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# Agrobotanical, nutritional and bioactive potential of unconventional legume - *Mucuna*

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## Abstract

Unconventional legumes are promising in terms of nutrition, providing food security, agricultural development and in crop rotation in developing countries. The wild legume, *Mucuna* consists of about 100 varieties/accessions and are in great demand as food, livestock feed and pharmaceutically valued products. *Mucuna* seeds consist of high protein, high carbohydrates, high fiber, low lipids, adequate minerals and meet the requirement of essential aminoacids. The seeds also possess good functional properties and *in vitro* protein digestibility. Hydrothermal treatments, fermentation and germination have been shown to be most effective in reducing the antinutrients of *Mucuna* seeds. Several antinutritional compounds of *Mucuna* seeds serve in health care and considerable interest has been drawn towards their antioxidant properties and potential health benefits.

All parts of *Mucuna* plant are reported to possess useful phytochemicals of high medicinal value of human and veterinary importance and also constitute as an important raw material in Ayurvedic and folk medicines. *Mucuna* seeds constitute as a good source of several alkaloids, antioxidants, antitumor and antibacterial compounds. Seeds are the major source of L-DOPA, which serve as a potential drug in providing symptomatic relief for Parkinson's disease. As cultivar differences in *Mucuna* influences the quantity of L-DOPA and lectin in seeds, future investigations should direct towards the selection of germplasm with low L-DOPA and lectin for human and animal consumption, while high L-DOPA for pharmaceutical purposes. Inexpensive means of processing techniques needs to be implemented to exploit the nutraceutical potential of *Mucuna* for the benefit of poor and rural development in developing countries.

**Keywords:** Antioxidants, antitumor activity, bioactive compounds, fodder, food, L-DOPA, Mucuna, nutrition, wild legumes

## Introduction

Bridging the gap between teeming population and food production is one of the important tasks of developing countries. Expensive staple foods and policy constraints on food imports are the major factors worsening the food situation in developing countries (Weaver 1994). Protein-energy deficiency has been recognized as the most common form of malnutrition in regions where people depend mainly on starch-based diets (FAO 1994, Pelletier 1994, Weaver 1994, Michaelsen and Henrik 1998). Livestock production, animal husbandry and maintenance of soil fertility play important role in rural development and in turn the economy of developing countries. Livestock nutrition is also one of the critical constraints to increase animal productivity in developing countries (ILRI 1995) and perpetual gap persists between the demand and supply of digestible crude protein and total digestible nutrients to livestock in Asian continent (Singh et al 1997). Supplementation of animal protein for monogastric animals is expensive and not easily affordable (Umoren et al 2005). Poppi and Mclennan (1995) have advocated increasing the quality of legume-based pasture diets to uplift the livestock production. Legume pastures have been projected as an economically viable alternative for proteins and calories in developing countries (Famurewa and Raji 2005, Rao 1994). Feed supplementation with native legumes is viable and provides additional proteins, minerals, energy in dry seasons and improves the overall nutritional status in developing countries (Guillion and Champ 1996). Some underutilized wild legumes adapted to adverse conditions have been explored for their nutritional advantages (Amubode and Fetuga 1983, USNAS 1975, Udedibie 1991, Siddhuraju et al 1995, 2000, Vijayakumari et al 1997, Vadivel and Janardhanan 2001a, Bhagya et al 2006, Sridhar and Seena 2006, Quiceno and Medina 2006). To fulfill the growing demands of plant-based proteins for humans and livestock, research is underway on the possibilities of employing underutilized legumes as inexpensive and elegant source of protein than conventional sources *viz*., soybean (*Glycine max*), groundnut (*Arachis hypogea*) and animal-based proteins (Chel-Guerrero et al 2002, Krause et al 1996, Siddhuraju et al 1995). Legumes have long shelf life and provide more proteins, abundant carbohydrates, high fiber, low fat (except oilseeds) and possess high concentration of polyunsaturated fatty acids. Legumes are also known for certain bioactive compounds, whose beneficial effects need to be explored for efficient exploitation. Thus, underexplored legumes assume importance in terms of nutrition, food security, agricultural development, enhancement of economy and rotation of crops to improve soil fertility. In view of rural development, the current review emphasizes the importance of unconventional legume, *Mucuna* as a source of food, feed and pharmaceutically valued compounds.

## *Mucuna*

The legume family (Fabaceae) is the third largest among flowering plants, consisting of approximately 650 genera and 20,000 species (Doyle 1994) and is the second most important plant source of human and animal nutrition (Vietmeyer 1986). Figure 1 shows *Mucuna pruriens* in natural habitat (southwest India) with pods, ripened and dried seeds.


**Figure 1.** Mucuna pruriens climber in natural habitat with hanging bunch of pods in southwest coast of India (a), ripened beans (b) and dried seeds (c)

Many of the legumes possess multiple uses such as food, fodder and pharmaceuticals. Some legume seeds are known for anti-cancerous compounds that retard or arrest the cancer growth. For instance, an alkaloid 'genistein' derived from kudzu beans (*Pueraria Montana* Lour.) has the unique property to retard cancer growth (Brink 1995) and 'trigonelline' of jackbean (*Canavalia ensiformis*) possesses anticancerous properties (Morris 1999). Similarly, 'canavanine' extracted from jackbean (*Canavalia ensiformis*) is also reported to be cytotoxic to human pancreatic cancer cells (Swaffer et al 1995). Legumes also serve as weed control (e.g. *Cassia*, *Mucuna*, *Sesbania*) as well as source of natural pesticide (e.g. rotenoids)

(Balandrin et al1985). Many varieties and accessions of the wild legume, *Mucuna* are in great demand in food and pharmaceutical industries. Nutritional importance of *Mucuna* seeds as a rich source of protein supplement in food and feed has been well documented (Siddhuraju et al 2000, Siddhuraju and Becker 2001a, Bressani 2002). *Mucuna* seeds constitute excellent raw material for indigenous Ayurvedic drugs and medicines due to the presence of 3,4-dihydroxy-L-phenylalanine (L-DOPA), which provides symptomatic relief in Parkinson's disease (Shaw and Bera 1993, Prakash and Tewari 1999). The decoction of *Mucuna* seeds also lowers the cholesterol and lipids of plasma in rats (Iauk et al 1989). Standley and Steyermark (1946) have reported the use of one of *Mucuna* species as dye (*Mucuna argyrophylla* Standl.). *Mucuna* is also being extensively used as cover crop, mulch and to control weeds in agriculture.

In *Mucuna* (synonym, *Stizolobium*) (Hutchinson and Dalziel 1954), about 100 varieties have been identified and described (Duke 1981, Buckles 1995). *Mucuna* has Latin names (*Mucuna pruriens* Baker; *Mucuna prurita* Hook), English names (cow-hitch plant or cowhage) and common names (velvet bean, devil bean). The species nomenclature '*pruriens*' in Latin refers to itching sensation due to the result of contact with pod hairs. *Mucuna cochinchinensis* cultivated in some parts of Southern Nigeria and Senegal was first found in French Cochin-China (Hashim and Idrus 1977). Since then it has spread to other tropical countries (India, Indonesia, Philippines and Peninsular Malaysia) (Hutchinson and Dalziel 1954, Ukachukwu and Obioha 1997). *Mucuna* is grown as a minor food crop by tribals and ethnic groups of Asia and Africa (Dako and Hill 1977, Iyayi and Egharevba 1998). It was cultivated widely for the first time in Floridan region during 1890's as cover crop for the purpose of maintenance of soil fertility and feed for monogastric animals (pigs) and ruminants. However, cultivation and utilization of *Mucuna* declined rapidly due to affordable inorganic fertilizers and it was replaced by soybean (Elittä and Carsky 2003). After realizing a rapid deterioration in soil fertility and side effects of chemical fertilizers during 1980's, re-exploitation of *Mucuna* in tropical regions began (Buckles 1995). Significant impact of *Mucuna* in weed control (e.g. *Imperata cylindrica*) led to renewed interest on its utilization and gained the support of various organizations (Chikoye and Ekeleme 2000, Carsky et al 2001). Traditional use of *Mucuna* as food crop by farmers at field level gained popularity due to good yield (Gilbert 2002, Ukachuwu et al 2002). Except for the pioneering research on *Mucuna* by Buckles (1995), no detailed reports are available on utilization of *Mucuna* as food and feed. Sure and Read (1921) have detailed the biological analysis of seed of Georgia velvet bean (*Stizolobium deeringianum*). Ferris (1917) and Fain and Tabor (1921) have mentioned on the use of *Mucuna* as ruminant feed. Scott (1916) and Lamaster and Jones (1923) have reported use of *Mucuna* seeds as feed for dairy cows. Tweedie and Carew (1963) also reported the use of velvet beans as ruminant feed. *Mucuna* plant has been used in mixed cropping with maize and cowpea and the yield and chemical composition of fodder have been described by Singh and Relwani (1978). Harms et al (1961) reported the influence of feeding various levels of velvet beans to chicks and laying hens. Species differentiation between *Mucuna* with reference to seedling morphology has been described by (Sastraprajada et al 1975). *Mucuna pruriens* has been extensively used as cover crop for enhancement of water infiltration, softening the soil, improvement of soil fertility and to suppress the weeds (*Acanthospermum hispidum, Euphobia hirta, Senescio vulgaris, Oxygonum sinuatum, Schkuria pinnata, Richardia brasiliensis, Bidens pilosa, Sonchus oleraceae*) (Osei-Bonsu et al 1994, Mwangi et al 2006).

## Agrobotanical features

*Mucuna* and their accessions are herbaceous twining annual plants. They possess trifoliolate leaves (leaflets are broadly ovate, elliptic or rhomboid ovate and unequal at the base); flowers white to dark purple and hang in long clusters (pendulous racemes); pods are sigmoid, turgid and longitudinally ribbed, seeds ovoid (4-6 per pod) and black or white. *Mucuna* pods are covered with reddish-orange hairs, which readily dislodge and cause intense skin irritation and itch due to presence of a chemical called mucunain. Kuo et al (2004) compared the external features of *Mucuna* based on morphological characteristics (small branches, leaves, length of leaves, racemes, calyx and pods) of four accessions (*Mucuna gigantea*, *Mucuna macrocarpa*, *Mucuna membranacea* and *Mucuna pruriens* var. *utilis*). Gurumoorthi et al (2003a) evaluated the agrobotanical traits of seven accessions of *Mucuna* (90 days-old plants) (Thachenmalai, black seed coat; Thachenmalai, white seed coat; Mundanthurai, white seed coat; Mundanthurai, black seed coat; Kailasanadu, white seed coat; Valanad, black seed coat; Mylaru, white seed coat) collected from five agroecological regions of Southern India and recorded a wide diversity in *Mucuna* accessions. Black seed coat bearing Thachenmalai accession exhibited high fertility index, biomass production and seed yield followed by Valand accession. The leghaemaoglobin of the seven accessions varied between 0.18 mM (Mundanthurai white accession) and 0.52 mM (Kailasanadu). Mundanthurai (black accession) registered the highest germination (99.75%), while it ranged between 79.75 % and 96% in rest of the accessions. Thachenmalai (black accession) and Mylaru flowered in 60 days of sowing against 61-67 days in other accessions. The authors inferred that genetic diversity existing between *Mucuna* accessions is not influenced by environment. However, a major finding by Capo-chichi (2002) is that the evaluation of some of the commonly utilized *Mucuna* accessions can be considered as mere varieties of *Mucuna pruriens*.

*Mucuna* grown in Taiwan consist of three species and one variety (*Mucuna gigantea*, *Mucuna macrocarpa, Mucuna membranacea* and *Mucuna pruriens* var. *utilis*)(Xu et al 1996, Li and Yang 2002, Kuo et al 2004). In West Africa, *Mucuna flagellipes, Mucuna sloanei*, *Mucuna prurines* var. *pruriens*, *Mucuna pruriens* var. *utilis* and *Mucuna cochinchinensis* are well established. In Malaysia, *Mucuna bracteata* are frequently planted in large plantations and small-holdings of oil palm and rubber as cover crops along with some of the other legumes (*Calopogonium caeruleum* and *Pueraria javanica*) (Ministry of Agriculture 2000). A yield of approximately 5000 kg seeds per hectare has been reported in well-managed irrigated fields from India (Singh et al1995, Farooqi et al1999). Maximum seed yield of 1.995 tonnes/ha (spacing of 1.0 m × 1.0 m, 10,000 plants/ha) has been reported by Krishnamurthy et al (2003) based on the results obtained from a field experiment (Zandu Foundation for Health Care Research Farm, Ambach, South Gujarat, India) on growing *Mucuna pruriens* (L.) DC. var. *utilis*.

## *Mucuna* as food and feed

### Food

Seeds of *Mucuna* constitute source of food for tribals and some ethnic groups of Asia and Africa (Dako and Hill 1977, Iyayi and Egharevba 1998). The immature pods and leaves serve as vegetables, while seeds as condiment and main dish by ethnic groups in Nigeria (Adebowale and Lawal 2003b). Farmers of Kenyan coast exclusively use *Mucuna* seeds in beverage preparation, while those dwelling at North-rift region use finely powdered roasted seeds for consumption (Saha and Muli 2000). Mature seeds are consumed by some of the Indian tribals (Mundari, Dravidian groups, Northeastern and Kanikkas) (Arora 1981, Jain 1981). Reports are available on the use of *Mucuna* seeds as food by Sri Lankan population (Ravindran and Ravindran 1988). Ukachukwu and Obioha (1997) reported that rural population of Nigeria (Enugu and Kogi) consumes seeds of *Mucuna cochinchinensis* during famine or scarcity of common legumes (Ukachukwu and Obioha 1997). Survey by Onweluzo and Eilittä (2003) revealed that in Enugu and Kogi, about 55% of population consumes *Mucuna* on cultivation, while about 40% cultivate for consumption as well as for marketing.

*Mucuna* seeds are usually toasted for 5-10 min before grinding and flouring to supplement as thickener in sauce or soup. Osei-Bonsu et al (1996) reported that people of Southern Ghana consume *Mucuna cochinchinensis* and *Mucuna utilis* (pounded, cracked or boiled up to 40 min) daily. After draining the cooked water, softened seeds are hulled, ground into paste and mixed with other ingredients (e.g. chillies, egg plant, onions, meat or fish) to prepare soup (Asadua and Nkwan), which is eaten along with starchy staples. The beans are also useful in preparation of oil soups (stew) (Osei-Bonsu et al 1996). The most popular recipes are stew, sauce (Akpoko ji/nkashi/Una) gel (Opka), roasted snacks (Akpaka Ide), porridge, Moi-Moi and fried cake. Consumption of these products did not cause any adverse effect on human health. *Mucuna sloanei* is used by the Igbo community in Sub-Saharan Africa as condiment or part of the main dish (Afolabi et al 1985, Ukachukwu et al 2002). Seeds of *Mucuna urens* are used as thickener of soup and vegetable oil by Igbo community of Southeastern Nigeria (Afolabi et al 1985, Ukachukwu et al 2002). Seeds are also used in beverages and thickening agents in recipes of several food items (Haq 1983, Wanjekeche et al2003). Finely powdered and roasted dry seeds of *Mucuna* serve as supplement of coffee of African tribals. Preparations of toasted and ground seeds of *Mucuna cochinchinensis* and *Mucuna utilis* are very popular among senior citizens of Nsukka and Igala regions of Africa (Ene-Obong and Carnovale 1992, Ukachukwu and Obioha 1997). Seeds of *Mucuna* accessions (*Mucuna sloanei* and *Mucuna flagellipes*) are cracked by hitting with a hard object before cooking, then hulled, ground, mixed with red palm oil to obtain yellow powder and marketed as soup thickener (Ezueh 1997). Consumption of *Mucuna* as food has also been reported from Mozambique and Malawi (Infante et al 1990, Gilbert 2002). Egounlety (2003) reported the methods of pretreatment of *Mucuna pruriens* var. *utilis* seeds for preparation of three foods stuffs (*Mucuna* tempe, *Mucuna* condiment and *Mucuna* fortified weaning food) through fungal (*Rhizopus oligosporus*) or bacterial (*Bacillus* sp.) fermentation and changes in biochemical composition of seeds on fermentation have been detailed. Fermentation of *Mucuna* with *R. oligosporus* resulted in pleasant cheese-like aroma that was retained up to 48 hr. In condiment preparation, as fermentation proceeds, the product attains dark colour. Egounlety (2003) recommended the use of *Mucuna* seeds as a good substrate for fungal or natural fermentation and for the production of *Mucuna* tempe and *Mucuna* fortified weaning foods at household level to overcome protein-energy malnutrition. Diallo et al (2002) reported formulation of four recipes (coffee, porridge, ragout and tau) from seeds of *Mucuna pruriens*. For preparation, seeds were soaked in freshwater over 48 hr (seed coat will be removed manually after 24 hr) replacing water once in every 12 hr followed by cooking up to 60-90 min in water. Consumption of such preparations by about 300 trained women volunteers did not result in any negative health effects (Diallo et al 2002). Use of polysaccharide gums extracted from *Mucuna flagellipes* in preparation of raw beef burgers containing graded levels (0.25, 0.5, 0.75 and 1.0%) has been reported by Onweluzo et al (2004). Beef burgers containing *Mucuna* gums significantly lowered shrinkage, elevated water holding capacity (WHC) and stability under ambient conditions (27±1°C; relative humidity, 90.6%). Overall acceptability score indicated that the *Mucuna* gum-stabilized beef burgers were acceptable and the seeds serve as effective stabilizers. Tempe, a fermented soybean food product is produced traditionally in Indonesia. Similarly, tempe is also produced in Japan using *Mucuna* seeds (Higasa et al 1996).

**Feed**

*Mucuna pruriens* has been compared to *Gliricidia sepium* (a recommended legume for supplementation of the grass-based diet) in dairy livestock feeding (Muinga et al 2003). Feeding experiment performed on Jersey cows revealed that *Mucuna* forage (2 kg DM/day) could be used to supplement dairy cows along with grass as basal diet. *Mucuna* and *Gliricidia* forages resulted in daily milk yield 5.2 and 5.5 kg/cow respectively. Ravindran and Ravindran (1988) stated that nutritive value of *Mucuna* can be improved further as livestock feed ingredient on soaking, germination and heat treatment to inactivate and reduce/destroy its antinutritional components (Aletor and Aladetimi 1989, Agunbiade and Longe 1996). Castillo-Caamal et al (2003) showed that the sheep fed with treated *Mucuna* seeds increased the weight and the growth response confirms the benefits with increased intake of nutrients and antinutrients.

Studies have been carried out on weaner pigs by feeding raw *Mucuna* seed meal by Esonu et al (2001). Feeding of raw seed meal resulted in deleterious effects on the performance as well as blood constituents of pigs. Emenalom et al (2004) studied the pathophysiological responses of weaner pigs fed with raw and cracked-soaked and cooked Nigerian *Mucuna pruriens* seed meals. Raw seed meal was poisonous to pigs, but relatively safe after thermal treatments. Raw and cracked-soaked and cooked meal in pig diets (15%, 20, 30 and 40%) against control diet indicated that the seeds are poisonous at 15% dietary inclusion and significantly affects the hematological and serum biochemical indices with 40% mortality. These clinical effects were pronounced in smaller pigs (17-18 kg) than bigger ones (21 kg) indicating that body weight as an important factor to overcome the toxic effects of raw *Mucuna* seed meal. Pre-heated

*Mucuna* seed meal proved safe for pigs at different dietary inclusion without improvement of most of the hematological and serum biochemical parameters. Poor weight gain of pigs receiving increased levels of the processed *Mucuna* seed diets indicates incomplete detoxification.

Supplementing 10% dry-roasted *Mucuna* seeds in broiler diet resulted in better growth of birds than raw seeds (Del Carmen et al 1999). Iyayi and Taiwo (2003) investigated the effect of incorporation of *Mucuna pruriens* seed meal on the performance of laying hens and broilers (18 week-old black Nera birds). In diets 1, 2, and 3, 40% soybean meal was replaced with autoclaved, raw and roasted (RMSM) *Mucuna* seeds respectively. None of the *Mucuna* diets showed the effect on egg (size, weight, length and width) and no meat or blood spots on the eggs. Similarly, egg yolk index did not significantly change on feeding *Mucuna* diet. In another set of experiment with broiler chicks (160 day-old), soybean meal was replaced with RMSM in conventional broiler diet (0, 33.3, 66.7 and 100%) at starter and finisher phases. None of the combination of RMSM affected the efficiency of feed utilization or weights of gizzards and hearts of birds. Addition of 6% RMSM had no effect on the organ weights, while weights of air sacs, small and large intestine and caeca reduced, while weights of liver and spleen were increased at 12 and 18% RMSM. Results of this study revealed that: (i) Laying hens ate normally with diets containing autoclaved or roasted *Mucuna* compared to raw *Mucuna* seed diet; (ii) If processed *Mucuna* seeds incorporated at 6% level of diet, it produced good egg quality against sole soybean meal diet; (iii) Processed *Mucuna* seeds are promising plant protein source to replace soybean meal in feeding broilers. Incorporation of RMSM at 6% in diets was optimum for the production of broilers from the starter to finishing phase. However, RMSM over 6% cause reduction in performance of the birds due to antinutritional factors and disrupted the digestive tract and other organs. The RMSM at 18% resulted in degenerative syndromes in the organs of the birds.

Siddhuraju and Becker (2001a) reported that fish fed up to 13% of *Mucuna* seed diet (raw or autoclaved) produced growth performances similar to respective control group and in feed utilization of common carp. However, the sensitivity of common carp to the antinutritional factors (total phenolics, L-DOPA or non-starch polysaccharides) of *Mucuna* seed meal resulted in low growth performance. Study by Siddhuraju and Becker (2003a) showed that use of all the processed *Mucuna pruriens* seeds significantly improve the growth performance and feed utilization of tilapia fish compared to raw seeds and the values are comparable with control diet. All diets containing raw *Mucuna* seeds significantly lowered the plasma cholesterol. However, significant negative influence on the hepato-somatic index was found in fish fed with raw as well as treated *Mucuna* seed meals. The raw seed meal at the 25% dietary protein included in the fish feeding experiment significantly reduced the growth performance and nutrient utilization. But at 25% dietary protein, processed *Mucuna* seeds resulted good feed utilization and growth.

## Nutritional properties

Studies have been carried out on the seed characteristics and chemical composition of three morphotypes of *Mucuna urens* (L.) Medikus (horse eye bean, Nigeria) by Adebooye and Phillips (2006) and their results revealed that all three morphotypes are good source of crude protein (19.97-20.57%), carbohydrate (73.29-75.49%), fat (1.84-5.05%) and vitamins (11.24-17.10%). Ezeagu et al (2003) studied the proximate composition of 12 *Mucuna* accessions from Nigeria and found high protein (24.50-29.79%), fat (4.72-7.28%), carbohydrate (59.20-64.88%), crude fibre (3.65-4.43%), starch (39.22-41.17%) and gross energy (16.64-17.17 kJ/g). Proximate composition of eight accessions of *Mucuna* seeds is projected in Table 1.

**Table 1.** Proximate composition (in %) of seeds of eight species of *Mucuna*

| Species | Crude protein | Crude lipid | Crude fibre | Ash | Crude carbohydrate | Reference |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| *Mucuna. cochinchinensis* | 29.79 | 6.51 | 4.19 | 4.16 | 59.54 | Ezeagu et al 2003 |
| *Mucuna gigantea* | 30.62 | 9.03 | - | 5.99 | 42.79 | Rajaram and Janardhanan 1991 |
| *Mucuna jaspeada* | 27.56 | 4.72 | 4.43 | 3.25 | 64.47 | Ezeagu et al. 2003 |
| *Mucuna monosperma* | 23.50 | 14.39 | 6.79 | 3.21 | 52.20 | Mohan and Janardhanan 1995 |
| *Mucuna pruriens* | 31.44 | 6.73 | 5.16 | 4.11 | 52.56 | Siddhuraju et al 1996 |
| *Mucuna solanei* | 24.00 | 6.50 | 5.30 | 3.00 | ND | Afolabi et al 1985 |
| *Mucuna utilis* | 26.40 | 4.10 | 6.30 | 3.70 | 59.50 | Ravindran and Ravindran 1988 |
| *Mucuna veracruz* (black) | 24.50 | 6.90 | 4.27 | 3.66 | 64.88 | Ezeagu et al 2003 |

*ND, Not determined*

## Proximal value

### Crude protein

Four Indian accessions of *Mucuna* consist of high amount of crude protein (20.2-29.6%) (Vadivel and Janardhanan 2000, Vijayakumari et al 2002). Crude protein of eight *Mucuna* accessions ranged between 24 and 31.44% (Table 1), which surpasses many wild legumes (*Atylosia scarbaeoides*, 17.3%; *Erythrina indica*, 21.5%; *Neonotonia wightii*, 15.1%; *Rhynchosia filipes*, 16.9%; *Tamarindus indica*, 14%; Arinathan et al 2003) and edible legumes (*Cajanus cajan*, 19.4%; *Cicer arietinum*, 20.7%; *Vigna trilobata*, 20.2%, and *V. unguiculata*, 15.9%; Jambunathan and Singh 1980, Nwokolo 1987, Arinathan et al 2003).

### Crude lipid

Crude lipid of *Mucuna* seeds showed wide variations. Some investigators reported as low as 2.8-4.9% (Ravindran and Ravindran 1988, Siddhuraju et al 2000), while others up to 8.47-14.0% (Janardhanan and Lakshmanan 1985, Vijayakumari et al 2002). Vadivel and Janardhanan (2000) reported crude lipid in intermediary range (6.3-7.4%). Adebowale et al (2005a) showed that the ether extract of whole seed, cotyledon and seed coat consists of 9.6, 9.8 and 3.0% crude lipid respectively. Crude lipid of eight *Mucuna* accessions ranged between 4.1-14.39% (Table 1)

### Crude fibre

Crude fibre of *Mucuna* seed accessions ranged between 5.3 and 11.5% (Janardhanan and Lakshmanan 1985, Ravindran and Ravindran 1988, Mohan and Janardhanan 1995). The dietary fibre was in the range of 6.7-19.5% (Siddhuraju et al 2000, Vadivel and Janardhanan 2000, Vijayakumari et al 2002), while the neutral detergent fibre and acid detergent fibre ranged between 10.3-25.9% and 9.3-20.4% respectively (Bressani 2002, Del Carmen et al 2002, Ayala-Burgos et al 2003). Table 1 reveals that crude fiber of eight accessions ranged between 4.19 and 6.79%. High crude fibre in diet is known to enhance the digestibility, decrease the blood cholesterol and reduce the risk of large bowel cancers (Anderson et al 1995, Salvin et al 1997).

### Ash and vitamins

Ash in *Mucuna* seeds ranges from 2.9-5.5% (Janardhanan and Lakshmanan 1985, Ravindran and

Ravindran 1988, Vadivel and Janardhanan 2000). Kay (1979) reported thiamine (13.9 ppm) and riboflavin (1.8 ppm) as major vitamins in seeds.

**Carbohydrates**

The low digestible and high resistant starch and soluble sugars in *Mucuna pruriens* var. *utilis* ranged from 9.2-10.5% in whole seeds and 10.1-11.5% in dehulled seeds (Siddhuraju et al 2000). Among the 12 accessions studied by Ezeagu et al (2003), total sugar ranged between 1.51 and 3.19 g/100 g with highest concentration in *Mucuna preata*. Ezeagu et al (2003) reported carbohydrate in the range of 59.20-64.88 g/100 g with highest concentrations in *Mucuna veracruz* (64.88 g/100 g). Structural, physicochemical, retrogradation behavior and functional properties of *Mucuna* seed starch were determined by Adebowale and Lawal (2003b, 2003c) and found that temperature has a pronounced impact on the swelling capacity and solubility and heat moisture conditioning reduced the solubility and swelling capacity of the native starch. Carbohydrates of legumes are known to reduce the plasma cholesterol and gradually elevate the levels of blood glucose (Leeds 1982, Walker 1982). Carbohydrates of eight accessions ranged between 42.79-64.88% (Table 1)

**Minerals**

Legumes form a rich source of minerals particularly potassium, magnesium, iron, zinc and calcium (Salunkhe et al 1985). Among the minerals of *Mucuna utilis* seeds,potassium was highest (778-1846 mg/100 g) followed by calcium (104-900 mg/100 g), iron (1.3-15 mg/100 g), zinc (1.0-15 mg/100 g), manganese (0.56-9.26 mg/100 g) and copper (0.33-4.34 mg/100 g). Some accessions of *Mucuna* are the rich source of phosphorous (98-498 mg/100 g) and magnesium (85-477 mg/100 g) (Janardhanan and Lakshmanan 1985, Ravindran and Ravindran 1988, Siddhuraju et al 2000, Vadivel and Janardhanan 2000). Ezeagu et al (2003) reported minerals of 12 *Mucuna* accessions of Nigeria, wherein potassium was the major element (*Mucuna georgia*, 300 mg/100 g; *Mucuna jaseada*, 846 mg/100 g) with high calcium (0.07-0.14%), phosphorus (0.44-0.56%) and iron (4.08-14.85 mg/100 g). Reports on seeds of *Mucuna pruriens* revealed high potassium (806-2790 mg/100 g) (Mary Josephine and Janardhanan 1992), while low potassium (356-433 mg/100 g) is also reported by Adebowale et al (2005a). Mineral composition of seed legumes is dependent on the soil edaphic factors including the genetic origin and geographical source (Vadivel and Janardhanan 2001b). It is known that iron, selenium, zinc and manganese strengthen the immune system as antioxidants (Talwar et al 1989). Similarly, magnesium, zinc and selenium are also known to prevent cardiomyopathy, muscle degeneration, growth retardation, alopecia, dermatitis, immunologic dysfunction, gonadal atrophy, impaired spermatogenesis, congenital malformations and bleeding disorders (Chaturvedi et al 2004). The variations in the mineral composition of some *Mucuna* seed accessions have been projected in Table 2, wherein potassium constitutes the major element.

**Table 2.** Mineral composition of seeds of six species of *Mucuna* (mg/100 g dry mass)

| Mineral | *Mucuna flagellipes*[a] | *Mucuna. gigantea*[b] | *Mucuna jaspeada*[c] | *Mucuna pruriens*[d] | *Mucuna pruriens* var. *utilis*[e] | | *Mucuna utilis*[f] |
|---|---|---|---|---|---|---|---|
| | | | | | White | Black | |
| Sodium | 11.10 | 35.30 | - | 4.10 | 12.70 | 25.70 | 70.00 |
| Potassium | 1322 | 2296 | 8460 | 2537 | 1575 | 1343 | 11110 |
| Calcium | 12.80 | 518 | 80.00 | 247 | 87.80 | 104 | 250 |
| Phosphorus | - | 194 | 470 | 459 | 499 | 376 | 220 |
| Magnesium | 58.30 | 506 | 170 | 72.40 | 120 | 109 | 110 |
| Iron | 82.00 | 9.42 | 6800 | 5.19 | 5.79 | 7.47 | 1.30 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Copper | 2.60 | 1.18 | 1.82 | 0.47 | 2.42 | 1.65 | 0.60 |
| Zinc | 7.30 | 8.24 | 4.60 | 1.71 | 5.26 | 12.20 | 1.00 |
| Manganese | 11.90 | 2.36 | 5.17 | 0.31 | 1.49 | 2.41 | 1.00 |

*[a]Ajayi et al 2006; [b]Rajaram and Janardhanan 1991; [c]Ezeagu et al 2003; [d]Mary Josephine and Janardhanan 1992;*

*[e]Siddhuraju et al 2000; [f]Ravindran and Ravindran 1988; -, Not determined*

## Fatty acids and amino acids

Only a few studies are available on the fatty acid composition of *Mucuna* seeds (Table 3). The fatty acid profile consists of high unsaturated fatty acids such as oleic acid (6.9-28.7%) and linoleic acid (21.4-49.5%) (Mohan and Janardhanan 1995, Siddhuraju et al 2000). Among the antinutritionally important and undesirable fatty acids, behenic acid ($C_{22:0}$) (0.73 to 3.76%) was reported in *Mucuna* seeds.

**Table 3.** Fatty acid composition of seeds of five accessions of *Mucuna* spp. (g/100 g lipid)

| **Fatty Acid** | ***Mucuna flagellipes*[a]** | ***Mucuna monosperma*[b]** | ***Mucuna pruriens*[c]** | ***Mucuna pruriens var. utilis* (white)[d]** | ***Mucuna pruriens* var. *utilis* (black)[d]** |
|---|---|---|---|---|---|
| Lauric acid (C12:0) | - | - | - | 0.03 | - |
| Myristic acid (C 14:0) | - | - | - | 0.16 | 0.17 |
| Palmitic acid (C16:0) | 10.71 | 24.60 | 20.16 | 20.05 | 21.81 |
| Stearic acid (C18:0) | 3.39 | 11.70 | 3.84 | 7.06 | 7.43 |
| Arachidic acid (C20:0) | - | - | 1.80 | 1.40 | 4.46 |
| Heneicosanoic acid (C21:0) | - | - | - | 0.05 | 0.05 |
| Behenic acid (C22:0) | 1.37 | 3.52 | 0.73 | 3.43 | 3.36 |
| Tricosanoic acid (C23:0) | - | - | - | - | 0.09 |
| Lignoceric acid (C24:0) | 3.85 | - | - | 0.91 | 0.87 |
| Myristoleic acid (C14:1) | - | - | - | 0.02 | ND |
| Palmitoleic acid (C16:1) | - | - | 1.72 | 0.29 | 0.30 |
| Elaidic acid (C18:1) | 60.68 | - | - | 0.03 | 0.03 |
| Oleic acid (C18:1) | - | 30.80 | 28.71 | 8.33 | 6.95 |
| Linoleic acid (C18:2) | 15.03 | 24.70 | 37.14 | 48.75 | 47.98 |
| Linolelaidic acid (C18:2) | - | - | - | 2.66 | 1.50 |
| Linolenic acid (C18:3) | - | 4.74 | 3.28 | 6.52 | 7.67 |
| Eicosenoic acid (C20:1) | 2.26 | - | - | - | - |
| Eicosadienoic acid (C20:2) | - | - | - | 0.05 | 0.05 |
| Cerotic acid (C26:0) | - | - | - | - | 0.05 |
| Sum of essential fatty acids | 15.03 | 29.44 | 40.40 | 55.27 | 55.65 |
| Sum of saturated fatty acids | 22.03 | 39.82 | 26.53 | 33.09 | 35.29 |
| Sum of polyunsaturated fatty acids | 77.97 | 60.24 | 70.85 | 66.91 | 64.70 |
| P/S Ratio[e] | 3.54 | 1.51 | 2.67 | 2.02 | 1.83 |

*[a]Ajayi et al 2005; [b]Mohan and Janardhanan 1995 ; [c]Siddhuraju et al 1996 ; [d]Siddhuraju et al 2000*

*[e]ratio of polyunsaturated/saturated fatty acids; -, Not detectable*

Among amino acids in legumes, usually lysine constitutes the highest, while sulphur-amino acids are limiting (Jansman 1996). Interestingly, Mohan and Janardhanan (1995) reported lysine and valine are limiting in white seed coat variety and sulphur-amino acids in black seed coat accession of *Mucuna*. Adebowale et al (2005a) showed highest total essential amino acids (555 mg/g protein) in *Mucuna* seeds. Threonine, lysine, leucine (black seed coat), phenylalanine and tyrosine (white seed coat) were deficient. Valine, isoleucine and histidine are higher than FAO/WHO requirement pattern for adults (Vadivel and Janardhanan 2000). Aspartic (8.9-19%) and glutamic (8.6-14.4%) acids were predominant in *Mucuna* seeds (Janardhanan and Lakshmanan 1985, Mary Josephine and Janardhanan 1992, Siddhuraju et al 2000). Glycine, histidine and proline of *Mucuna utilis* are comparable with soybean (Bau et al 1994), while alanine, serine and arginine are low (Siddhuraju et al 2000). The essential amino acids, valine, isoleucine, tyrosine and phenylalanine are higher than FAO/WHO reference pattern (FAO/WHO 1990). Lysine in *Mucuna* seeds varied from 327-412 mg/g N, while deficient in sulphur-amino acids 116-132 mg/g N (Laurena et al 1991, Rajaram and Janardhanan 1991, Mary Josephine and Janardhanan 1992). Amino acids of four accessions have been compared with FAO/WHO requirement pattern for adults and soybean in Table 4.

**Table 4.** Amino acid composition of seeds of three *Mucuna* spp. compared with soybean and FAO/WHO pattern for adults (mg/100 g protein)

| **Amino acid** | ***Mucuna cochinchinensis*[a]** | ***Mucuna pruriens*[b]** | ***Mucuna solanei*[c]** | **Soybean[d]** | **FAO/WHO pattern[e]** |
|---|---|---|---|---|---|
| Glutamic acid | 16.8 | 17.23 | 10.03 | 16.90 | |
| Aspartic acid | 13.6 | 8.16 | 6.94 | 11.30 | |
| Serine | 3.45 | 4.10 | 3.32 | 5.67 | |
| Threonine | 5.04 | 3.64 | 2.04 | 3.76 | 3.4 |
| Proline | 13.45 | ND | 3.30 | 4.86 | |
| Alanine | 7.45 | 2.81 | 3.61 | 4.23 | |
| Glycine | 5.43 | 5.12 | 3.08 | 4.01 | |
| Valine | 6.98 | 5.57 | 3.65 | 4.59 | 3.5 |
| Cystine | 1.04 | 0.84 | 1.72 | 1.70 | |
| Methionine | 1.32 | 1.28 | 1.18 | 1.22 | [f]2.5 |
| Isoleucine | 9.08 | 4.12 | 2.70 | 4.62 | 2.8 |
| Leucine | 7.27 | 7.85 | 5.16 | 7.72 | 6.6 |
| Tyrosine | 5.46 | 4.76 | 11.16 | 1.24 | |
| Phenylalanine | 7.69 | 3.85 | 14.81 | 4.84 | [g]6.3 |
| Tryptophan | 2.34 | 1.35 | ND | 3.39 | 1.1 |
| Lysine | 6.78 | 6.60 | 13.47 | 6.08 | 5.8 |
| Histidine | 2.36 | 3.14 | 1.13 | 2.50 | 1.9 |
| Arginine | 8.05 | 7.16 | 11.81 | 7.13 | |

[a]*Adebowale et al 2005a;* [b]*Siddhuraju et al 1996;* [c]*Afolabi et al 1985;* [d]*Bau et al 1994;* [e]*FAO/WHO 1991;*
[f]*Cystine + Methionine;* [g]*Tyrosine + Phenylalanine; ND, Not detectable*

## Protein quality

Janardhanan and Lakshmanan (1985) studied the seed proteins of *Mucuna pruriens* and reported highest quantity of globulins (62%) followed by albumins (21%). Some reports indicated that globulin was maximum (9-16.7%) followed by albumin (4-9%), glutelin (1.3-2.9%) and prolamin (0.8-2%) in *Mucuna* seeds (Vadivel and Janardhanan 2000, Vijayakumari et al 2002). Adebowale and Lawal (2003a) reported the presence of five polypeptide seed protein subunits (200, 116, 82, 63, and 59 kDa) in *Mucuna pruriens*. Machuka (2000) characterized the seed proteins of seven varieties of *Mucuna pruriens* of Nigeria (Veracruz-white, *utilis*, IRZ, Pruriensis, Cochinensis, Rajada and Ghana) based on SDS-PAGE profiles and found globulin and albumin as rich fractions. Seven albumin and six globulin polypeptide band patterns were seen along with minor bands. No varietal difference were seen in the band patterns and N-terminal sequencing revealed the presence of consensus sequence DDREPV-DT-PL. Mohan et al (1993) demonstrated electrophoretic banding pattern of seed proteins of *Mucuna*. Based on banding pattern of albumins and globulins of *Mucuna* species, they concluded that the *Mucuna utilis* evolved from *Mucuna pruriens*.

Protein digestibility is one of the major determinants of the nutritional quality of legumes and influences bioavailability of amino acids (Reddy and Gowramma 1987). The *in vitro* protein digestibility (IVPD) values of both white and black raw *Mucuna* seeds was found to be 68% and 69% respectively (Siddhuraju and Becker 2001c). The IVPD of *Mucuna* seeds ranged between 71.5 and 76.9% and they were higher than some of the common pulses including soybeans (Chitra et al 1995, Ravindran and Ravindran 1988). The IVPD of whole as well as dehulled raw *Mucuna* seeds (67.4-70.2%) was similar to raw chick pea and soy bean, while lower than kidney beans (Siddhuraju et al 2000). The IVPD increased on cooking seeds of *Mucuna utilis* (71.5 vs. 80.3%) (Ravindran and Ravindran 1988). Gurumoorthi et al (2003b) studied five accessions of *Mucuna prurines* var. *utilis* (three white and two black coat) obtained from Western Ghats of India and reported high IVPD in white seed accessions (74.88-76.92%) than black seed accessions (72.41-72.86 %).

**Functional properties**

The acceptability of legume seed flour depends mainly on the nutritional value as well as functional properties (Pour-El 1981). The functional properties of seed flour assume importance in the development of food product. Proteins and starch are the main contributors for changes in functional properties such as foaming, protein solubility, oil and water absorption and emulsification (Kerr et al 2000, Kinsella 1979). Adebowale et al (2005b) studied the functional properties on full fat and defatted flours of six *Mucuna* species: *Mucuna cochinchinensis, Mucuna deerigeana, Mucuna pruriens, Mucuna rajada, Mucuna veracruz* (mottle) and *Mucuna veracruz* (white). The bulk density of the flours increased on defatting. The isoelectric point of the proteins ranged between 4 and 5. The protein solubility decreased as the pH increased to isoelectric point followed by progressive increase in protein solubility with further increase in pH. Defatted flours showed higher water and oil absorption capacities (WAC and OAC) than full fat samples. The results showed that *Mucuna veracruz* (white) showed the lowest water absorption capacity (1.40 g/g), while water absorption capacity was high *in Mucuna veracruz* (mottle) (2.20 g/g). *Mucuna veracruz* (mottle)and *Mucuna rajada* possess highest gelation capacities (20%), while lowest (14%) was in *Mucuna veracruz* (white) and *Mucuna deerigeana*. The foaming capacities in full fat flours are lower than defatted flours. The foaming capacity in full fat flours ranged between 9.6% (*Mucuna veracruz* white) and 19.23% (*Mucuna pruriens*),while the foaming capacity in defatted flours ranged between 50.0% (in *Mucuna pruriens* and *Mucuna veracruz* white) and 84.30% (*Mucuna veracruz* mottle). Emulsion capacity ranged from 78-90% in full fat flours and 56-68% in defatted flours. Ahenkora et al (1999) compared the functional properties of raw and heat-processed *Mucuna* seed flours. The raw flours showed minimum protein solubility at pH 4.5 and formed stable emulsions as well as foams, while heat-processed flours exhibited better WAC as well as OAC, but lower protein solubility, emulsion and foam capacities. Moist heating of the seed flour resulted in increased WAC (140% vs. 156%) as well as OAC (76% vs. 86%). The emulsion capacity was 60% and 50% respectively in raw and heat-processed flours. The decreased emulsion capacity was attributed to decreased protein solubility due to thermal treatment. Heat treatments resulted in decreased foam capacity (53% vs. 4%) and foam stability (10 vs. 9 %). Adebowale and Lawal (2003b) reported the functional properties and retrogradation behavior of native and chemically modified starch of *Mucuna pruriens* seed flours. Chemical modifications increased the WAC of the native starch and the acetylation produced a marked difference in native starch (1.71 vs. 1.21 g/g). Acetylation increased the OAC of native starch, while reduction in oxidized starch. Acetylation reduced the lowest gelation concentration of flours from 80-60 g/l, increased the swelling power and solubility, while oxidation reduced the swelling power, but increased the solubility (swelling power: native starch, 2.7-13.3 g/g; acetylated starch, 3.6-15.6 g/g; oxidized starch, 2.3-9.9 g/g) (solubility: native starch, 21-143 g/g; acetylated starch, 36-147 g/g; oxidized starch, 52-200 g/g).

## Anti-nutritional properties

Presence of antiphysiological and toxic factors in legumes decreases the overall nutritional qualities. Seeds of *Mucuna* contain several anti-nutritional factors such as L-DOPA, total free phenolics, tannins, haemagglutinin, trypsin and chymotrypsin inhibitors, anti-vitamins, protease inhibitors, phytic acid, flatulence factors, saponins and hydrogen cyanide (Skerman et al 1988, Emenalom and Udedibie 1998, Vadivel and Janardhanan 2000). In addition, *Mucuna* seeds are also known to possess inhibitory factors like lipoxygenase, goitrogen and oxalates (Ologhobo and Fetuga 1984, Balogun and Fetuga 1989, Ologhbo 1992, Oke et al 1996), methylated and non-methylated tetrahydroisoquinolines (0.25 %) (Siddhuraju et al 2001b). Consumption of uncooked seeds of some of the legumes (e.g. soybean) results in marked enlargement of the thyroid glands (Mc Carrison 1933) due to presence of goitrogens. So far no detailed studies are available on the goitrogens of *Mucuna* seeds.

### L-DOPA

Although L-DOPA is pharmacologically an active ingredient (Pieris et al 1980), it is potentially antinutritional and toxic if ingested in large amounts (Mary Josephine and Janardhanan 1992, Siddhuraju et al 2000, Bressani 2002). It has been recognized that the presence of L-DOPA in *Mucuna* seeds is a major impediment to consider it as food or feed. Intoxication on over consumption of *Mucuna* seeds is related to the quantity of L-DOPA (Janardhanan and Lakshmanan 1985). Vadivel and Janardhanan (2000) reported high amount of L-DOPA in black seed (6.7-7%) than white seed accessions (5.9%) of India. The L-DOPA ranged between 4.0 and 8.34% (*Mucuna veracruz*) in some Nigerian *Mucuna* accessions (Ezeagu et al 2003). Bell and Janzen (1971) studied six accessions of *Mucuna* (*Mucuna andreana*, *Mucuna pruriens*, *Mucuna mutisiana*, *Mucuna holtoni*, *Mucuna urens*, *Mucuna sloanei*) collected from Puntarenas, Costa Rica, Isla Providencia, Colombia, Peoria and Florida and reported L-DOPA between 5.9 and 9.0%. In a study of 36 *Mucuna* accessions of Africa, America and India, Lorenzetti et al (1998) recorded L-DOPA from 2.2-7.2%, while surveys carried out by St. Laurent et al (2002) on 38 accessions revealed the range between 1.81% (*Mucuna pruriens* var. *utilis* grown in the USA ) to7.64% (*Mucuna pruriens* var. *cochinchinensis* grown in Bénin).

Eilitta et al (2002) have opined that variations in L-DOPA is dependent not only on the genetic makeup of *Mucuna* but also the geographic location, while Capo-chichi et al (2003) inferred that L-DOPA is influenced mainly by genotype vs. accession than genotype vs. environment. Based on a study of 36 accessions of *Mucuna utilis* of Africa, America and India, Lorenzetti et al (1998) concluded that *Mucuna* cultivated close to equator (10¢) shows significantly higher quantity of L-DOPA than those cultivated away from the equator. Capo-chichi et al (2003) studied the effect of interactions of genotype vs. environment on L-DOPA concentration in various *Mucuna* accessions and found that the latitude has a major influence in some accessions. At all the geographical locations studied, the early maturing accession (Rajada) possess least L-DOPA (2.4-4.4%) followed by similar Ghana accession (3.1%-5.6%), while late maturing accessions possess the higher quantities (e.g. *Mucuna cochinchinensis*, 5.4%; *Mucuna deeringiana*, 5.4%; *Mucuna preta*, 5.5%; *Mucuna utilis*, 5.2%).

### Protease inhibitors

Those compounds, which suppress the proteolytic activity of digestive enzymes, are considered as protease inhibitors (e.g. trypsin/chymotrypsin). Presence of protease inhibitors in diet cause considerable decrease in the digestibility of dietary protein due to the formation of irreversible trypsin and trypsin inhibitor complexes. The trypsin and chymotrypsin inhibitor activity in two black and three white seed accessions of *Mucuna pruriens* var. *utilis* of different regions of the Western Ghats of India have been studied by Gurumoorthi et al (2003b). Generally, black seed accessions showed higher trypsin and chymotrypsin inhibitor activity than white seed accessions (trypsin: 48.20-49.60 vs. 45.20-46.10 TIU/mg; chymotrypsin: 28.7 and 30.1 vs. 26.2 and 27.1 CIU/mg). Ravindran and Ravindran (1988) reported high anti-tryptic activity (2170 TIU/g) in raw seeds of *Mucuna utilis* collected from India. Udedibie and Carlini (1998) also found high concentration of trypisn inhibitors (11865 TIU/g) in seeds of *Mucuna pruriens* var. *utilis* of Brazil. Trypsin inhibitors of 12 *Mucuna* accessions of Nigeria was in the range of 30.81-51.55 TUI/mg (Ezeagu et al 2003) with highest in *Mucuna veracruz* (mottled). However, low trypsin inhibitor activity have also been reported by Carew et al (2002) and Del Carmen et al (2002) (4.71-6.90 TIU/mg) in *Mucuna prurines* seeds grown at the farm of Escuela Agricola Panamericana, Honduras.

**Saponins**

Saponins possess a carbohydrate moiety attached to a triterpenoid or a steroidal aglycone. They form a group of compounds, which on consumption causes deleterious effects such as hemolysis and permeabilization of the intestine (Cheeke 1996, Price et al 1987). Saponins in *Mucuna* seeds ranged between 1.2 and 1.3% (Siddhuraju and Becker 2001a, 2005).

**Phytic acid**

Phytic acid in legumes has been reported to lower the nutritional value due to limiting the bioavailability of dietary minerals and essential trace elements (e.g. iron, zinc, calcium) in human intestine (Brune et al 1992, Ryden and Selvendran 1993, Gustafsson and Sandberg 1995). Vitamin C being an iron absorption enhancer, it is known to counteract the inhibitory effects of phytate in intestine (Siegenberg et al 1991). Siddhuraju et al (2000) reported phytate 1.05-1.22% in dehulled seeds of several germplasms of *Mucuna pruriens*. Siddhuraju and Becker (2001c) also reported phytates content to be 0.9% in raw *Mucuna* seed meal. The seeds of both white and black accessions possess phytates more or less of similar quantity (0.86-0.9%), which is comparable to other conventional legumes (soybean 1.20-1.75; common bean, 0.90-1.69; lupine, 0.76-1.63) (Hídvégi and Lásztity 2002). Ezeagu et al (2003) also studied various accessions of *Mucuna* and found phytates between 0.48 and 0.85%. Phytate phosphorus in 12 *Mucuna* accessions of Nigeria was in the range of 0.07-0.25% with highest in *Mucuna veracruz* (mottled) (Ezeagu et al 2003).

**Polyphenols**

The main concern with phenolic compounds is their ability to decrease digestibility by complexing with dietary proteins. They are known to lower the activity of several digestive enzymes (e.g. a-amylase, trypsin, chymotrypsin, lipase). Phenolics also complex with iron and prevents its absorption (Brune et al 1989, Hurrel et al1999), reduce the absorption of nutrients (e.g. vitamin B12) and cause damage to the mucosa of digestive tract (Liener 1994a). The total phenolics of *Mucuna* seeds varies between 3.1 and 4.9% (Vadivel and Janardhanan 2000, Mohan and Janardhanan 1995). Siddhuraju et al (2000) studied the total phenolics and tannins of different germplasm of *Mucuna* and found high concentration in the black seed accessions (6.1 and 0.55% respectively) than white seed accessions (5.5 and 0.37 % respectively). Tannins belong to the family of high molecular weight phenolics known to strongly bind the proteins and decrease the *in vitro* protein digestibility (Sathe and Salunkhe 1984). Tannins of *Mucuna* seeds generally range between 0.03 and 0.06% (Mohan and Janardhanan 1995, Vadivel and Janardhanan 2000), but high amount of tannin (0.24%) was also reported by Gurumoorthi et al (2003b). As most of the polyphenols and tannins are present in the seed coat than cotyledon (Deshpande et al1982, Ravindran and Ravindran 1988, Singh 1993), decortication of *Mucuna* seeds before using for formulation (cooking or other recipes) will be effective to substantially reduce their concentration.

### Hemagglutinins

Lectins are widely distributed in plant kingdom including legumes and possess high degree of specificity towards sugar component and thus have diagnostic importance. The lectin activity can be evaluated by agglutination tests with erythrocytes, which is due to the interaction of multiple binding sites on the lectin molecule with specific glycoconjugate receptors on the surface of the cell membranes. On ingestion, lectins exhibit unique property to bind carbohydrate-containing molecules and resist digestion (Pusztai 1989). Diets with significant amount of lectins are known to combine with brushborder cell lining and cause non-specific interference with the absorption of nutrients (Liener 1994a). Lectins are also known to induce severe reduction in feed intake and are implicated in the pathogenesis of coeliac disease (Kolberg and Sollid 1985). Siddhuraju et al (1996) reported hemagglutinating activity of *Mucuna pruriens* seed lectins against the human erythrocytes A, B, and O (164, 82 and 14 HU/mg protein respectively). Interestingly, low lectin activity in *Mucuna pruriens* seeds with O compared to A and B groups has been reported (Vijayakumari et al 2002). Surprisingly, Jesse (2000) has reported the absence of hemagglutinating activity in *Mucuna* seeds, wherein the assay was performed using rabbit erythrocytes. Gurumoorthi et al (2003b) studied five *Mucuna* accessions of the Western Ghats of India and reported that white seed accessions possess high haemagglutinating activity with human A blood group (156-162 mg/protein), while all the accession exhibited low haemagglutinating activity against human O blood group. Interestingly, Udedibie and Carlini (1998) reported that seeds of *Mucuna pruriens* of Brazil is devoid of hemagglutinating activity against human (A, B and O), rabbit and pig erythrocytes. Similarly, Machuka (2000) reported the absence of haemagglutination activity against rabbit erythrocytes in seven Nigerian varieties of *Mucuna pruriens*.

### Flatulence factors

Large-scale consumption of seeds of most of the legumes results in flatus. Oligosaccharides are known to be the main compounds responsible for flatus (Reddy and Salunkhe 1980). Such oligosaccharides cannot be hydrolyzed or absorbed in monogastric animals as they lack of a-1,6 galactosidase activity in the small intestine. Thus, microorganisms in the large intestine utilize these oligosaccharides and result in generation of flatus gases (e.g. *Entamoeba histolytica*, *E. hartmanni*). In *Mucuna pruriens*, verbascose has been considered as the main oligosaccharide responsible for flatus (Vijayakumari et al 1996).

### Melanin

Melanin in seeds is responsible for negative health effects (Dollery 1999, Hegedus 2001). It has been predicted that melanin may be present in *Mucuna* seeds even after processing. For instance, cooking or soaking in water with sodium bicarbonate resulted in darkening, which is presumed to be due to conversion of L-DOPA into melanin (Nyirenda et al2003). Hence, future studies may be directed towards alkaline additives in minimizing and understanding the conversion of L-DOPA into melanin.

## Seed processing

Edibility of *Mucuna* seeds is dependent on the heat labile antinutritional factors (Arnold et al 1971). Most of the processing methods employed involve application of heat to eliminate or reduce the level of toxic and inhibitory substances. However, detectable levels of some antinutrients will remain even after thermal treatment (e.g. lectins). Hydrothermal treatments, fermentation and germination have been shown to be most effective in reducing the antinutrients of *Mucuna* seeds (Wanjekeche et al 2003). In West Africa, seeds require extensive boiling and soaking to eliminate some of the toxic constituents before consumption (Carsky et al 1998). Various processing methods have been employed by investigators to reduce the L-DOPA of *Mucuna* seeds. Egounlety (2003) reported decrease of L-DOPA after pretreatment of *Mucuna pruriens* var. *utilis* seeds. Raw *Mucuna* seeds showed initial L-DOPA up to 6.36%, which was reduced to 4.71% on boiling for 45 min followed by dehulling. Similarly, other treatments also showed significant reduction of L-DOPA (boiling, 45 min + dehulling + soaking, 12 hr reduced L-DOPA to 2.29%; boiling, 45 min + dehulling + soaking, 12 hr + re-soaking, 12 hr reduced to 1.36%; boiling, 45 min + dehulling + soaking, 12 hr + re-soaking, 12 hr + re-boiling, 45 min reduced to 0.64%). Wanjekeche et al (2003) reported that boiling the whole mature seeds of *Mucuna pruriens* in alkaline solution known as 'Magadi soda' (hydrated sodium carbonate) reduced L-DOPA by 59.3% (5.75% vs. 2.34%), while boiling in cob ash, citric acid and bean stover ash solution reduced it by 58.1, 49.7 and 47.4% respectively (5.75 vs. 2.81, 2.89, 3.02%). Boiling seeds in water or germination up to 5 and 7 days followed boiling, reduced L-DOPA up to 24.9 and 38.5% respectively.

Diallo and Berhe (2003) demonstrated two ways to reduce L-DOPA of *Mucuna* seeds: (i) cracking the seeds and soaking them in running water (from a faucet) for 36 hr; (ii) placing whole seeds in a cloth bag and leaving them immersed in a flowing river for three days. The results revealed that cracking *Mucuna* seeds followed by leaching removed L-DOPA faster than whole seeds. Leaching of cracked and whole seeds in running water via faucet up to 48 hr decreased L-DOPA up to 0.08 and 1.60% respectively (control: whole seeds, 4.93%; cracked seeds, 4.33%). Bressani et al (2003) evaluated the impacts of a variety of processing methods to reduce L-DOPA and trypsin inhibitors of *Mucuna* seeds. Soaking for 96.5 hr at 22°C resulted in 70% retention of L-DOPA, while the retention decreased to 51% at 45°C and 27% at 66°C after 96.5 hr of soaking, indicates that water temperature plays a significant role in reduction. The L-DOPA was significantly reduced on replacing the soaked water periodically. In white and mottled seeds of *Mucuna*, soaking and periodically changing water (60°C) resulted in reduction of L-DOPA up to 22-30% of the initial value within 48 hr. Nyirenda et al (2003) studied the effects of different processing methods suitable for household and community level preparations (soaking, boiling, soaking + boiling, with or without sodium bicarbonate) on L-DOPA of *Mucuna* seeds. Raw seeds possessed initial L-DOPA of 3.75, 3.90 and 4.36% for white, speckled and black seeds respectively, while pre-soaked speckled beans possessed an initial level of 4.02%. Soaking grits (1.5 l) + boiling (1.5 l) followed by soaking in (1.5 l) for 24 hr in the presence of sodium bicarbonate (0.25%) extracted approximately 90% of L-DOPA (4.02% vs. 0.39%). Similar treatment to whole seeds reduced L-DOPA up to 67%. Soaking grits (24 hr in 3 l water without sodium bicarbonate) reduced L-DOPA up to 54% (4.02 vs. 1.86%). However, in the absence of sodium bicarbonate, boiling the whole seeds and grits without soaking in water reduced L-DOPA only up to 48.5% (4.02 vs. 2.07%) and up to 57% (4.02 to 1.72%) respectively. Bressani et al (2003) have concluded that, even though combinations of boiling, treating with sodium bicarbonate and soaking reduced L-DOPA, boiling alone was the best method for removal in *Mucuna* seeds. At International Institute of Tropical Agriculture (IITA), Benin, a recipe for the preparation of detoxified *Mucuna* flour has been developed, wherein L-DOPA was totally absent and the incorporation of these detoxified flours was appreciated by the locals (Versteeg et al 1998).

Various processing methods have been tried by investigators to reduce L-DOPA of *Mucuna* seeds. Most of the methods employed were based on the use of water, chemicals and thermal treatments (Bressani 2002, Diallo and Berhe 2003, Gilbert 2002). Siddhuraju et al(1996) found dry treatments to be most effective in reducing L-DOPA in *Mucuna* seeds and attributed the reduction to racemization under roasting. Dossa et al (1998) also showed that grilling was a better technique than cooking in reducing L-DOPA concentration. Garcia Echeverria and Bressani (2006) studied the effects of various cooking treatments (microwave, vapor, in various water solutions at pH 3, 6, 7, 9 and 11 and by cooking in alkaline condition using sodium hydroxide/potassium hydroxide/calcium hydroxide) on the reduction of L-DOPA in *Mucuna* seeds. Their results indicated that none of the treatments used were effective in eliminating L-DOPA of *Mucuna* except for calcium hydroxide treatment at pH 9 with washing in hot water (reduction up to 80.4%).

Ukachukwu and Obioha (2000) reported that boiling of *Mucuna cochinchinensis* up to90 min ($100\text{-}105^{o}C$) failed to eliminate all of the haemagglutinating activities. Excessive heating of some legumes may ensure the removal of haemagglutinins, unfortunately such practices lower the protein availability as well as protein digestibility (Kakade and Evans 1965). Cooking and autoclaving are known to reduce the hemagglutinating activity up to 89-99% (Vijayakumari et al 1996). Cooking of seeds of *Mucuna cochinchinensis* up to 3 hr (at 100°C) eliminated the haemagglutinin activity (Onwuka 1997).

Moisture in seeds plays an important role in the destruction of trypsin inhibitors (Liener and Kakade 1980). Udedibie and Carlini (1998) showed that trypsin inhibitors could be completely inactivated in *Mucuna* seeds on cooking (1 hr, at 96°C). Complete elimination of trypsin inhibitor activity was achieved at 48 hr of soaking in water followed by 30 min cooking. Toasting of the seeds was unsuccessful in complete elimination of trypsin inhibitors, wherein only 42% eliminated against control (6979 vs. 11865 TIU/g). Antitryptic activity in raw seeds of *Mucuna utilis* (2170 TIU/g) was totally eliminated on cooking (Ravindran and Ravindran 1988). Bressani et al (2003) showed that germination and malting significantly decrease trypsin inhibitor activity (2 days vs. 6 days; 1.88 vs. 0.82 TUI/mg). They also demonstrated that roasting of *Mucuna* seeds reduced the trypsin inhibitors significantly (raw vs. 30 min roasting; 18.90 vs. 1.58 TUI/mg). Wanjekeche et al (2003) reported that trypsin inhibitor was reduced up to a greater extent (89.7%) on boiling the seeds in water (27.18 vs. 2.80 TIU/mg). Germination up to 5 and 7 days resulted in reduction of trypsin inhibitors up to 84.5 and 85.4%.

Autoclaving and cooking of pre-soaked *Mucuna* seeds in different solutions resulted in significant decline in phytate content (27-34% and 38-51%) (Siddhuraju and Becker 2001c). Both dry heat treatment and autoclaving reduced the phytic acid in the seeds of *Mucuna pruriens* (36% and 47%) (Siddhuraju et al 1996). Soaking in distilled water is also more effective in decreasing phytic acid of *Mucuna pruriens* seeds than soaking in sodium bicarbonate solution (Vijaykumari et al 1996). Seed processing techniques (e.g. soaking, germination, hydrothermal processing, fermentation) increased cereal and legume enzyme activity. For instance, seed germination resulted in activation or synthesis of phytase and lactic acid fermentation is favourable for cereal phytase activity (Sandberg 2002). Phytic acid was reduced more on soaking seeds in distilled water than sodium bicarbonate solution (27 vs. 17%), following cooking up to 90 min and autoclaving up to 45 min resulted in further decline of phytic acid (18 and 44%).

Cyanide, an antinutritional component of legume seeds can be eliminated on soaking and removal of testa before boiling. The hydrogen cyanide (HCN) is significantly reduced during dry heat treatment (67%) and autoclaving (68%) *Mucuna pruriens* seeds (Siddhuraju et al 1996). Ravindran and Ravindran (1988) opined that cooking significantly reduce HCN in seeds of *Mucuna utilis*. Cooking reduces the cyanide content up to 46%, while autoclaving up to 75%. Cooking is a safe method to eliminate toxicity in legume seeds because it destroys the enzyme linamarase at 72°C, but not the glucoside. Most of the liberated HCN was lost through volatilization during cooking and cyanide is rapidly converted to thiocyanides or other compounds (Montgomery 1980).

Siddhuraju et al (2000) reported a significant reduction in total phenolics (up to 80%) in *Mucuna* seeds by dehulling or by soaking followed by irradiation. Vijayakumari et al (1996) studied the effects of soaking, cooking and autoclaving on some of the antinutritional features of seeds of *Mucuna pruriens*. Total free phenolics showed significant reduction in soaking sodium carbonate solution (56%) than in distilled water (47%). Autoclaving up to 45 min significantly reduced the tannins (71%). They recorded significant reduction in hemagglutinin activity against human blood groups (A, B and O) through cooking and autoclaving.

Agbede and Aletor (2005) reported the impacts of several methods of processing on the antinutritional features of *Mucuna pruriens* seed flours. The lectin was completely eliminated by dehulling + cooking and dehulling + roasting than raw seeds (4.0 HU/mg). Autoclaving (raw or dehulling), dehulling + roasting and dehulling + soaking in urea completely removed trypsin inhibition activity of raw seeds (25.3 mg/g). Phytin and phytin phosphorus were highest in raw *Mucuna* seeds (15.3 and 4.3 mg/100 g) and lowest in dehulled + roasted seed flours (6.0 mg/100 g). The cyanide content, averaged 18.6 mg/kg in raw seeds was not detected after roasting or dehulling + roasted samples.

## Pharmaceutical importance

## Medicinal properties

All parts of *Mucuna* plant are known to possess high medicinal value (Caius 1989, Warrier et al 1996). *Mucuna pruriens* has been reported to contain several useful phytochemicals (Morris 1999). The alkaloid screening resulted in the confirmation of the presence of 5-methoxytryptamine in all the samples tested and serotonin confined to fresh leaves and stems (Szabo 2003). Various compounds present in pods, seeds, leaves and roots of *Mucuna* includes: bufotenine, choline, N,N-dimethyltryptomine, 5-oxyindole-3-alkylamines, indole-3-alkylamine and B-carboline (Ghosal et al 1971). Gupta et al (1997) reported the antiepileptic and antineoplastic activity of methanol extract of *Mucuna pruriens* roots. Roots of *Mucuna* are used in Ayurveda and in indigenous medicines to relieve constipation, nephropathy, strangury, dysmenorrhoea, amenorrhoea, elephantiasis, dropsy, neuropathy, consumption, ulcers, helminthiasis, fever and delirum. The leaves are aphrodisiac, anthelmintic and useful in treating ulcers, inflammation, helminthiasis, cephalalgia and general debility. *Mucuna* pod hairs are blended with honey and are used as vermifuge. The paste prepared from pod hairs are also used as stimulant and mild vesicant (Sastry and Kavathekar 1990). *Mucuna birdwoodiana* seeds are also used to treat joint pain and irregular menstruation (Ding et al 1991). Seeds of *Mucuna* are prescribed as powder to treat leucorrhoea, spermatorrhoea and wherever aphrodisiac action required (Nadkarni 1982). Seeds possess anabolic, androgenic, analgesic (pain-relieving), anti-inflammatory, anti-Parkinson's, antispasmodic, antivenin, aphrodisiac, febrifuge (fever reducing), hormonal, hypocholesterolemic (cholesterol lowering), hypoglycemic, immunomodulator, nervine (nerve balancing), neurasthenic (nerve pain relieving), antilithic (kidney stones preventing or eliminating), antiparasitic, cough suppressant, blood cleanser, carminative (gas expelling), central nervous system stimulant, diuretic, hypotensive (blood pressure lowering), menstrual stimulant, uterine stimulant and vermifuge. There are a number of value-added phytochemicals of *Mucuna* seeds of medicinal importance (e.g. alkaloids, alkylamines, arachidic acid, behenic acid, betacarboline, beta-sitosterol, bufotenine, cystine, dopamine, fatty acids, flavones, galactose, gallic acid, genistein, glutamic acid, glutathione, glycine, histidine, hydroxygenistein, 5-hydroxytryptamine, methionine, 6-methoxyharman, mucunadine, mucunain, mucunine, myristic acid, niacin, nicotine, prurienidine, prurienine, riboflavin, saponins, serine, serotonin, stearic acid, stizolamine, threonine, trypsin, tryptamine, tyrosine, valine, vernolic acid).

*Mucuna* seeds are in high demand in international market after the discovery of L-DOPA, which serves as a potential drug as anti-Parkinson's disease (Farooqi et al 1999) and provides symptomatic relief (Nagashayana et al 2000). *Mucuna* seeds produce hypoglycemic effect and the fruits possess a weak neuromuscular blocking effect in rats but not in alloxan-treated rats (Joshi and Pant 1970). Presence of bioactive alkaloids such as nicotine, physostinginine and serotonin in the *Mucuna* seeds has been reported by Duke (1981). Mucunine, mucunadine, prurienine and prurieninine are the additional four important alkaloids isolated from seed extracts (Mehta and Majumdar 1994).

## Antinutrients in health

Besides typical medicinal properties, several antinutritional compounds of *Mucuna* seeds serve in health care in a variety of ways. Considerable interest has been drawn recently towards their antioxidant activities and potential health benefits. Epidemiological studies have correlated the consumption of plant produce with high phenolics to reduction of cardio-cerebrovascular diseases and cancer mortality (Hertog et al 1997). Polyphenols are important phytochemicals due to their free radical scavenging and *in vivo* biological activities as reported by many investigators (Rice-Evans et al 1996, Bravo 1998). Tannins are also known to possess health benefits, wherein they are 15-30 times more efficient in free radical quenching activity than Trolox and other simple phenolics (Hagerman et al 1998).

The phytic acid of *Mucuna* possesses antioxidant, anticarcinogenic and hypoglycemic activities (Graf and Eaton 1990, Rickard and Thompson 1997, Shamsuddin et al 1997) and are effective at low concentrations. Saponins are recently shown to have hypocholesterolemic as well as anticarcinogenic effects (Koratkar and Rao 1997). Cholesterol lowering effect in animals and humans through the formation of mixed micelles and bile acids into miceller bile acid molecules by saponins have been reported by Okenfull et al (1984). Liener (1994b) reported that the protease inhibitors in *Mucuna* seeds enhance the pancreatic secretary activity.

## Experimental evidence

### L-DOPA

Cell suspension cultures of seeds of *Mucuna pruriens* accumulate L-DOPA (Pras et al 1993). Paul and Joseph (2001) studied the effects of seeds of *Mucuna urens* on the gonads and sex accessory glands of male guinea-pigs and showed the presence of potential male antifertility agent. Due to the presence of L-DOPA, *Mucuna pruriens* serve as a precursor of neurotransmitter and thus used as aphrodisiac and prophylactic agent in patients suffering from oligospermia to elevate the sperm count and improve the ovulation in women. As L-DOPA acts as a nervine tonic, it prevents male and female sterility. The effectiveness of using *Mucuna* seed powder over synthetic L-DOPA has been established by clinical trials (Hussain and Manyam 1997). However, some reports reveal that administration of L-DOPA have some serious side effects in patients suffering Parkinson's disease (e.g. confusion state, hallucination, nausea, vomiting, anorexia) (Infante et al 1990, Reynolds 1989). *Mucuna* plants are known to resist most of the pest-caused diseases due to high amount of L-DOPA (Takahashi and Riperton 1949).

### 'Speman'

It is a polyherbal formulation consisting of *Argyreia speciosa, Asteracantha longifolia, Lactuca scariola, Leptadenia reticulate, Mucuna pruriens, Orchis mascula, Parmelia perlata, Tribulus terrestris* and Suvarnavanga. A study was conducted on 50 male patients having idiopathic infertility to evaluate the efficacy of Speman in the management of male subfertility. The results confirmed that Speman improves the sperm count including the morphology and physiological motility of sperms. Clinical trials conducted in patients with infertility confirmed that Speman facilitates in assisted conception (Kumar 1979, Mukherjee et al 2003).

### Antioxidants

Alcoholic extracts of *Mucuna pruriens* seeds have been studied for antioxidant properties by *in vitro* and *in vivo* methods by Tripathi and Upadhyay (2002). The *in vitro* evaluation in rat liver homogenate to understand the chemical interaction of various phytochemicals with different species of free radicals revealed no changes in the rate of aerial oxidation of GSH (reduced form of glutathione), but it significantly inhibited $FeSO_4$-induced lipid peroxidation with inhibition of superoxides and hydroxyl radicals. The *in vivo* tests using albino rats up to 30 days revealed no toxic effect on oral administration up to a dose of 600 mg/kg body weight. Similarly, no impact was seen on the level of TBA-reactive substances, reduction in glutathione level and superoxide dismutase (SOD) activity in the liver. The activity of serum GOT, GPT and alkaline phosphatase was also unaltered. With these observations, Tripathi and Upadhyay (2002) concluded that the alcohol extract of the seeds of *Mucuna pruriens* has an anti-lipid peroxidation property, which is mediated through the removal of superoxides and hydroxyl radicals. Siddhuraju and Becker (2003b) compared the antioxidant activities of methanolic extract of *Mucuna pruriens* var. *utilis* and several non-protein amino/imino acids: L-DOPA, L-3-carboxy-6,7-dihydroxy-1,2,3,4-tetrahydroisoquinoline (compound I), (-)-1-methyl-3-carboxy-6,7-dihydroxy-1,2,3,4-tetrahydroisoquinoline (compound II) and 5-hydroxytryptophan (5-HTP) and with synthetic antioxidants (BHT and BHA) and quercetin. They found that all the tested compounds and seed extract significantly potent in free radical-scavenging against α, α-diphenyl-β-picrylhydrazyl (DPPH) radicals. Hydroxyl and superoxide anion radicals were effectively scavenged by the tested compounds. Among the non-protein amino/imino acids and seed extract, the highest peroxidation-inhibiting activity was recorded for 5-HTP (up to 95%). Interestingly, in linoleic acid/β-carotene-bleaching system, L-DOPA, compound I and compound II served as pro-oxidants, while seed extract showed only weak antioxidant activity as in linoleic acid emulsion. Rajeshwar et al (2005a) investigated the antioxidant activities of methanol extract of seeds of *Mucuna pruriens* in various *in vitro* models by measuring the hydrogen donating ability in the presence of DPPH radical. Methanol extract at 100 µg/ml revealed an inhibition of up to 90.16% and the $IC_{50}$ was 38.5 µg/ml. The effect of methanol extract on reducing power was studied based on the reaction of ferric ($Fe^{+3}$) to ferrous ($Fe^{+2}$) revealed that the reducing power of the extract increases with the elevated concentration. Rajeshwar et al (2005a) concluded that the methanol extract of seeds of *Mucuna pruriens* showed strong antioxidant activity through inhibiting DPPH and hydroxyl radical, nitric oxide and superoxide anion scavenging, hydrogen peroxide scavenging and reducing activities compared with different standards such as L-ascorbic acid, curcumin, quercetin and α- tocopherol.

**Antitumor activity**

Rajeshwar et al (2005b) evaluated the antitumor and *in vivo* antioxidant status of the methanol extract of *Mucuna pruriens* seed in Ehrlich Ascites Carcinoma (EAC) tumor bearing mice. The methanol extract treated animals at the doses of 125 and 250 mg/kg showed significant reduction of tumor volume, packed cell volume (PCV), tumor (viable) cell count and restored the hematological features. The extract was also successful in restoring to near normal levels of hepatic lipid peroxidation, free radical scavenging enzyme (GSH) and antioxidant enzymes (SOD and CAT) in tumor-bearing mice.

**Antibacterial activity**

The tissues of *Mucuna monosperma* (e.g. leaf, stem, seed kernel, fruit coat) showed antibacterial activity against *Bacillus cereus*, *Escherichia coli*, *Proteus vulgaris* and *Staphylococcus* (Manjunatha et al 2006). The wound-healing potency of methanolic extracts of stem bark, seed kernel and leaves of *Mucuna monosperma* also been reported by Manjunatha et al (2005). The stem bark and seed kernel extracts showed significant wound-healing potential in Swiss Wistar rats, which was evident by decrease in the epithelialisation, increase in wound-contraction, skin-breaking strength, dry weight of granulation tissue and the quantity of hydroxyproline. Wound-healing potential has been attributed to the presence of several phytochemicals such as flavonoids, triterpenoids, tannins and sterols of *Mucuna* seeds.

## Toxins and toxicity

Presence of mutagenic or carcinogenic substances in any of the edible legume is of major concern. Even though Versteeg et al (1998) indicated such fears in *Mucuna*, no scientific literature were available on the presence of any of the mutagenic or carcinogenic substances. Recently, Burgess et al (2003) examined for the presence of some tumerogenic substance in heated/roasted seeds of *Mucuna pruriens* through literature search, Ame's test and chromatographic studies. The search revealed no 'known carcinogenic' substances in *Mucuna* that have been listed in Europe and US. No articles in the Medline database were available which link the word '*Mucuna*' to the terms such as 'cancer', 'tumor' or 'mutagen'. The search for benzo [a] pyrene, a known carcinogenic polycyclic aromatic hydrocarbon in heated seed samples by GC-MS revealed its absence. The results of the Ame's test also showed that both raw and roasted *Mucuna* seeds did not possess any mutagenic agents.

Presence of hallucinogenic indoles (e.g. *N*-*N*-dimethyltryptamine, bufotenine, serotonin), the major antinutritional compounds in *Mucuna* apart from L-DOPA assume importance (Ghosal et al 1971). These compounds have been reported in all parts of *Mucuna pruriens* (pods, seeds, leaves and roots) (Ghosal et al 1971). Szabo and Tebbett (2002) confirmed the presence of tryptamine derivatives in *Mucuna* tissues through liquid chromatographic techniques. Serotonin, a natural constituent in plants (e.g. pineapples, banana) is a well known mammalian neurotransmitter, which has wide impacts on nerves, smooth muscles, respiration, heart and cardiovascular systems. Szabo (2003) assayed five related alkaloids (tryptamine, serotonin, *N-N*-dimethyltryptamine, 5-methoxy- dimethyltryptamine and bufotenine) in tissues and seed samples of 20 accessions of *Mucuna* by liquid chromatography and mass spectra (LCMS). The study revealed that neither tryptamine nor *N-N*-dimethyltryptamine were found in any of the samples analyzed ($<0.05$ µg/g). Bufotenine was present in low concentration in seeds (1.48 µg/g), while average quantity of 5-methoxy-dimethyltryptamine in seeds was 0.64 µg/g. Based on these observations, it was concluded that most of the tryptamine derivatives are characterized by poor absorption, rapid peripheral metabolism and active only in the presence of oxidase inhibitors. Presence of low amount of indolealkylamines does not affect the nutritional potential of *Mucuna* seeds. Consumption of *Mucuna* seeds has been linked to aphrodisiac conditions, emetics and poisoning by Duke (1981) and Ukachukwu (2000).

Fungal and mycotoxin contamination is also of main concern to minimize the economic losses and reduce the potential health risks to humans and livestock (Ueno 2000). Reports on fungal contamination and mycotoxins of *Mucuna* seeds are scarce except for a study by Roy et al (1988), who isolated five *Aspergillus flavus* in *Mucuna pruritia* seeds, which were capable of producing aflatoxin (1.16 mg/g).

The toxicity on consumption of *Mucuna* seeds and their preparations results in dizziness, diarrhea, pathologic changes in organs, growth depression and death (Hashim and Idrus 1977, Ene-Obong and Carnovale 1992, Emenalom and Udedibie 1998). The toxicity of *Mucuna* seeds (*Mucuna cochinchinesis*) on blood profile, carcass characteristics and pathological changes were studied on feeding 153 week-old broilers for a prolonged duration (Ukachukwu et al 2003). The diets were formulated to contain 0, 2, 4, 8 and 16 g *Mucuna*/kg feed and feeding experiments revealed significant reduction of RBC, PCV and haemoglobin. Based on the carcass characteristics, liver was the only organ affected, its weight was significantly depressed and lesions of the liver at all the stages of slaughter were seen. No significant differences were seen among in the percent weights of most of the organs at all the slaughter stages. Thus, Ukachukwu et al (2003) concluded that incorporation of seeds of *Mucuna cochinchinensis* in the diet of birds did not affect relative meat yield at any of the slaughter stages and the toxicity is mainly due to the haemagglutinating activity (4267 HU/g).

## Conclusions

- The wild legume, *Mucuna* occurs naturally in a wide variety of tropical geographical conditions.
- *Mucuna* seeds are promising nutraceutically-valued natural plant produce that needs further exploration for its improvement and utility in rural development.
- Although seeds of some varieties are used in traditional medicine, as food and the whole plant as forage and pasture, no specific interest has been shown to develop genetically the elite germplasm.
- Safe levels of consumption of *Mucuna* and their products by livestock need to be standardized.
- Presence of stinging hairs is an undesirable agronomic trait of *Mucuna* plants, which has to be eliminated for ease of domestication of the germplasm through breeding.
- Application of fungal enzymes for reduction of antinutrients and improvement of flavours need to be initiated.
- Development of new food products through blending *Mucuna* seeds flours with other unconventional legumes can be investigated.

- Application of modern methods of preservations (e.g. radiation processing, modified atmospheric packaging) will be important for storage and improvement of shelf life of *Mucuna* and their products.

- Cultivar differences are known to occur in the quantity of L-DOPA and lectin of *Mucuna* seeds and these differences could be exploited to select low L-DOPA and low lectin germplasm for human and animal consumption, while high L-DOPA for pharmaceutical purpose.

- New and inexpensive means of processing techniques have to be applied to use *Mucuna* as food, fodder and to exploit the phytochemicals at industrial scale.

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