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working paper

USE OF LESSER-KNOWN PLANTS AND PLANT PARTS AS ANIMAL FEED RESOURCES IN TROPICAL REGIONS

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USE OF LESSER-KNOWN PLANTS AND PLANT PARTS AS ANIMAL FEED RESOURCES IN TROPICAL REGIONS

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Preface

Around 2.6 billion people in the developing world are estimated to have to make a living on less than US$2 a day and of these, about 1.4 billion are 'extremely' poor; surviving on less than US$1.25 a day. Nearly three quarters of the extremely poor – that is around 1 billion people – live in rural areas and, despite growing urbanization, more than half of the 'dollar-poor' will reside in rural areas until about 2035. Most rural households depend on agriculture as part of their livelihood and livestock commonly form an integral part of their production system. On the other hand, to a large extent driven by increasing per capita incomes, the livestock sector has become one of the fastest developing agricultural sub-sectors, exerting substantial pressure on natural resources as well as on traditional production (and marketing) practices.

In the face of these opposing forces, guiding livestock sector development on a pathway that balances the interests of low and high income households and regions as well as the interest of current and future generations poses a tremendous challenge to policymakers and development practioners. Furthermore, technologies are rapidly changing while at the same time countries are engaging in institutional 'experiments' through planned and un-planned restructuring of their livestock and related industries, making it difficult for anyone to keep abreast with current realities.

This 'Working Paper' Series pulls together into a single series different strands of work on the wide range of topics covered by the Animal Production and Health Division with the aim of providing 'fresh' information on developments in various regions of the globe, some of which is hoped may contribute to foster sustainable and equitable livestock sector development.

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Executive Summary

A study was conducted to harvest indigenous knowledge on feed resources with the aim to enlarge feed resource base by identifying alternative and lesser-known feeds. For sustainable intensification of animal production, the use of such feed materials is of great importance mainly for three reasons: the global demand for grains being higher than the global grain production, stiff competition between man and livestock for the existing food and feed resources, and the need for feeds that are adapted to harsh environmental conditions due to the ongoing climate change. The study identified 20 plants which are available in harsh environment conditions of the tropics and sub-tropics, palatable to animals, fed by farmers and contain crude protein levels higher than some commonly used ruminant feeds. Other nutritional and medicinal attributes reported by the respondents are also discussed in this paper. The cultivation, use and promotion of such under-utilized plants, available in harsh environment conditions, will enhance plant biodiversity and also increase animal productivity in challenging situations of high temperature, water scarcity and soil degradation being increasingly inflicted by the ongoing climate change.

Introduction

Livestock production occupies approximately 30% of global arable land (FAO, 2008a). With fast depletion of natural resources, ever-increasing population pressure and rising living standards, it has become extremely important to diversify the present-day animal agriculture to meet increasing demand for animal products. From 2000 to 2020, the global meat and milk consumption is expected to rise from 233 to 300 million tonnes and from 568 to 700 million tonnes, respectively. Egg production will also increase by 30%. An area of livestock production that calls for critical examination is the availability of feed resources. The global production of cottonseed, rapeseed, soybean meal and sunflower seed in 2009–2010 were 13, 34, 165, 13 million tonnes, respectively (USDA, 2011). These oil seeds are the main sources of protein-rich meals used in the manufacture of both compound animal feeds and homemade concentrate mixes. There has also been a relatively high rate of usage of these meals in compound animal feeds with consumption very close to production at 14, 34, 161, and 12 million tonnes, respectively (USDA, 2011).

The interest in search for alternative/additional food and feed ingredients is of paramount importance mainly because of the global demand for grains which has exceeded the production and stiff competition between man and the livestock industry for existing food and feed materials (McCalla, 2009). In addition, depletion of soil quality, lack of water and climate change continues to affect productivity of crop and forage plants, impacting adversely the animal productivity (Pearson and Langridge, 2008). With 20% of all cultivated areas, 30% of forests and 10% of grasslands presently undergoing degradation, a quarter of the world's population is sustained by production on degraded soils (FAO, 2008b). A challenge therefore for animal nutrition scientists is to introduce and promote alternative feed resources that have high nutritive value and are adapted to harsh environmental conditions. The on-going climate change is also expected to create harsher conditions: high temperature, droughts, floods and drastic climatic variations, with the greatest impact to be felt among 'subsistence' or 'small holder' farmers in developing countries (Morton, 2007). Wild under-utilized plant resources must therefore receive more attention (Sansoucy, 1994).

Currently the commonly grown trees and shrub legumes that have gained wide acceptance by farmers were lesser-known about 30–50 years back (Shelton and Brewbaker, 1994). Such forages and shrub trees include *Gliricidia sepium, Calliandra calothyrsus, Sesbania sesban* and *Sesbania grandiflora,* and many species of *Desmodium* (including *Codariocalyx*). *Leucaena* has received the most attention as animal feed and has been cultivated over large areas of the tropics (Devendera, 1986; Devendra, 1993; Moog, 1998). The same is true about soybean meal, rapeseed meal and many other feed resources that were lesser-known or unconventional some decades ago.

There are a number of other lesser-known and under-utilized plants adapted to local, harsh conditions available today that have tremendous potential as livestock feed. The neglect of potentially excellent animal feed resources also results in loss of plant biodiversity. In the last over five decades, over 75% plants have become extinct (FAO, 2010), largely because these were not being utilized. In lieu of this, the cultivation and judicious use of such plants as feed resources is expected to enhance plant biodiversity. Thus, there is a need to identify such potential feed resources and use them to conserve biodiversity.

The aim of this study was to identify lesser-known, alternative feed resources that have potential to enhance animal productivity. The chemical composition of plants/plant parts used, their palatability and medicinal value to animals are reported in this paper.

Methods

This study involved the use of a questionnaire (See Annex). From the FAO database, 832 individuals including animal nutritionists, university professors, laboratory technicians, extension workers and animal science professionals were sent a questionnaire meant to gather the *in vitro* and *in vivo* nutritive value, environmental adaptability, as well as other relevant information on the use of lesser-known plants as animal feed. The lesser-known feed resources, as identified by the respondents, were subjected to an arbitrary screening process. The popular databases such as Scopus, Science Direct, Google Scholar, Elsevier, EBSCOhost and Agricola were screened for the identified lesser-known feed resources through the questionnaire, and only those with less than ten hits with respect to their feeding value have been presented in this publication. The plants identified through this study may also be considered as lesser studied. Total number of filled questionnaires was forty, but only 20 were selected since the remainders did not contain adequate information with regards to the plant's nutritive value as an under-utilized plant. Respondents and their email addresses have been listed as the data sources in Table 1.

Feed resources were categorized as 'very good', 'good' and 'fair' based on their crude protein (CP) content provided by the respondents. Feed resources containing CP content ≥16% were designated as 'very good', while those containing between 8 and 16% were designated as 'good', and those assigned 'fair' had CP content ≤ 8%.

Results and Discussion

Currently one billion people worldwide live in a state of hunger. Of these between 700 and 800 million live in developing countries in the tropical and subtropical regions and approximately 70% of these are smallholder farmers. According to FAO's state of the world's resources, based on the two most dominant development paths (industrialization or agriculture), it is likely that there would be substantial losses in natural resources in most developing countries in the next two decades (FAO, 2009). This implies further increase in scarcity of feed resources.

Lesser-known crops are under-utilized species, characterized by local consumption and production system and high adaptation to agro-ecological nichés and marginal areas, and are usually harvested in the wild. Other features include fragile or non-existent seed supply systems, representation by ecotypes or landraces and often not well represented in *ex situ* gene banks (Biodiversity International, 2011). The key constraint that needs to be overcome for effective utilization of such lesser-known plants is the lack of biological, nutritive and to some extent, medicinal value of such plants (Hackett, 1991; Kala, 2005).

Table 1 presents information on scientific and common names of some lesser-known plants, their distribution and climatic and edaphic conditions for their growth. Three factors related to climate change were to be considered by survey respondents to determine suitability of such lesser-known plants in these regions. The factors were soil degradation, temperature and precipitation. Global soil degradation is on the increase, especially in the countries within the tropics. According to FAO, in Africa alone 6.3 million hectares of degraded farmland have lost their fertility and need to be regenerated to meet the food demand of a population set to more than double by 2050 (FAO, 2011). The lesser-known plants reported in this survey thrive on soils such as alluvial, sandy poorly drained, porous limestone, dry whereas others are adapted to saline and acidic soils. Situated mostly in tropical and subtropical countries, these plants will play a two-fold role. In addition to providing feed resources from plants adapted to low quality soils, leguminous plants such as *Psophocarpus scandens* will aid in improving soil fertility through nitrogen fixing, and also make the farming systems more sustainable by reducing the energy costs associated with fertilizer production and application. Mismanagement of arable areas by farmers and grazing areas by livestock owners is one of the major causes of soil degradation in tropical areas. Thus, introduction and promotion of such leguminous plants will have tremendous benefits in such regions. The negative impacts of climate change are worsened by decreased rainfall, increased surface temperature and increased CO_2 and CH_4. Deforestation is one of the causes of the negative impacts of climate change. Afforestation will therefore likely decrease the effects of floods and drought, nutrient cycling and erosion (Daily *et al*., 1997, Millennium Ecosystem Assessment 2005). The average annual temperature in Africa is 26.7 °C. In East and South East Asia, the daily temperature range is 10–25 °C. The Intergovernmental Panel on Climate Change (IPCC) forth assessment report indicates that past and present climate trends in Asia predict surface temperature increase between 1–4 °C over a century (Gruza and Rankova, 2004). The duration

Table 1. Distribution of some lesser-known plants and agro-climatic conditions for their growth

Scientific name	Common name	Distribution	Season of harvest	Average Temp. (°C)	Precipitation (mm)	Soil type
Feed resources containing ≥16% crude protein						
[1]*Psophocarpus scandens*	Kikal kasa	Tropical Africa at lower altitudes	May to September	25	1200–1800	Adapted to alluvial and sandy soils
[2]*Urtica angustifolia*	Nariin navhit khalgai	East Asia, mainly China, Japan, Korea.	June to August	20–26	800–2200	Thrives on alluvial and sandy soils
[3]*Urtica dioica*	Stinging nettle, common nettle	North America, Europe and much of Asia and North Africa	June to September	15–25	670–2000	Grows in light (sandy), medium (loamy) and hard (clay) soil
[4]*Sesbania grandiflora*	Ye-thagyi	West Africa and Tropical Asia including, India, Indonesia and Malaysia	November to June	22–30	800–2200	Well adapted to alkaline, poorly drained, saline, heavy clay soils
[5]*Colocasia esculenta*	Taro	Most parts of Africa, Asia and Europe		20–30	2500	Grows in deep, moist or even swampy soils alluvial loams with high water-table
[6]*Alysicarpus vaginalis*	Alyce clover	Humid, sub-humid tropical and sub-tropical lowlands of West Africa and East Asia	December to June	20–30	900–2000	Grows on coralline sands to moderately acid clays. It has low salinity tolerance
[7]*Bromus auleticus*	Cevadilha vacariana	South America, mainly southern Brazil, Uruguay and Argentina	An evergreen plant; green in spring, summer, autumn, winter	18	385–1340	Located in clay loam with an accentuated drainage
[8]*Pithecellobium dulce*	Thinbaw-Magyi	South America, Asia and Africa	April to September	18 –28	400–1650	Thrives on most soil types, including clay, limestone, and sands. It also has tolerance of heat, salinity, and impoverished soils
[9]*Enterolobium cyclocarpum*	Parota	Found in South America	April to September	23–28	750–2500	
Feed resources containing >8 and <16% crude protein						
[10]*Paspalum dilatatum*	Dallisgrass	South America, Subtropics of USA, Australia, and Africa	Paspalum is a summer-active perennial grass native	20–35	900–1300	Grows best on deep, moist, fertile, sandy loams and clays usually of alluvial or basaltic origin.
[11]*Desmodium heterocarpon*	Desmodium	Mainland China, India, Sri Lanka through Myanmar, Thailand, Malaysia, Philippines, Indonesia and the Pacific Islands	June to August or September	20–30	1200–4500	Well adapted to low fertility and acid soils

cont.

Table 1. *Cont.d*

Scientific name	Common name	Distribution	Season of harvest	Average Temp. (°C)	Precipitation (mm)	Soil type
[12]*Adesmia latifolia*	Babosas	Southern Brazil, Eastern Argentina and Uruguay	June to September	20–28	500–900	Growns on flooded soils, marshes with pH 6-7; not common on drier areas
[13]*Paspalum plicatulum*	Capim coqueirinho	South America and Central America	May to September	17–27	1200–1500	Grows on a wide range of soils from poor to well-drained sands to clays
[14]*Dalbergia Sisso*	Kala-padauck	Himalayas of India, Pakistan and Nepal	Harvested during long dry seasons	10–40	500–2000	Adapted to pure sand and gravel to rich alluvium of riverbanks. It can also grow in slightly saline soils
[15]*Iris lactea*	Khos khairst tsahildag	Southern Africa and South America, Europe and temperate parts of Asia	Harvested during the summer	10–25	240–1142	Grows in sandy loamy soil
[16]*Festuca dolichophylla*	Chillihua, Qoya	South America:	Perennial plant that matures in the spring	10–22	285–1134	Adapted to well drained, moist to dry soil
[17]*Hemarthria compressa*	Whip grass	Asia and most of Africa	It can withstand short, seasonal dry periods, but does not tolerate long droughts	31–35	600–1500	Thrives on soils of any texture, providing moisture is adequate. It tolerates acid soils down
[18]*Cistus Ladanifer*	Esteva (Portugal), Xara (Spanish), Rock-rose (English)	Southern France, the Iberian Peninsula and in northern Africa (Morocco and Algeria)	May/June to August	12–25	400–1500	Adapted to dry soils in warm open areas
Feed resources containing ≤ 8% crude protein						
[19]*Agave salmiana*	Maguey or Agave	India, South east Asia, Pacific Island and Australia	Agave are perennial evergreen xerophytes	13–26	250–1270	Tolerates well-drained as well as shallow limestone soil
[20]*Achnatherum splendens*	Tsagaan ders	Found in China	June to August or September	10–25	366–2500	Adapted to slightly alkaline as well as sandy soil with high levels of salinity

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of heat waves in many Asian, African and even temperate countries are becoming significantly longer (Cruz *et al.*, 2007; Tran *et al.*, 2005). The 1–4 °C projected rise in surface temperature in these regions is predicted to result in the extinction of many flora or fauna (Fischlin *et al.*, 2007). The introduction/cultivation of trees and shrubs need to be encouraged, especially with choice of plants that will suit such environments. The lesser-known plants reported here are adapted to temperature range of 10–35 °C, can grow in a wide range of precipitation (Table 1) and many of which are already thriving in these regions. The frequency and intensity of rainfall in many parts has increased, causing an increase in the number and severity of floods; the number of rainy days has actually decreased along with the total amount of precipitation (Gruza and Rankova, 2004). An increase in the occurrence of dry weather is therefore projected for South Asia, East Asia and South East Asia (Walsh, 2004). Due to such uncertainty, adaptation measures need to be diverse, flexible and robust (Locatelli *et al.*, 2008). Traditional or indigenous knowledge of lesser-known plants are particularly relevant to climate change adaption. The use of plants identified in this study therefore has a significant role in the changing scenarios driven largely by ongoing climate change.

Table 2 presents common names of some lesser-known plants, their nutritive value (categorized with respect to CP content) and some medicinal uses. In the tropical and subtropical areas of the world where animals are fed on low quality feeds, protein becomes the most limiting and expensive nutrient in animal agriculture (Mohamed-Saleem and Kaufmann, 1991). Temperate forages tend to contain higher CP levels than warm season forages (Lin *et al.*, 2001). In addition, CP concentration decreases with forage maturity and with decrease in nitrogen fertilization, which is often the case in the tropics (Graham and Vance, 2003).

Adequate amounts of protein and energy are required to properly balance forage based diets for ruminants (Leng, 1991). This is especially true when low quality forages form majority of the diet, as is often the case during seasons of low rainfall, drought or in environments with degraded soils (Rutagwenda *et al.*, 1990; Moss and Goodchild, 1992; Ball *et al.*, 2001). The level of CP is known to influence intake of forages, and therefore for optimum rumen function presence of adequate amount of protein in the diet is a must (Lazzarini *et al.*, 2009). Voluntary feed intake declines in forages containing less than 7% CP (NRC, 2000). This underscores the critical nature of protein in ruminant diets. Signs of protein deficiency include lowered appetite, weight loss, poor growth, depressed reproduction and performance and reduced milk production (Ball *et al.*, 2001; FAO, 2004). Based on a minimum CP of 15-18% for adequate growth in ruminants, this study considers forages containing CP ≥16% as very good, >8 and <16% as good and ≤8% as fair. Table 3 shows crude protein content of plants and grains commonly used as protein sources in animal feeds.

Table 2. Chemical composition and nutritive value of some lesser-known plants or their parts (processed and unprocessed) used as animal feed

Scientific name	Plant Part Used	Plants parts consumed by humans	Chemical Composition (%)							NV[a]	In vivo results	Other relevant information
			CP	NDF	ADF	ADL	Ash	Ca	P			
[1]*Psophocarpus scandens*	Leaf	Leaves and seeds	28–30	33–40	22–23	-	10–15	1.5	04	IVDMD[b] 50% IVCPD[c] 73% (for monogastrics; pig model)		Leaves are known to promote milk production in lactating women (glactogogue). Not cultivated but collected from the wild by consumers
[2]Urtica Angustifolia Fisch	Leaf	Leaves	28	20	20	8	20	-	-		The leaves are fed to cattle, sheep and goats at all physiological stages. Farmers grade this plant as 'excellent' and no negative reactions have been observed by farmers	The leaves are used for nursing weakened animals
[3]*Urtica dioica*	Tender leaves and young shoots	Tender leaves and young shoots	25	-	-	-	-	-	-	Urtica leaves are rich in Vit A, Vit C, Fe, K, Mg, Ca They also contain flavanoid glycosides, lignin glycosides, sitosterols, formic acid, histamine, and acetyl choline	The plant is fed to cattle and buffalo	Young shoots are used for treatment of rheumatism, arthritis, anemia, hay fever, kidney problems, pain, sprains and swelling, human prostate cancer, and excess menstrual blood flow. Roots and seeds are used in treatment of diarrohea and intestinal worms. Leafy and young shoots are used in dishes such as soup, curries and 'parathas' (stuffed bread)

cont.

Table 2. *Cont.d*

Scientific name	Plant Part Used	Plants parts consumed by humans	Chemical Composition (%)							NV[a]	In vivo results	Other relevant information
			CP	NDF	ADF	ADL	Ash	Ca	P			
[4]*Sesbania grandiflora*	Leaf	Flowers	25	-	-	-	-	-	-		The plant is fed to cattle at all physiological stages.	
[5]*Colocasia esculenta*	Leaf and roots	Pods	20–25	9	-	-	7–9	-	-		Leaves and pods are fed to pigs at all physiological stages	
[6]*Alysicarpus vaginalis*	Leaf	None	18–23	43–61	33–46	6	15	-	-	Sheep Study Digestible DM was 36–49% DM degradation expressed as effective rumen degradability was 51.3% (in cattle) The protein degradation expressed as ruminal degradable nitrogen was 63% (in cattle)	Leaves are fed to cattle, sheep and goats; only adult animals	
[7]*Bromus auleticus*	Leaf	Seeds	16–25	61–65	25–31	-	-	-			Leaves are fed to cattle, sheep and goats; at all physiological stages.	

cont.

Table 2. *Cont.d*

Scientific name	Plant Part Used	Plants parts consumed by humans	Chemical Composition (%)							NV[a]	In vivo results	Other relevant information
			CP	NDF	ADF	ADL	Ash	Ca	P			
[8]*Pithecellobium dulce*	Pods		21 (VG)	-	-	-	-	-	-		Pods are fed to cattle, sheep and Goats; only adults	
[9]*Enterolobium cyclocarpum*	Pods	Seeds	15–16	34–35	-	-	-	-	-	Rumen OM and DM digestibility: 86% and 71%, respectively. Good growth performance (239 g/sheep/d) when ground pods are incorporated at 50% of ration DM in sheep	Pods are fed to cattle, sheep and goats but preferred by young and pregnant animals. Farmers grade it as a 'fair' animal feed resource	Saponin content reduces protozoa in the rumen, probably leading to a reduction in methane production in the rumen
[10]*Paspalum dilatatum*	Leaf	Seeds	15	65–68	42–44	-	-	-	-		Leaves are fed to cattle, sheep and goats; at all physiological stages	
[11]*Desmodium heterocarpon*	Leaf	None	12–15	41–56	31–49	-	-	0.09–0.13	0.03	DM digestibility (in sacco): 41–44%	Leaves are fed to cattle, sheep and goats; only adults	
[12]*Adesmia latifolia*	Leaf	Seeds	11–24	-	-	-	-	-	-		Leaves are fed to cattle, sheep and goats; at all physiological stages	

cont

Table 2. *Cont.d*

Scientific name	Plant Part Used	Plants parts consumed by humans	Chemical Composition (%)							NV[a]	In vivo results	Other relevant information
			CP	NDF	ADF	ADL	Ash	Ca	P			
[13]*Paspalum plicatulum*	Leaf	Seeds	11–22	55–66	39–46	-	-	-	-		Leaves are fed to cattle, sheep and goats; at all physiological stages	
[14]*Dalbergia Sisso*	Leaf	None	14	-	-	-	-	-	-		Leaves are fed to cattle, sheep and goats at all physiological stages	
[15]*Iris lactea*	Leaf	Seeds	10	50	44	-	-	-	-		Leaves are fed to cattle. Camel consume leaf and stem. These are also consumed by sheep, goats, at all physiological stages. Farmers grade this plant as a 'fair' feed resource	Leaves are used as anti-bacterial, treatment of wounds originated from thermal burn. Roots, seeds and flowers are used in the treatment of pneumonia, bronchitis, chronic gastric and anthelmintic purposes. In Japanese traditional medicine seeds are used for treating swellings and snake bite wounds, and roots for temperature reduction
[16]*Festuca dolichophylla*	Seeds and Leaf	None	8–12	-	-	-	-	-	-		Seeds and leaves are fed to cattle, sheep and goats at all physiological stages. Farmers consider it as a 'very good' feed resource	

cont

Table 2. *Cont.d*

Scientific name	Plant Part Used	Plants parts consumed by humans	Chemical Composition (%)							NV[a]	In vivo results	Other relevant information
			CP	NDF	ADF	ADL	Ash	Ca	P			
[17]*Hemarthria compressa*	Leaf	None	8–13	69–72	35–37	4–6	7–9	-	-		Leaves are fed to cattle, sheep and goats; only adults. Farmers consider this a fair feed resource.	
[18]*Cistus Ladanifer*	Seeds, leaf and soft stem	None	10	30	27	8	5	0.6	0.2	DM and OM digestibility: 36% and 31% respectively.	The plant is grazed mainly by goats and sheep. Rabbits also consume leaves	The leaves were used in ancient times to treat cold, cough, menstrual problems, diarrhoea, and rheumatism. They leaves were also known to be anti-septic, anti-infectious, anti-microbial, anti-viral, bactericidal, anti-inflammation, anti-arthritic , astringent and mucolytic. It is also used as a tonic for the nervous system
[19]*Agave salmiana*	Leaf	Yes; Stem	2–5	19–41	-	-	9–14	-	-		Leaves are fed to cattle; at all physiological stages. Farmers grade it as a 'good' animal feed.	
[20]*Achnatherum splendens*	Leaf	Yes; leaf	7	49	29	29	4	-	-		Leaves are fed to cattle, sheep and goats; at all physiological stages. Farmers grade this plant as a 'good' feed, and no negative reactions have been observed by farmers	

[a]NV: Nutritive Value; [b]IVDMD : *In Vitro* Dry Matter Digestibility.; [c]IVCPD: *In Vitro* Crude Protein Digestibility

CP: Crude Protein; NDF: Neutral Detergent fibre; ADF: Acid Detergent Fibre; ADL: Acid Detergent Lignin; DM: Dry Matter; OM: Organic Matter

Table 3. Crude protein (CP) content (% of DM) of common animal feeds

FORAGES		
Scientific name	**Common name**	**CP**
Panicum maximum	Tanganyika grass	6
Pannisetum purpureum	Napier grass	6
Gliricidia sepium	Gliricidia	22
Leucaenia leucocephala	Leucaena	24
Sesbania grandiflora	Sesbania	28
Medicago sativa	Alfafa	22
OIL SEED MEALS/ CAKE		
-	Cotton seed meal	36
-	Soybean meal	44
-	Sun flower cake	24

Source: Adapted from Mlay *et al*. (2006)

Soybean meal is considered an excellent protein source across the world since it contains 44–48% CP (NRC, 1994; AGRISTATS, 2009). It also has an excellent amino acid profile (Cromwell, 1999) and high digestibility of 75–85% (Loerch *et al*., 1983; Khorasani *et al.*, 1990). Another standard crop that could be used as a basis for comparison is alfalfa, which is known as the 'queen of forage crops' due to its highest feeding value amongst all cultivated perennial forage legumes (Russelle, 2001).

The CP content in the plants identified as lesser known in this study ranged from 2–30% (Table 2); categorized into three groups, namely 'very good', 'good' and 'fair'. Plants (part of plant) that were categorized as very good sources of protein include *Psophocarpus scandens* (leaf), *Colocasia esculenta* (leaf and tuber), *Urtica dioica* (tender leaves and young shoots) *Urtica angustifolia Fisch* (leaf), *Bromus auleticus* (leaf), *Adesmia latifolia* (leaf), *Sesbania grandiflora* (leaf), *Pithecellobium dulce* (pods) *and Alysicarpus vaginalis* (leaf). It can be deduced from the information provided by the respondents that very little or no processing of these feed resources is done before feeding. For instance, heat treatment is known to destroy trypsin inhibitors and gelatinize starch to improve nutrition and digestibility of oilseed meals (Hoffa *et al*., 1973; Anderson and Walter, 1995). Grinding reduces the particle size of feed, improves intake, and increases the surface area for enzyme hydrolysis (Svihus *et al*., 2004; Amerah and Ravindran, 2007). Thus, a possible reason for some plants such as *Enterolobium cyclocarpum* (pods) graded 'very good' based on CP and rated 'fair' by farmers could be due to lack of processing before their feeding and/or lower availability of CP present to the animal. Any negative impact of feeding all the above-mentioned plants was not reported. Farmers can therefore be encouraged to use these plants as animal feeds since their CP contents are comparable to cotton-seed meal, soybean meal and sun-flower cake. In addition to their high value in terms of CP content, they are adapted to tropical environments and most are highly palatable to cattle, sheep and goats at all physiological stages. The nutritive value of these feed sources is also comparable to the commonly used plant feeds such as *Leucaenia leucocephala* and *Sesbania gradiflora* leaves. Only *Pithecellobium dulce* (pods) *and Alysicarpus vaginalis* (leaf) are fed to adult ruminants while the rest can be fed to to animals at all physiological stages. The plants within the category rated as 'good', *Paspalum dilatatum* (seeds) has the highest CP of 15%, and *Hemarthria compressa* (leaf) contains 8%, which is the minimum. The average CP content of the plants under the 'good' category is 14%, indicating that these feed resources would be able to meet the minimum requirement of 15–18% needed for growth and development of ruminants. All these plants withstand adverse weather conditions and are palatable to cattle, sheep and goats at all physiological stages. Against the scenarios of ongoing global warming the use of plants as feed that are adapted to high temperatures, poor soils and droughts is the key to sustainability of animal agriculture.

Only two plants are categorized as 'fair': *Agave salmiana* (leaf) and *Achnatherum splendens* (leaf). As these plants have CP content very close to the minimum requirement of ruminants, they were not considered poor but 'fair'. These feed resources possess CP levels higher than in *Panicum maximum* and *Pannisetum purpureum*, which have approximately 6% CP. The maintenance requirement of animals can be met using these two feeds identified as 'fair' in this study.

Conclusions

Although there is a wider collection of genera that can be considered 'tropical trees and shrub legumes' (Hanson, 2010) only few have received much research attention for use as animal feed. It is concluded from the present study that many lesser-known plants with good nutritional values and high palatability are already in use in some pockets of the world; and if their use as animal feed is promoted, these would enhance animal productivity as well as contribute to conservation of plant biodiversity. Collaborative efforts among scientists and farmers must particularly be directed towards establishing and developing innovative feeding systems using high protein fodders from promising species of trees and shrubs that are adapted to harsh environmental conditions. The ultimate objective of the future research on lesser-known plants should be to: a) improve the availability of feed resources to provide an adequate strategic feed supplementation to animals during critical periods, b) increase biodiversity, and c) meet the challenges of on-going climate change. It is hoped that the information generated through this study would contribute to fulfilling these objectives.

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Annex. Questionnaire

Getting ready to meet the challenges of high temperature, water scarcity and soil degradation by using lesser-known plants adapted to harsh conditions

OBJECTIVE

To harvest indigenous knowledge on feed resources, leading to enlargement of feed resource base and increase in biodiversity

1. Country:

2. Location/ Region:

3. GPS data point (if available):

4. Minimum and maximum temperature of the location:

5. Average rainfall of the location:

6. Altitude:

PLANT ISSUES

(Please use a separate questionnaire sheets for each plant/plant part)

1. Common and botanical names of the plant/plant part used as feed by farmers:

   Common name:

   Botanical Name:

2. Type of plant:

a) Annual ☐ Biannual ☐ Perennial ☐

b) Tree ☐ Bush ☐ Herb ☐
   Creeper ☐ Others ....

3. Is the plant cultivated or does it grow in the wild? Approximate Size of area (hectares) on which plant grows in your country.

4. During which month(s) / season (s) is the plant cultivated?

5. During which month (season) it is harvested:

6. How long does it take for the plant to reach a stage for use as feed? After first cutting how long does it take to be cut again?

7. How many cuttings per year?

8. Method of propagation:

   Seed ☐ Leaf ☐ Stem ☐ Root ☐

9. Are the plants irrigated by artificial means?

10. Soil type on which the plant grows

    Alluvial ☐ Sandy ☐ Black Soil ☐
    Saline ☐ Saline Sodic ☐ Other: ....

11. What part of the plant is fed to animals?

    Seed ☐ Leaf ☐ Roots ☐ Pods ☐

12. In what state is this plant/plant part fed?

    Wet ☐ Dry ☐ Processed ☐

13. If processed, what kind (s) of processing?

14. Is this feed resource harvested and stored?
    If stored, how stored?

15. Is the chemical composition of the plant / plant part known?

    Yes ☐ No ☐

    If yes, please provide information on chemical composition (% in dry matter):

    Crude Protein (CP):
    Neutral Detergent Fibre (NDF) :
    Acid Detergent Fibre (ADF):
    Acid Detergent Lignin (ADL):
    Ash:
    Others:

16. Any available literature on the use of this plant in animal feeding?

    Author(s):
    Name of Journal / Report:

17. Has any in vitro or in vivo research been done on this plant/plant part?

    In vitro: Yes ☐ No ☐

    If yes, please provide in vitro results (also please give source of the information/reference):

    In vivo: Yes ☐ No ☐

    If yes, please provide main in vivo results (also please give source of the information/reference and the species of animal used for in vivo study):

18. Do humans eat any part of this plant?

    Yes ☐ No ☐

19. If yes, which part?

20. How do farmers grade this plant / plant part as a feed?

    Poor ☐ Fair ☐ Good ☐
    Very Good ☐ Excellent ☐

21. Could you give an approximate number of famers in your country that use this plant as feed?

    a) < 100 ☐ b) 100–500 ☐ c) >500 ☐

22. To which species of livestock is this plant / plant part fed?

    a) Cow:
    b) Buffalo:
    c) Sheep/Goat:
    d) Yak:
    e) Rabbits:
    f) Others:

23. Which species prefers it best (if fed to more than one species)?

24. At what physiological stage of the animal the plant / plant part is fed?

    Young ☐ Pregnant ☐ Lactating ☐
    Only Adult ☐ All Stages ☐

25. Have animals ever reacted negatively in any way to this plant / plant part?

    Yes ☐ No ☐

    If yes, please describe main symptoms:
    ....
    ....
    ....
    ....

26. Any indigenous knowledge on medicinal value of this plant / plant part. For example, prevention of bloat, induction of oestrus, helps in removal of placenta, etc.
    ....
    ....
    ....
    ....

27. Any other information related to this plant?
    ....
    ....
    ....
    ....

Your time and effort in answering this question is really appreciated

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