Underutilised crops for famine and poverty alleviation:
a case study on the potential of the multipurpose
Prosopis tree

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In its native Latin America, the Prosopis tree (also known as Mesquite) has multiple uses as a fuel wood, timber, charcoal, animal fodder and human food. It is also highly drought-resistant, growing under conditions where little else will survive. For this reason, it has been introduced as a pioneer species into the drylands of Africa and Asia over the last two centuries as a means of reclaiming desert lands. However, the knowledge of its uses was not transferred with it, and left in an unmanaged state it has developed into a highly invasive species, where it encroaches on farm land as an impenetrable, thorny thicket. Attempts to eradicate it are proving costly and largely unsuccessful.

In 2006, the problem of Prosopis was hitting the headlines on an almost weekly basis in Kenya. Yet amidst calls for its eradication, a pioneering team from the Kenya Forestry Research Institute (KEFRI) and HDRA’s International Programme set out to demonstrate its positive uses. Through a pilot training and capacity building programme in two villages in Baringo District, people living with this tree learned for the first time how to manage and use it to their benefit, both for food security and income generation. Results showed that the pods, milled to flour, would provide a crucial, nutritious food supplement in these famine-prone desert margins. The pods were also used or sold as animal fodder, with the first international order coming from South Africa by the end of the year. Collecting the pods also helped to prevent the unregulated spread of the tree. The wood provided a high quality charcoal, and the timber, which is harder than oak, is currently being developed as a certified, sustainably managed product for regional and international markets.

Subsequent spontaneous diffusion of this knowledge and skills base between community groups in Baringo District provides further evidence of its acceptability and usefulness by beneficiary groups. This demonstrates how knowledge can change perceptions, turning a problem into a valuable resource. On a global scale, the habitats that Prosopis invades are typically arid and resource poor, and often correspond with poverty and conflict affected areas. As such, it holds the potential to provide vital food, fuel and income generation in extreme marginal conditions. Yet this evidence of its usefulness might still be insufficient to halt the eradication programmes being planned for this underutilised tree.

INTRODUCTION TO THE GENUS PROSOPIS

Prosopis is a leguminous and highly drought resistant tree. Many species of Prosopis exist, but P. juliflora and P. pallida are the only two species that are truly tropical, native to Central and South America but have since spread to the Pacific and Australia, India
and Pakistan, Africa and the Middle East, through deliberate introductions and then weedy invasions. In more sub-tropical areas, *P. glandulosa* and *P. velutina* from North America are the most commonly introduced and invasive species. It is well acknowledged that left uncontrolled, *Prosopis* becomes a highly invasive weed, and the issue of how to control it has caused much debate.

*Prosopis* trees were deliberately introduced pan-tropically during the last two centuries, into Australia and the Pacific (Panetta and Carstairs, 1989), India and Pakistan (Reddy, 1978; Luna, 1996), and throughout Africa (Hughes, 1991; Jama and Zeila, 2005). Tolerance to drought and poor quality soils, tolerance of repeated cutting and the generation of multiple products were all reasons for the widespread introduction of these trees firstly by colonial administrations and lastly by development agencies. However in all areas, indigenous knowledge on its management and uses was not transferred, and as a consequence, introduced trees have become an invasive pest.

In its native South America, *Prosopis* is utilised as an important natural resource, particularly the wood which can be used as a fuel, either directly or as charcoal, and as timber for poles, boards and cants. The wood has a very high calorific value for burning (FAO, 1997) and also makes good charcoal. For structural use, the heartwood is strong and durable and has relatively high dimensional stability with low shrinkage (FAO, 1997). In addition to wood products, the legume pods *Prosopis* produces are high in sugars, carbohydrates and protein, and typically produce yields ranging 1–8 t/ha per year but can produce yields up to 10 t/ha (Felker, 1979). Being a deep rooted tree, pod production is far less dependent on rainfall than fruit trees, and *Prosopis* generally produces pods every year, independent of rainfall, making it a crop that people and livestock can depend on in drought stricken areas (Pasiecznik, 2001).

Additional uses include: as a source of nectar and pollen for honey production, exudates gums, tannins, dyes, fibres and medicinal use. The extensive use and management of *Prosopis* in its native environment has prevented it becoming an invasive weed. Regular pruning allows the trees to produce useful timber products rather than reverting to impenetrable thickets and using the pods reduces proliferation by seed.

However, although there continue to be widespread attempts to eradicate *Prosopis*, even though these are proving largely unsuccessful, there is a developing consensus that the only way of controlling its spread is by converting weedy stands to managed agroforestry systems. This paper uses a case study in the Baringo district of Kenya to demonstrate how the transfer of indigenous knowledge may have the potential to control the problem of an invasive weed whilst benefiting resource-poor communities.

**INTRODUCTION OF PROSOPIS INTO KENYA**

The origins and pattern of introduction of *Prosopis* species into east Africa are not well known as it clearly existed before the large-scale introductions that occurred in the 1980s. *P. juliflora* may have been introduced by livestock from Sudan or southern Africa or by traders from India or southern Africa. Although it is considered that there were isolated *Prosopis* trees in Kenya in the 1930s, the first documented introduction of the tree in Kenya was in 1973, when seeds were imported from Brazil and Hawaii for the rehabilitation of quarries in the saline soils at Baobab Farm near Mombasa (Jama and Zeila, 2005). However, the first major planting programmes of the 1980s occurred as part...
of a dryland forestation scheme supported by the FAO and funded by various aid agencies including Finland, along the Tana River, and Norway in Turkana District.

As far as is known, no efforts were made to manage the first plantations and by 1990 naturalisation and invasion were both observed. No interventions were made at that time as people were unaware of the risks posed by this non-native invasive species. So, throughout the 1990s, *Prosopis* quickly spread, aided by livestock, and local perceptions of *Prosopis* became increasingly negative. In a report (Aboud *et al.*, 2005) based on 73 interviews carried out in the Baringo district, local people highlighted the following problems with *Prosopis*:

- It was regarded as highly aggressive forming impenetrable thickets that choked out other plants and reduced biodiversity.
- It blocked irrigation schemes when it occurred near watercourses.
- It was also thought to actually encourage soil erosion because the understorey of herbaceous plants was eliminated by competition.
- By extensively drawing on groundwater, dense stands of *Prosopis* were thought to lower the water table.
- It was also perceived to cause problems with livestock; although palatable, it was thought to cause tooth problems for goats, and digestive problems for sheep and goats if fed over a prolonged period.

In a similar study in the Baringo district (Mwangi and Swallow, 2005) of 65 individuals in the Ng’amo area and 48 in the Loboi area, 85–90% favoured complete eradication.

By 2004, the Ilchamus community in the Baringo district of Kenya had begun legal action against the FAO and the Government of Kenya, aided by a local NGO, ‘Community Museums of Kenya’. They claimed that *P. julifora* was introduced without adequate assessment of the future risks. With increasingly negative coverage in the media, the government considered whether to declare *Prosopis* a ‘National Disaster’ and opt for wholesale clearing of stands by bulldozer and introducing biological control agents.

**Control and eradication of Prosopis**

As *Prosopis* became recognised as a problem woody weed in many countries, a wide range of control measures have been developed. Most control programmes have been attempted against *P. glandulosa*, *P. velutina* and *P. ruscifolia*, and fewer major control programmes have been implemented on *P. juliflora* and *P. Pallida*. The most extensive eradication attempts have occurred in the USA for almost a century, but these have generally had limited success (Jacoby and Ansley, 1991). Similar but less intensive eradication programmes have also been implemented in Argentina, Paraguay, South Africa, Sudan, Pakistan and Australia. These programmes all showed that it was virtually impossible to completely exclude *Prosopis* species from a site once they had become established, so the term ‘eradication’ became gradually replaced with that of ‘control’.

The three main recognised methods of controlling *Prosopis* species in its native range are mechanical, chemical and fire (see Jacoby and Ansley, 1991). Biological control has also attracted much interest especially in Australia and South Africa.

Hand clearance is the simplest form of mechanical control and was the first method used for controlling *Prosopis* in the Americas. Trees are felled, then all stumps
and seedlings uprooted. Whilst being very effective, it is generally considered too labour intensive and expensive except for clearing smallholdings of high value land. Root ploughing and chaining are often the most effective mechanical means. For root ploughing, large trees are first felled. Chaining involves pulling two large chains between two large tractors, pulling over larger trees and uprooting them. Both of these methods are effective but incur high costs.

Chemical treatments use herbicides to kill the trees. Effectiveness is often limited by the poor uptake of the chemical as *Prosopis* has thick bark and small leaves with a protective waxy layer. Formulating an appropriate mixture of chemicals for trees of mixed ages and sizes within a stand can also prove difficult. Many chemicals, also failed to completely kill the trees and infested sites frequently needed respraying every 5–7 years.

Fire is probably one of the original tools used to manage *Prosopis*. Young seedlings can be destroyed by fire, but older trees build up a layer of protective thick bark and will resprout after fire. Fire can, however, be used to prevent the reestablishment of young *Prosopis* seedlings or to remove dead trees that have been killed by chemical treatment.

The limited success of chemical and mechanical treatments, has generated increased interest in biological control methods using bruchid beetles that are host specific and can destroy substantial amounts of seed thereby having the potential to limit invasion. (Kingsolver *et al.*, 1977). The majority of the work on biological control has been carried out in South Africa with the *Algarobius prosopis*. Using the bruchid beetle in conjunction with another seed feeding insect, *Neltumius arizonensis*, has proved the most successful method.

Changes in grazing practice may also have an impact on the spread of *Prosopis* seed. Ingestion and passing by cattle has been shown to improve the germination of the seed (Peinetti *et al.*, 1993; Danthu *et al.*, 1996). Conversely, seed that has passed through sheep (Mooney *et al.*, 1977), goats (Harding, 1991) or pigs (Peinetti *et al.*, 1993) shows much reduced viability compared to cattle.

In the Baringo district, a survey of the Ng’ambo and Lobio areas (Mwangi and Swallow, 2005) showed that minimal attempts had been made to control *Prosopis* at a community level. Most efforts were being done by individuals or families on homesteads and smallholdings using mechanical methods, uprooting seedlings or whole trees, cutting, and pruning, and burning cut stumps. The majority of individuals in the Ng’ambo district reported that they uprooted or cut *P. juliflora* trees during land preparation. The frequency of this activity varied from once to four times a year with some reporting that they uprooted seedlings continuously throughout the season. A net monetary balance was calculated taking account of the benefits such as selling the products as posts or fuel wood and the losses such as the amount of labour required to clear the trees. This identified that the highest losses were associated with individuals who identified themselves as herders, despite the benefits of *Prosopis* as fodder during periods of scarcity.
FACTORS AFFECTING UTILISATION OF PROSOPIS

In its native South America, Prosopis is utilised extensively and not considered an invasive weed. Where it has been introduced, the extent to which it is utilised varies widely around different areas of the world. Much of this is dependent on both people’s knowledge and perception of the tree which are influenced by a wide range of factors. The most important of these is how it affects their livelihoods (Binggeli, 2001; Pasiecznik et al., 2001) but many other factors are involved including damage to properties or ecosystems, the aesthetics of the species and also its portrayal in the media (Veitch and Clout, 2001). Studies in India (Pasiecznik et al., 2001) have shown that levels of income and occupation are an important influence. Those on a lower income regard it as an important source of firewood, whereas those on a higher income who can afford bottled gas have a negative perception of Prosopis as they do not need to use it as a source of fuel. Pastoralists and herders are also more likely to have a negative perception due to the possible negative effects on livestock, such as digestive and tooth problems, whereas housewives who have to gather firewood are more likely to regard it as a positive asset.

In Kenya, the uses of Prosopis can vary within a localised region of the country. For example, a study of two regions within the Baringo district (Mwangi and Swallow, 2005) showed that Prosopis was extensively used but the uses differed markedly between the districts. In the Ng’ambo region, 94% of respondents used Prosopis wood for construction poles whereas in the Loboi region, the most popular use was for fuel wood (58% of respondents). A number of barriers to its use were reported. The strong thorns made harvesting the products difficult and also caused punctures in vehicles used to transport products. The weight of the wood made transportation of poles difficult and its hardness made it difficult to cut. Marketing of P. juliflora was also reported to be difficult as its products were already abundant throughout the area.

It is now acknowledged that a degree of control may be achieved through intensive utilization of tree products and by improved management. Trading of its products, converting a weed into a valuable resource, presents an opportunity for socio-economic benefits to the communities living in marginal areas of the country where extensive areas of Prosopis are found. Furthermore, invasive Prosopis is now common in many parts of Sahelian and eastern Africa, including Kenya and Niger where large populations face malnutrition due to drought, a situation exacerbated by mass movements of refugees in response to food shortages and military conflicts. In these situations Prosopis has potential at least as a famine food, if not as a regular source of nutrition.

The following section focuses on a training programme in the Baringo district to control and exploit the Prosopis tree where a number of initiatives were put in place to improve the knowledge and management practices. Around Marigat and Salabani locations in Baringo District, KEFRI managed a two year pilot project funded by the FAO on improved Prosopis management and utilisation, from 2004. Practically, there was one year of effective work on the ground which ended with a final field day and workshop in Marigat in August attended by senior government officials and representatives from UN agencies such as UNEP, FAO and others. Details of this training course are in Pasiecznik et al., (2006). The course dealt firstly with how a Prosopis stand should be managed to turn it into a useful production system, then focused
on its principal uses as timber, fuel wood and as a potential human food. These are outlined in the following sections.

PLANTATION MANAGEMENT

The initial step towards converting weedy thickets into productive stands was to improve knowledge on plantation management. A full account of how plantations can be managed is provided in Pasiecznik et al., (2001) and this emphasised the importance of maintaining an optimum density for the system in question. For example, a single rotation coppice system may contain trees at a density of 5000 trees/ha whereas an open silvopastoral system may only have 100 trees/ha. These recommendations can vary considerably according to conditions such as soil fertility and rainfall.

Around Marigat and Salabani, invasive stands were initially completely cleared leaving only rows of trees that were high-pruned. Tree stumps were removed, or killed by burning. These cleared strips were then either sown with forage grasses such as *Cenchrus ciliaris*, or cultivated with rainfed crops. These permanent systems were experimented with by Farmer Field Schools comprising local people and a coordinator, and these provided a focal point where opinions could be exchanged and the system adapted. This system of extension appeared to be a successful mechanism for encouraging local communities to experiment with *Prosopis*.

It is also important that the remaining trees are managed properly. Unlike traditional timber species, *Prosopis* are cut frequently throughout their lifetime. The most common operations are the removal of selected stems and side branches to form a single stem, crown pruning, coppicing, lopping and pollarding. In February 2006, HDRA/KEFRI training in the region provided a demonstration of *Prosopis* management on a single tree basis. This included: selecting trees to keep and those to remove, singling or high-pruning multi-stemmed shrubs and trees, removing seedlings, killing cut stumps, tools for pruning and clearing, and environmental benefits from thinning and pruning. These techniques are now being applied by trainees to trees around their own homes and fields. A follow-up visit to Salabani in November 2006 showed that these concepts had been taken up by the local community. Around many farmsteads, thinning and pruning was carried out by individuals on their own land, leaving single-stemmed trees at wide spacing as had been recommended. This had also been applied to public buildings such as the grounds of the local school, showing that the knowledge had been successfully adapted and adopted. The same techniques were also disseminated in two outreach demonstration courses in Garissa and Bura, also attracted much interest. It was recommended that such demonstrations now be taken nationwide, and to more remote villages in each district.
USING PROPOSIS AS TIMBER

Turning *Prosopis* wood into timber products is a key way of adding value to the products. *Prosopis* timber is generally very hard and durable and it has been used for products such as railway sleepers, parquet flooring and in joinery (FAO, 1997). Training and awareness-raising courses on timber processing took place in Garissa, Baringo and Tana River districts in 2006. This used the simplest machinery, the chainsaw but with added guide attachments. The use of simple guides or attachments fixed to the chainsaw bar differentiates chainsaw milling from the more widespread but more dangerous method of ‘freehand’ milling. Three types of guides, frame mills, rail mills and carriage mills are commonly used, and the properties of these are described in Pasiecznik et al., (2006). Detailed reports of both courses and all project outputs are also available on the project website ([http://chainsaw.gwork.org](http://chainsaw.gwork.org)).

A full economic study was also undertaken comparing the economics of chainsaw milling over the nearest alternative systems using (circular) bench saws (Samuel et al., 2007). This study showed that the biggest difference between the setups was the time to pay back the capital, with the chainsaw frame milling only taking 101 days whilst the bench saw would take over six years.

Training courses were generally well received with frequent requests on where to purchase the milling attachments. Prior to this, there had been only one attempt to mill *Prosopis*, with a local landowner purchasing logs at Ksh 300 each and taking them 100 km to Nakuru to the nearest sawmill. However, these sawmills were not accustomed to the hardness of the timber, and cost of transport was
prohibitively high. In contrast, this new approach, with low capital investment, low operational costs, and ‘turning trees to timber’ on the spot where they fall, allowed a completely novel concept of timber processing.

An example of one demonstration, showed the potential for producing timber on site. A local carpenter was buying timber from Garissa, 100 km away, which made up a major part of his running costs, and he estimated that the nine 3 ft lengths of 2x2 in (90 cm by 5x5 cm) that had been produced from a short Prosopis log in 15 minutes had a market value of Ksh1000 (US$15), and he stated that he would now find a chainsaw operator to start converting Prosopis trees and use this local timber for making furniture.

A further training course for converting sawn boards into finished products was later held at the request of people from the Baringo district. Four hand-held power tools; a planer, belt sander, jigsaw and drill, a hand saw and a selection of spare blades, drill bits, sandpaper, etc. were demonstrated in Garissa and Bura. Here, people were exposed to ‘turning trees to timber’ and ‘turning timber to traded products’, the transformation of a Prosopis log into finished parquet tiles and craft items in the same afternoon. This was taken one stage further at a carpenter’s workshop in Marigat, with a continuous production line set up, where logs were milled and the boards processed into finished items, producing a wide range of products, from chapatti boards and stools, to parquet flooring tiles and shaped craft items for the tourist market, such as wooden Africa and Kenya shaped wall hangings, animal shaped chopping boards, etc.

A telephone survey of Nairobi-based timber companies indicated that there was a ready market for products. Prices for finished hardwood tongue-and-grooved parquet flooring at Ksh600-1200 (US$9-18) per square metre, made potential supplies from Prosopis very attractive. More work is required to produce quality finished samples and begin a serious campaign to attract the interest of these and similar companies in Kenya. A UK marketing survey (Bakewell-Stone, 2006) also identified a number of potential importers of Prosopis timber products which can be taken forward when a consistent supply is forthcoming. KEFRI are to further test local markets by preparing samples, calculating returns, and arranging the first Prosopis timber stakeholder meeting.

Conservative estimates of the amount of Prosopis wood available suggest that there is an ample supply to meet demand. The original Prosopis plantations established in Kenya are now 16-20 years old, and these are now ready for exploitation as a timber. Trees from a 1500 ha Prosopis plantation established in the 1980s now have diameters over 40 cm, thus giving mean annual diameter increments in excess of 2 cm/yr. At 2 x 4 m spacing, and with a utilisable bole of 40 cm over bark diameter and 1.5 m in length, there would be an estimated standing timber volume of 250 m$^3$/ha. Taking a very low conversion rate of only 20% recovery, guaranteeing that all sapwood would be removed, this gives a potential 50 m$^3$/ha of sawn timber, or 75,000 m$^3$ in just this one single plantation.

Although accurate data for the area of plantations established in the 1980s are not available for the country as a whole, a conservative estimate of 15 times that for the Bura plantation would give a total area of mature stands of 22,500 ha, which could yield over one million cubic metres of sawn timber. This would make a
significant impact on Kenya’s timber balance, and this does not take into account timber from naturalised stands which are also known to contain very large standing volumes with diameters in excess of 40 cm.

Growth rates are also high. This indicates to potential buyers of *Prosopis* timber for parquet flooring or other uses that adequate supplies exist and can be sustained at least in the near future. Although such exploitation would begin with low levels, as experience, technologies and markets would need to develop, it is clear that the supply of *Prosopis* timber is not in doubt, and improved management leading to the production of longer and straighter stems, thus improving recovery, can only benefit the situation. The appropriate technology of chainsaw milling for converting *Prosopis* logs to sawn timber in remote areas has been tested in 2006, and the economics have been assessed and compared with tractor bench saws, and comparisons with other mobile sawmills is in progress. In areas such as drylands that have no history of timber exploitation, there is a distinct lack of appropriate processing skills, and any training and development must appreciate this if it is to succeed. Risks in drylands are often so high and returns so low as to severely limit investment, and high value timber has been identified as the one product that has the potential to realise significant profits and livelihood improvements.

**USING PROSOPIS AS POLES**

Although highest returns can be made from turning *Prosopis* wood into cants and boards, the production of posts and poles continues to meet an import need for local rural construction. It has good durability in these structures although the sapwood is easily and quickly attacked by insects (Pasiecznik, 2001). A recent development has been the contracting of the Forestry Department to provide long, thin, flexible sticks of *Prosopis* for making the framework of simple structures for Somali refugees in Garissa District. For use as fence posts, some anecdotal reports note that they are resistant to decay for at least for two years, whilst others note infestation with wood borers. A study was completed this year (Chepkwony JC, 2006, BSc thesis, Moi University, Nairobi, Kenya) which found that *Prosopis* heartwood was unsuitable for pressure treatment with a timber treatment agent, with only minimal uptake in the wood. Further studies are being considered by KEFRI, using water soaking or heat-treatments to reduce immediate attack. Amerindians used to reduce insect attack by only harvesting on a waning moon, which may reduce sugar content in the sapwood, and this technique could also be tested in any future trials.

**USING PROSOPIS AS FUEL WOOD**

*Prosopis* wood is used extensively for domestic fuel in arid and semi arid zones around the world. The wood burns evenly and hot due to its high carbon content (Goel and Behl, 1992) and has a high calorific value (NAS, 1980; Khan *et al.*, 1986) making it very suitable for this purpose.

In Kenya, views commonly held by many people in Marigat or Bura are that before the 1980s, the land was bare, dust storms were commonplace, and women had to walk long distances in search of firewood. With the spread of *Prosopis*,
Firewood is now easily accessible and in plentiful supply, and the dust storms have ceased completely. The government is starting to realise the exploitation of invasive stands as a means to control weedy invasions while also providing much needed firewood for Somali refugees, while also reducing conflict with local people over collection of firewood. There are an estimated 140,000 refugees in camps around Garissa town, and the UNHCR has very recently contracted the Forestry Department to supply them with 500 tonnes of firewood. Similar schemes could provide valuable sources of firewood to Sudanese and Somali refugees in camps in northern and north-eastern Kenya, while also providing much needed local employment, revenue for the state and help to control the spread of *Prosopis* on government land.

*Prosopis* charcoal is consumed widely in urban areas and is widely acknowledged to be of high quality. There are many regions of the world where charcoal makes a large contribution to the local economy including Haiti (Lea, 1996), India (Kanzaria and Varshney, 1998) and Peru (Diaz Celis, 1995). It is more popular than that from other trees according to a recent KEFRI survey. However, Kenyan government policy is that the production and transport of charcoal is illegal unless a license has been applied for and approved. This law was introduced in an attempt to stop the cutting of natural forests for charcoal, seen in earlier decades as one of the main causes of deforestation. However, changing this law alone has been identified as the one single most important means of promoting *Prosopis* exploitation, as charcoal is widely and commonly used in rural and even in urban areas (Choge and Pasiecznik, 2005). This issue was clearly stated in a policy brief produced in 2005 (Choge and Pasiecznik, 2005) and may have already led to some change in the perception of the issue, supported by continuous lobbying from KEFRI and other groups. The Ministry of Environment and Natural Resources has now submitted a Cabinet Memorandum for discussion by parliament, with a request for an immediate but restricted lifting of the ban, to allow the production and sale of charcoal from *Prosopis* areas, i.e. where *Prosopis* is causing problems through its invasiveness.

In two cases, this ban was lifted on a special trial basis. Around Garissa, 240 ha of government land infested with *Prosopis* was leased via the Forestry Department with permission to exploit and sell charcoal. The use of improved ‘Casamance kilns’ was promising, with up to 49% recovery in three days. Land was cleared but stumps were left, and were only removed when incentives were provided, such as the provision of seedlings of improved mango varieties. The biggest success of the project was in starting-up trade, but the project failed to establish and develop a solid market for charcoal in the district. The price for charcoal is Ksh120-140 (approximately US$2) per 25 kg bag.

In Baringo, a similar scheme was established as part of the FAO pilot project. However, there was little uptake of charcoal making in the area which was generally believed to be because the local people are pastoralists and would not change the activities of their ancestry. Thus, although some entrepreneurs have begun to produce and sell charcoal and have witnessed an improvement in their livelihood, this is making an insignificant impact on *Prosopis* invasions. There may be scope for leasing government land in the region to people from outside the area in an attempt to reduce tree density. As in India, however, removal of the roots must be a
stipulation of any leasing agreement with charcoal makers, or otherwise resprouting will lead to tree densities equal or worse than before, within only a year after cutting.

**USING PROSOPIS FOR HUMAN CONSUMPTION**

Although food products made from *Prosopis* flour are consumed in the native range in South and Central America, this indigenous knowledge has not followed *Prosopis* trees across the Atlantic and the fruit are unused or provide only fodder for livestock. Pasiecznik (2002) argues that in Central and South America, many rural economies rely heavily on native *Prosopis* to supply a trade in processed products.

Before January 2006, *Prosopis* pods were occasionally sucked and chewed by children, but producing and consuming food using milled *Prosopis* pod flour was unheard of in Kenya. This changed in 2006 in areas where the project has worked, though further training, demonstration and extension is still needed, also developing and adapting methods for reducing risks of negative health effects.

During the training course run in Marigat, Baringo in February 2006, a strong demand was shown by local beneficiaries for experience in food uses. Maize and wheat flour were most commonly used, occasionally millet flour. Wheat flour was used for chapatis, pancakes, mandazi and cakes, and maize flour for the traditional ugali and uji. For mandazi, participants noted, a proportion of the wheat flour could be substituted with maize flour, being cheaper, to reduce the cost with no real effect on taste. This was used as an example of how *Prosopis* flour could and should be used, as a low cost and nutritious substitute for up to one fifth of the flour in any of the previously described foods. A large sack of flour had already been prepared using a tractor powered hammer mill given as part of the FAO project. The participants, however, felt this flour was too coarse, and it was then sent to a ‘posho mill’, a type of mill found in every village, privately-owned for hire, to mill locally purchased grains. Milling the pods, not just to release the protein in the seed, but also to prevent further spread of the seeds as a weed, was very much a new concept to the participants, and this knowledge may have large impacts as the tree and pods are adaptively managed in the future.
The quality of the flour for chapatti making was found to be greatly improved by sieving to remove coarseness. The group went into production with minimal trainer input, making chapatis at different mix ratios, pancakes, mandazi, ugali, uji and cake, and they were entirely proactive in the new recipes. Participants also experimented with other uses including roasting the flour to make a form of coffee substitute and making a *Prosopis* cake.

The general consensus was that the best ratio was 20% *Prosopis* flour mixed with other flours. The most acceptable proportions in a mix depend on what it is being used for, as due to its very low starch content it is less suitable for bread making. Other previous work on cooking with *Prosopis* flour (Cruz, 1986) showed that bread containing up to 5% *Prosopis* flour was acceptable whereas biscuits could contain up to 25%. Hand ground flour with the seeds and capsules removed was not popular as it was considered to be too bitter. Including the seeds increases protein content and reduces bitterness.

There were also discussions on how to take this knowledge forward, by making *Prosopis* foods for other events such as weddings, church gatherings and women’s group meetings. A ‘recipe book’ produced after the Baringo training (Choge et al., 2006) was also in great demand. Further outreach and training is needed to take this to the more drought-hit districts of Turkana, Mandera and Wajir.

The fruit produced by *Prosopis* is high in sugars, carbohydrates and protein. Pods from species of section Algarobia, which includes the common weedy species in Africa, contain 7-22% protein, 30-75% carbohydrates, 11-35% crude fibre, 1-6% fat and 3-6% ash (e.g. Oduol et al., 1986; Galera et al., 1992; Anttila et al., 1993). Care should be taken in interpreting food value data for *Prosopis* from the literature as these may be given for whole pods, for only the pulp (mesocarp) or seed
fractions. The proximate analyses of whole pods from *P. juliflora* and *P. pallida* from many parts of the world are given in Pasiecznik *et al.*, 2001).

The main soluble component of the pulp of *P. pallida* is sucrose (46%), representing over 90% of total soluble sugars, while the reducing sugars, glucose, fructose and xylose, are present in very small amounts (Cruz *et al.*, 1987; Sáenz *et al.*, 1987).

Dietary fibre represents 30% of the pulp and is largely insoluble. More than half of the fibre fraction consists of neutral polysaccharides (Bravo *et al.*, 1994). High iron levels have been reported in *P. juliflora* from Ecuador and Brazil (Figueiredo, 1975; Marangoni and Alli, 1988) but no figures for its bio-availability are given. The vitamins C, B6 and calcium pantothenate are present in significant amounts in pulp from *P. pallida* pods (Grados and Cruz, 1996).

The fat content of pulp is low, but is reported to be 7% in *P. pallida* seed cotyledons (Jiménez and Vergara 1977) with the major fatty acids found in extracted oil being linoleic acid (39%), oleic acid (29%), palmitic acid (13%) and stearic acid (10%). Similar values have been reported for *P. juliflora* (Marangoni and Alli, 1988).

Table 1 shows the composition of flour from whole *P. juliflora* pods produced in the course of the present study. This confirms the product as a high protein, high sugar material of considerable human food value.

<table>
<thead>
<tr>
<th>Component</th>
<th>Value (g/100 g dry matter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein (g)</td>
<td>16.2</td>
</tr>
<tr>
<td>Total sugars (g)</td>
<td>13.0</td>
</tr>
<tr>
<td>Fructose (g)</td>
<td>3.2</td>
</tr>
<tr>
<td>Glucose (g)</td>
<td>0.8</td>
</tr>
<tr>
<td>Galactose (g)</td>
<td>0.8</td>
</tr>
<tr>
<td>Sucrose (g)</td>
<td>7.5</td>
</tr>
<tr>
<td>Maltose (g)</td>
<td>&lt;0.4</td>
</tr>
<tr>
<td>Lactose (g)</td>
<td>0.7</td>
</tr>
<tr>
<td>Carbohydrate (g)</td>
<td>69.2</td>
</tr>
<tr>
<td>Energy value (kJ)</td>
<td>1530</td>
</tr>
<tr>
<td>Dietary fibre (g)</td>
<td>47.8</td>
</tr>
<tr>
<td>Fat (g)</td>
<td>2.12</td>
</tr>
<tr>
<td>Monosaturated fatty acids (g)</td>
<td>0.4</td>
</tr>
<tr>
<td>Polysaturated fatty acids (g)</td>
<td>1.06</td>
</tr>
<tr>
<td>Saturated fatty acids (g)</td>
<td>0.56</td>
</tr>
<tr>
<td>Sodium (mg)</td>
<td>20</td>
</tr>
<tr>
<td>Ash (g)</td>
<td>6.0</td>
</tr>
<tr>
<td>Total solids (g)</td>
<td>93.5</td>
</tr>
</tbody>
</table>

Table 2 shows an analysis of amino acid content of a flour sample taken from the Baringo district. In common with previous data (Cruz *et al.*, 1987), this confirms that in the flour nearly all the essential amino acids are present in amounts which fulfil the requirements of the FAO/WHO 'standard protein', thus indicating an
acceptable nutritional quality of the protein. Methionine and cysteine are the limiting amino acids. It is much higher in lysine than wheat flour making it particularly suitable for vegetarians who often lack this amino acid. Medical studies also show it to release sugars into the blood much more slowly than wheat flour, typically taking 4-6 hours rather than 1-2 hours which make it particularly suitable for diabetics (Bakewell-Stone, 2006).

Table 2. Amino Acid content. Analysis after hydrolysis 24 h at 110°C

<table>
<thead>
<tr>
<th>Amino Acid</th>
<th>Content (g/100g dry matter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cysteic acid</td>
<td>0.00</td>
</tr>
<tr>
<td>Aspartic acid</td>
<td>1.99</td>
</tr>
<tr>
<td>Threonine</td>
<td>0.42</td>
</tr>
<tr>
<td>Serine</td>
<td>0.62</td>
</tr>
<tr>
<td>Glutamic acid</td>
<td>1.43</td>
</tr>
<tr>
<td>Proline</td>
<td>1.22</td>
</tr>
<tr>
<td>Glycine</td>
<td>0.41</td>
</tr>
<tr>
<td>Alanine</td>
<td>0.47</td>
</tr>
<tr>
<td>Cystine</td>
<td>0.07</td>
</tr>
<tr>
<td>Valine</td>
<td>0.54</td>
</tr>
<tr>
<td>Methionine</td>
<td>0.08</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>0.34</td>
</tr>
<tr>
<td>Leucine</td>
<td>0.82</td>
</tr>
<tr>
<td>Tyrosine</td>
<td>0.18</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>0.38</td>
</tr>
<tr>
<td>Histidine</td>
<td>0.32</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>0.00</td>
</tr>
<tr>
<td>Lysine</td>
<td>0.47</td>
</tr>
<tr>
<td>Arginine</td>
<td>0.76</td>
</tr>
</tbody>
</table>

Clearly, if Prosopis is to be adopted as a human food in Kenya, as is already the case in South America, then it is also necessary to test the product for microbial contamination, mycotoxins and antinutritional factors. A sample of flour from Kenya was tested by Leatherhead Food International, Leatherhead, UK, and results were 38 ppb Ochratoxin A, 4.7 ppb for Aflatoxin B1 and 5.8 ppb total aflatoxin. The levels of total aflatoxin and Aflatoxin B1 exceed the stringent EU maximum levels for cereals of 5 and 3 ppb, respectively, but not the maximum levels adopted in the USA (10 ppb), Brazil (20 ppb) or India (30 ppb) (FAO, 2004). The Ochratoxin A level in Prosopis flour exceeded the maximum level of 5 ppb that has been proposed as an international standard by CODEX for Ochratoxin A in wheat, barley, rye and their derived products (USFDA, 2003).

However, only one Kenyan Prosopis flour sample has been analysed so far and this had been produced from pods harvested in the wild and stored for several months. Far higher levels of Ochratoxin A are occasionally found in samples, included in European grain samples, when harvest, drying and storage conditions favour fungal growth and toxin production (Jørgensen et al., 1996; Elmholt and Rasmussen, 2005). Similarly, significant levels of aflatoxin in common food products have been routinely reported in West Africa (Bankole and Adebambo, 2003).
and East Africa (Kaaya and Warren, 2005). In Uganda, 29.6% of common food samples analysed tested positive for aflatoxin and approximately 12% exceeded 100 ppm total aflatoxin (Kaaya and Warren, 2005). Nevertheless, these results are of sufficient concern to warrant further study to determine toxin levels in freshly harvested pods, and in pods and flour after various periods of storage, and to develop appropriate harvesting and storage methods to minimise risk to human health. Among steps that may be necessary are early harvest, thorough drying and control of moisture levels during storage, discarding infested seeds, control of insect infestation and avoidance of carry over of inoculum in storage facilities.

Appropriate methods can be found in the traditional and improved storage methods used in South America where Prosopis originated. Traditional pod stores in North America tend to consist of large baskets made from natural fibres, with a rain-proof roof, raised off the ground to prevent predation and to keep the pods dry (Felger, 1977). In Brazil, standard agricultural barns or special rooms with wooden floors and walls are used for storing other dried animal feeds (e.g. da Silva, 1996). In Peru, rustic closed rooms were used, made from mud bricks, but these have largely been replaced with built block buildings (Grados and Cruz, 1996). Special storage units for P. pallida pods are built, 5 x 5 x 4 m high, which are capable of storing 40 t of pods (Díaz Celis, 1995). In India, layers of dry pods are laid down alternately with layers of sand. This is said to increase storage time to three years. Periodic checking of the pods in the store is recommended to assess any damage due to fungal infections, high moisture content or pests. Removal of infected pods should be carried out immediately. In Peru, however, once a pod store is filled, it is sealed with clay and opened only when the whole batch is to be sold.

USE OF PROSOPIS AS ANIMAL FEED

Although the project concentrated on the use of Prosopis as a human food and for timber use, there is considerable scope for the use of pods as an animal feed. Ripe pods are highly palatable with a moderate level of digestible protein and high energy content (Yadav et al., 2004; Mahgoub et al., 2005). Initial feasibility studies (Pasiecznik et al., 2006) suggest that there is a ready market in the region of at least 300 t/month. This could potentially bring in £86,400 a year into some of the most marginal communities and remove 70 billion seeds from the district, thus also having a significant impact on the spread of the weed.

Despite this potential, there are still barriers to overcome before this can be taken up on a scale that has a significant impact. Firstly, it appears that local collection and milling for zero grazing does not comply well with traditional extensive grazing of livestock by pastoral groups who are unwilling to collect and mill what they see as forage and not fodder. There are also some concerns about the impact of feeding Prosopis pods to livestock with one study claiming a small proportion of cattle becoming ill when fed pods (Alder, 1949) and another claiming neurological damage (Tabosa, 2006). However many of the concerns have been stirred up in newspaper reports culminating in the presentation of a toothless goat in a court in Nairobi to demonstrate its ill effects (East African Standard, 30 September 2006). Lastly, there have been reports in the Kenyan press of farmers
(East African Standard, 3 April 2007) being dissatisfied with the price they were receiving for the pods in relation to the amount of time it took them to gather them.

CONCLUSIONS

It is widely acknowledged that Prosopis has caused many problems due to poorly managed introductions. Most eradication attempts have proved unsuccessful and it is generally becoming accepted that control through utilisation is a more feasible course of action. With invasive species, the most appropriate methods of control may be found in the place where it originally comes from, and looking at ways in which it is used in its native Americas, where it is generally less of a problem, has generated a number of ways the plant can be exploited. These were demonstrated in Baringo district and follow up visits have confirmed that these techniques have been taken up into the community by spontaneous diffusion. So far, use of timber and human food has received the most attention, however, there is also great potential for use as a cattle feed, although some barriers need to be overcome to establish this.

At present the market for products is still in its infancy, but has shown some movement in the last year with six timber companies in Nairobi interested in seeing wood samples and a feed company putting in an order for 8 tonnes of pods. Further initiatives need to be put in place to establish marketing channels and supply chains for the products to maximise its exploitation potential.

Meanwhile Prosopis is still a topic of debate in the Kenyan press and articles highlighting both the positive and negative virtues of the plant continue to be published. It is not clear whether these case studies will provide sufficient evidence of the benefit that can be brought to communities to turn around a large body of people still calling for its complete eradication.

Acknowledgements

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http://chainsaw.gwork.org/.


