pakistan, Western Australia and elsewhere (Fagg and Stewart, 1994). In Sri Lanka, it is one of the most important species for bee forage due to its very copious nectar flow (Orwa *et al*., 2009). Prosopis pod meal could replace the 75% of maize grain in the diets of Nile tilapia (*Oreochromis niloticus*) fry without affecting animal performance (Lima *et al*., 2009). A diet supplemented with 60 g kg^{-1} of prosopis pods improved growth performances, feed and nutrients utilization whole body composition (dry matter, protein and energy content) in Nile tilapia fry (Mabrouk *et al*., 2008). Hydrothermically processed *Prosopis juliflora* seed meal as a supplementary diet for *Labeo rohita* was found to be rich in protein (330 g kg^{-1}) having anti-nutritional factors in permissible limits and containing adequate essential amino acids except lysine, methionine and cysteine. The growth of fish (weight gain, specific growth rate, feed conversion ratio and protein efficiency ratio) fed diet with soaked prosopis seed meal at 20% replacement was higher among the test diets but lower than the reference diet. Therefore, considering the easy availability and its nutritional quality, processed *Prosopis juliflora* seed meal can be incorporated in carp diet at 20% inclusion level (Bhatt *et al*., 2011).

In Peru, pigs have been fed 1-3 kg prosopis pods. Pigs fed on rations containing 70% sun-dried seeds in Hawaii gained 595 g day^{-1}. Kiln-dried prosopis seeds gave lower gains. This may be due to low digestibility associated with millard reactions as a result of high temperature during drying. Inclusion of more than 10% ground dried prosopis pods in post weaning piglets had detrimental effects on growth rate and the feed conversion ratio. Growth rate decreased and feed conversion ratio increased with increased inclusion rate of the pods (Silva *et al*., 1989). Prosopis flour included at up to 50% in growing finishing pigs had no effect on growth performance and carcass quality (Lima Filho *et al*., 1998). The replacement of up to 35% of maize by prosopis flour in lactating sow rations in the north-east of Brazil has been reported (Riveros, 1992).

A maximum incorporation level of 20% prosopis pods in broiler diets has been reported. Prosopis pods could partially replace maize and offered up to 20% in the broiler diet (with enzyme supplementation). Inclusion at 30% increased the feed conversion ratio (Choudhary *et al*., 2005). Broilers fed a diet containing 20% had the highest live weight, weight gain and the best feed conversion ratio (Al-Beitawi *et al*., 2010). A 10% inclusion rate in broiler diets did not have any adverse effects on performance in starter and finisher diets (Vanker *et al*., 1998). Inclusion of 7.5-14% prosopis pods is recommended in layer diets. Prosopis pod meal was used to replace up to 100% of wheat bran (7.5% of the diet) in rations for laying hens with no effect on intake, feed conversion ratio or egg weight (Riveros, 1992). The inclusion of prosopis pod meal up to 13.6% in iso-nitrogenous and iso-caloric diets did not adversely affect laying hens performance but a 30% inclusion level reduced egg and mass weights and affected feed to egg mass ratio. In laying quails, prosopis pod meal could be included up to 15% in partial maize replacement of iso-nitrogenous and iso-caloric diets without an adverse effect on laying performance. A 25% inclusion level reduced feed intake and egg mass (Vilar da Silva *et al*., 2002). Horses and donkeys can consume between 2-6 kg day^{-1} or 1.2 kg/100 kg W prosopis pods. Prosopis pod meal could replace 100% of maize cob meal (75% of diet DM) in mares without altering DM intake, though NDF digestibility will be affected (Da Silva Stein *et al*., 2005).

CONCLUSION

Prosopis juliflora is an invasive multipurpose dry land tree or shrub native to South America, Central America and the Caribbean. It was introduced to Kenya in the 1970s to rehabilitate environmentally degraded areas. Due to the invasive nature of prosopis if not well managed it can directly or indirectly affect the food security of local residents. In Kenya, indigenous knowledge of prosopis management has lacked in the areas where it was introduced and spread and it has remained under-utilized and unmanaged. The local people were not advised on the management practices to fully exploit prosopis. This has resulted in reduction of grazing land, livestock poisoning and dense thickets causing alarm among the local communities. However, prosopis leaves and pods are high in sugar and protein content and are a rich food source for humans and livestock like sheep, goats, cattle, pigs and poultry. Prosopis pods and

leaves are livestock feed resources in Kenya that have not been fully utilized. They are available in the ASALs which comprise about 75% of Kenya which are characterized by low (<100 mm) and erratic rainfall. Therefore, harvesting, processing and preservation of these prosopis products whenever they are available should be adopted. This will ease the seasonal feed variability, ease the demand for cereal grains and oil cakes for manufacture of livestock feed especially during the dry season. This will indirectly contribute sustainable supply of livestock products throughout the year. Therefore, technologies should be developed on the sustainable utilization of prosopis products to enhance livestock feed supply and ensure minimal environmental degradation.

IMPLICATIONS

The under-utilization of prosopis in the Kenya ASALs has lead to the reduction of grazing land, formation of impenetratable thickets and poisoning of livestock. This has led to the local communities calling upon the government to eradicate prosopis which is not easy. However, in the countries where prosopis was introduced from, there are natural forests or plantations which harnessed for timber, charcoal, honey, gums, human and animal feed. Similar benefits can be reaped by the Kenyan communities in the ASALs with prosopis. Therefore, technologies and management strategies for sustainable utilization of prosopis should be developed and employed as soon as possible. This will lead to economic empowerment and income diversification of these communities.

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