Mucuna as a Food and Feed Crop: An Overview

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Abstract

A number of species of the genus *Mucuna* have been used as food or feed. This paper reviews such uses as well as factors impacting *Mucuna*'s potential as a food and feed. *Mucuna* has been used as a minor food crop in a number of African and Asian countries, and its use as a feed was extensive particularly in southern USA in the first half of the 20th century. A number of anti-nutritional compounds commonly found in beans are also present in *Mucuna* but their concentrations are typical and they are therefore not expected to pose a limitation to its use as a food or feed. However, *Mucuna* also contains L-Dopa (3,4-dihydroxy-L-phenylalanine) and a number of other compounds which have given rise to its medicinal uses, notably that of L-Dopa for Parkinson's disease. *Mucuna*'s L-Dopa concentrations are variable (typical range reported 3-6%) and little is known of the impact of

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environmental and genetic factors on the concentration. Few studies have documented the presence and quantity of other toxic compounds in *Mucuna*. However, some research has been conducted on factors impacting *Mucuna*'s potential as a food and feed, and future efforts should build on such research.

1. Introduction

Mucuna is no newcomer in the pots cooking over fires throughout the tropics, nor has it been untested in tropical, and even temperate, pastures and feeding stalls. Though in the past decade the majority of research and extension efforts on *Mucuna* have focused on its soil-improving qualities, it has been used as a food and feed in a number of countries throughout the globe. Its most extensive utilization has seemingly been as a feed crop in the first part of the 20th century in the southern United States, where it was cultivated on over 1.5 million hectares and became a landscape feature for decades. Its properties as a feed crop have been investigated formally for over one hundred years, and its quality as a food crop has also received the attention of food scientists and development workers over the past decades.

This paper discusses issues that are relevant to *Mucuna*'s food and feed uses, ranging from its taxonomy and ecological adaptation to its nutritional qualities and anti-nutritional factors, from its historical and present uses as food and feed crop to research and development efforts on its potential as food and feed. The objective of this paper is to present an overview of these issues to provide a context for the focused workshop papers presented later in this volume. Workshop papers providing more specific information on a particular topic are referred to throughout the text, and certain papers may be referred to in multiple locations as appropriate.

2. *Mucuna*: The Plant

The genus *Mucuna* belongs to the family Fabaceae (Leguminosae) and includes up to 150 species of annual and perennial legumes of pantropical distribution. It is thought to originate from China, Malaysia, or India. The most commonly cultivated varieties are vigorously growing, twining annual legumes.

Many scientific names have been proposed to identify the various cultivars of *Mucuna*, often referred to by seed color and by the origin of the seed, leading to taxonomic confusion. Indeed, seemingly no modern institution may surpass the knowledge that many early-century researchers working in the southern United States had of agronomic, botanical, and taxonomic characteristics of different *Mucuna* accessions.[10] However, it is now well accepted in the taxonomic community that most cultivars of *Mucuna* belong to the species *M. pruriens* (see for instance Kay, 1979; Wilmot-Dear, 1984 and 1991). Two main varieties are encountered, *M. pruriens* var. *pruriens*, known for its particularly itching hairs on the pods, and *M. pruriens* var. *utilis*, similar in shape, but possessing velvety pods, hence the frequently used English common name, velvetbean. For obvious reasons, the *utilis* types have become more popular in agricultural practices. Taxonomy of *Mucuna* is discussed in more detail by St-Laurent *et al.* (this volume).

Many common names are used for *Mucuna* (e.g., velvetbean, *pica-pica*, bengal bean, *nescafé*, *ojo de venado*, *pois mascate*, *kara benguk*, *olhos de burro*) (Weber *et al.*, 1997; Faridah Hanum and van der Maesen, 1996). One of its Sanskrit names, *atmagupta*, ("having hidden properties"), seemingly denotes its importance as a medicinal plant while another, *kapikachchhu* ("monkey's itch"), refers to the unpleasant characteristic of its many accessions (Hamdard, 1972).

[10] Large-scale efforts to collect *Mucuna* accessions worldwide were started in 1906 by the United States Department of Agriculture, and resulted into twenty *Mucuna* accessions obtained by 1909; Piper (1910) gave detailed descriptions of nine of these in 1910. Breeding efforts began in 1908. Scott (1919) described six varieties, two of which are hybrids, and listed a number of articles on breeding efforts on *Mucuna*. In Georgia, breeding work continued until the 1940s (G. Prine, personal communication).

Modern *Mucuna* characterization is ongoing on several fronts. A Ph.D. project utilizing molecular techniques and working with the the cultivated species is underway[11]. Characterization of variability in such characteristics as photoperiod and thermal responses and maturity cycle are underway by various researchers in the UK (Keatinge *et al*.; 1996, Qi *et al*., 2000). Researchers in southern India have characterized local *Mucuna* species and accessions for agronomic and nutritional factors (Janardhanan and Rajaram, 1993; Janardhanan, 1990). Still a great deal remains unknown regarding the variability in a number of characteristics of the cultivated *Mucuna* factors that greatly impact its potential as a food, feed, and green manure/cover crop. In this volume, Temple and Huyck discuss the potential of breeding *Mucuna* and the considerations that need to be taken into account in any future breeding work.

Mucuna is adapted to a wide range of environmental conditions, contributing to its popularity as a green manure/cover crop. It grows best in warm, humid conditions, and in altitudes below 1600 m. It is adapted to a wide variety of soils, typically nodulates well and throughout its range, has been relatively free of disease and pests, a characteristic that has been attributed to its L-Dopa content (Janzen, 1971; Rehr *et al*., 1973).

Various studies have confirmed *Mucuna*'s high biomass production and its ability to both fix and recycle large amounts of nitrogen, other factors explaining its success as a green manure/cover crop. In the TROPSOILS program trials in Brazil, *Mucuna* grown during the rainy season produced up to 8.5 t ha^{-1} of aboveground dry matter, containing 252 kg of nitrogen (Lathwell, 1990; Lobo Burle *et al*., 1992). In the Atlantic Honduras, where *Mucuna* has been widely and spontaneously adopted by farmers, Triomphe (1996) measured an average dry matter biomass production of 11.7 t ha^{-1}, containing 295 kg ha^{-1} of nitrogen, 58% of which was in mulch. In farmer-managed fields in Benin, West Africa, Sanginga *et al*. (1996) measured an average N content of 313 kg ha^{-1} in sole-cropped and 166 kg ha^{-1} in inter-

[11] Ph.D. project of Ludovic Capo-chichi at the University of Auburn, Alabama, USA.

cropped conditions. In this volume, R. Gilbert reports on research results from Malawi, where *Mucuna*'s potential as a soil improver is demonstrated.

The use of *Mucuna* as food and feed as well as research conducted on these themes are briefly reviewed in the following pages. Due to the relatively scanty literature on the topic, as well as the possibility of taxonomic confusion, this review will focus on different species in the genus *Mucuna*.

3. *Mucuna* As Food and Feed

Mucuna has been used as food and feed in a large number of countries where it has been introduced. Where *Mucuna* is consumed by humans, it is typically the beans that are consumed, though in some areas immature pods and leaves have also been eaten. For animal feed, both beans and foliage have been utilized. As a food crop, it has typically maintained a minor status, while as a feed it has been tested and proven on large scale, especially in the southern United States during the first half of the century. Its potential as a food and feed are affected by two opposing forces: on the positive side, by its relatively good seed and forage yield and beneficial composition of nutrients and minerals, and on the negative side, by its substantial L-Dopa content and numerous other anti-nutritional compounds.

Though obviously greatly dependent on environmental conditions, cropping system, and management practices (factors contributing to the large variability observed), *Mucuna* generally produces relatively high seed yields. In Florida, Scott (1919; 1946) reported pod yields ranging between 1 and 4 t ha^{-1} with typical pod yields of 3 t ha^{-1}, estimating that 60% by weight is seed. Low *Mucuna* seed yields have been reported in semi-arid northern Cameroon, at 200-250 kg ha^{-1} for a cultivar named *utilis* and 1400 kg ha^{-1} for a cultivar named *cochinchinensis* in the Nigerian savanna zone (Carsky *et al.*, 1998). During the 1998 government seed purchases from smallholder farmers in southern Mexico, seed yields in nine locations grown under intercropped conditions varied between 100 and 1250 kg ha^{-1} (GAC-RED, 1999). Extremely high average seed yields of 2290 kg ha^{-1} were obtained on 1142 sites in Malawi, as reported by R. Gilbert (this volume).

Mucuna seeds are a relatively good source of crude protein and fats (Prakash and Misra, 1987; Rajaram and Janardhanan, 1991; Mohan and Janardhanan, 1995; Ajiwe *et al*., 1997), have a relatively favorable amino acid composition (though certain amino acids are deficient), and contain high amounts of certain minerals, including Ca, Mg, and Fe (Rajaram and Janardhanan, 1991; Mary Josephine and Janardhanan, 1992; Prakash and Misra, 1987). The relatively good nutrient concentration of *Mucuna* is further discussed by R. Bressani (this volume), who compares data on other, commonly used beans to *Mucuna*; in addition, in this volume various other authors report nutrient contents for the *Mucuna* accessions that they have worked with Burgos *et al*., Del Carmen *et al*., Carew *et al*., Flores *et al*., Maasdorp *et al*., Ukachukwu *et al*. (all this volume). Although *Mucuna* leaves as well as young pods seem to have been consumed by certain communities, little information is available on their composition.

Mucuna produces extensive foliage that can be used as forage. *Mucuna* forage in Sri Lanka, when harvested at 90 days, was of moderate quality, containing 20.6% of crude protein and had 55.3% *in vitro* organic matter digestability (IVOMD) (Ravindran, 1988); similar values have been reported in Mexico (Guevara Hernández *et al*., n.d.). A number of species of the genus *Mucuna* have been used as food or feed. This paper reviews such uses as well as factors impacting *Mucuna*'s potential as a food and feed. *Mucuna* has been used as a minor food crop in a number of African and Asian countries, and its use as a feed was extensive particularly in southern USA in the first half of the 20^{th} century. A number of anti-nutritional compounds commonly found in beans are also present in *Mucuna* but their concentrations are typical and they are therefore not expected to pose a limitation to its use as a food or feed. However, *Mucuna* also contains L-Dopa (3,4-dihydroxy-L-phenylalanine) and a number of other compounds which have given rise to its medicinal uses, notably that of L-Dopa for Parkinson's disease. *Mucuna*'s L-Dopa concentrations are variable (typical range reported

3-6%) and little is known of the impact of environmental and genetic factors on the concentration. Few studies have documented the presence and quantity of other toxic compounds in *Mucuna*. However, some research has been conducted on factors impacting *Mucuna*'s potential as a food and feed, and future efforts should build on such research.

3.1. *Mucuna*´s Use As Food

Mucuna has been used as a traditional minor food crop for centuries and is reported to have been used in the eighteenth and nineteenth centuries in the foothills and lower hills of the eastern Himalayas and in Mauritius (Buckles, 1995), as well as in the Philippines, Java, and in Hokkaido, Japan (Piper and Tracy, 1910). In addition to *M. pruriens*, the use of other species of *Mucuna* has been reported.

While traditional use as food continues today in many countries of Asia and Africa, *Mucuna* never seems to have found acceptance as a food in Latin America, despite a one hundred year presence there. In the countries where *Mucuna* has been a traditional food crop, it has become the object of interest for a number of national food scientists, especially in Asia where *Mucuna* originates. In India, where such food uses have probably been studied most in-depth, the beans of various species of *Mucuna* have been reported to be used by a number of ethnic groups: by northeastern and Oceanic tribes such as Onges, Great Anadamans and Xompens (wild species, *M. gigantea*; Rajaram and Janardhanan, 1991) and by Mundari and Davidian groups (*M. utilis*; Mary Josephine and Janardhanan, 1992). The Kanikkars, a hilltribe of Kerala in S. India, have been reported to consume the seed after boiling that is repeated seven times (*M. utilis*; Janardhanan and Lakshmanan, 1985; Mohan and Janardhanan, 1993). In large parts of Sri Lanka, especially low-income groups consume *M. pruriens* after an overnight soaking and long cooking (Ravindran and Ravindran, 1988). *Mucuna*'s use as a minor food crop has also been reported from the Philippines (*M. pruriens* or *cochinchinensis*; Laurena *et al.*, 1994). In Java and Indonesia, *Mucuna* has been widely used in a fermented staple, *tempe*, but soyabean, commonly considered to be more palatable, has largely replaced it in recent decades. Indonesia's recent economic recession has resulted in decreased soybean cultivation and possibly a renewed interest in *Mucuna* (Hairiah[12]).

In Sub-Saharan Africa, *Mucuna*'s use as a minor food crop has been reported from a number of countries. Research efforts on *Mucuna* as a food and feed crop have been particularly active in Nigeria, where use of various species of *Mucuna* has been reported. *M. sloanei* is used, among others, by the Igbosof eastern Nigeria as a condiment or as a part of the main dish (Afolabi *et al*., 1985), *M. urens* as a soup thickener or condiment (Achinewhu, 1984), and *M. flagellipes* as a soup thickener (Onweluzo *et al*.1994); *M. pruriens* is also consumed as a soup and stew ingredient (Ukachukwu *et al*., this volume). In the forest region of Ghana, small amounts of *Mucuna* (*M. pruriens*) are consumed in a daily soup for which beans are boiled for at least 40 minutes, the water discarded, seed coats removed, and the endosperm ground into a fine paste (Osei-Bonsu *et al*., 1995). Ten to fifteen beans are consumed per meal. Immature beans are reportedly preferred due to their reduced cooking time. Food use of *Mucuna* has also been reported from Mozambique (Infante *et al*., 1990), from Zambia (Peterson[13]), from Malawi (Gilbert, this volume). Also in this volume, Ukachukwu *et al*. further discuss the food utilization in West Africa, while Gilbert, and Szabo and Tebbett present detailed methods to prepare *Mucuna* in Malawi, and the resulting L-Dopa levels in the food.

In Latin America, *Mucuna* has not been reported to be consumed traditionally, but in this century it has developed acceptance as a coffee substitute in the highlands of Guatemala and in parts of southern Mexico thereby earning itself a name "nescafe" (Buckles, 1995). In the southern USA, during the first half of the century, no food use seems to have developed, though the early accounts refer to attempts to eat *Mucuna*, at times with ill effects (Piper and Tracy, 1910).

[12] K. Hairiah (personal communication).
[13] J. Peterson (personal communication).

In recent years, *Mucuna*'s potential food uses have become the object of interest of several projects that have promoted *Mucuna* for soil conservation and weed suppression. In Honduras, World Neighbors/CIDICCO/ACORDE (1992) have produced a recipe booklet containing 23 recipes utilizing *Mucuna*, while Derpsch and Florentin (1992) have developed another recipe for processing *Mucuna*. However, use of *Mucuna* as food has not caught on. In this volume, C. Bunch discusses the experience of World Neighbors to promote *Mucuna* as a food crop, and their decision to terminate the project, while M. Price describes the role of ECHO (Educational Concerns for Hunger Organizations) in meeting the information needs of those interested in *Mucuna*'s food potential.

In Africa, several projects have worked on *Mucuna*'s food uses. Perhaps the most influential and largest to date has been in the Republic of Benin, in West Africa, where research efforts led by the International Institute of Tropical Agriculture, accompanied Sasakawa-Global 2000 (SG2000)-funded *Mucuna* promotion efforts by the government's extension service CARDER (Centre d'Action Régionale pour le Développement Rural). The focus of these efforts was the development of *Mucuna* flour with low concentration of L-Dopa to a level that would not be toxic. A recipe was developed that included cracking the seed, two overnight soakings, various water changes, and boiling for at least 20 minutes; such preparation reduced the L-Dopa content from the initial approximately 6 to 0.32-0.42%. As in the suggested recipe for *pâte*, the traditional maize-based staple in Benin, only one-third of the flour was from *Mucuna*, the final L-Dopa content of the *pâte* was only 0.08 to 0.10% (Versteeg *et al.*, 1998). However, toxicologists recommended additional testing for toxic proteins, carcinogenic and mutagenic components, and semichronic, allergic, or immunological effects, especially associated with long-term consumption (Versteeg *et al.*, 1998). More recently, similar efforts have been initiated in the Republic of Guinea, where SG2000 has collaborated with the Ministry of Agriculture in *Mucuna* food promotion, and in Malawi, where a researcher affiliated with the Rockefeller Foundation has been interested in developing the utilization of *Mucuna* as a food. These projects are recounted by Diallo *et al*. and Gilbert in this volume.

During the recent efforts to decrease *Mucuna*'s L-Dopa concentration in foods or feeds, R. Myhrman from Judson College, Illinois, and his students have quantified the L-Dopa concentrations for researchers and development workers worldwide. In this volume, M. Price describes how Judson College became involved in this line of work while R. Myhrman reviews some of the main results obtained.

In both traditional and newly developed recipes of *Mucuna*, the same approaches have been employed for detoxification, namely relatively lengthy or repeated boiling times and discarding of the water. In some recipes, *Mucuna* seeds have also been ground before boiling and *Mucuna* has been diluted with other foods, such as maize. Precautions against excess consumption of *Mucuna* have been seemingly taken in areas with traditional food use, and have been urged during many of the recent efforts.

Perhaps the most detailed published description of the effects of *Mucuna* ingestion on humans is almost 80 years old. Miller *et al*. (1925) described an experiment in which *Mucuna* was eaten both by researchers and several students, "some of whom ate rather freely of them" (p. 1113).[14] After ingestion of *Mucuna* prepared in several different ways, it took about an hour for the various symptoms to develop: "feeling of fullness and heaviness in the stomach, headache, nausea, irritation and restlessness" (p. 1113). Though only one person vomited, the general conclusion was that this was "a horrible feeling that one does not wish to undergo the second time" (p. 1114).

In the case of the newly developed recipes, elimination of toxins has not been complete, and various individuals associated with the projects report side effects such as dizziness after having eaten the *Mucuna* seed (Flores[15], Gilbert[16]). No information is available on the frequency of the incidence of

[14] Two or three students ate 70g of cooked finely ground beans.
[15] M. Flores, CIDICCO (personal communication).
[16] R. Gilbert, University of Florida (personal communication).

such symptoms in areas of traditional use, but poorly processed *Mucuna* is known to have caused symptoms in Java and Indonesia (Hairiah[17]), as well as in Nigeria (M. Eilittä, field notes October 14-15, 2000). No studies or detailed reviews have been conducted to determine safe consumption levels of *Mucuna* foods. For L-Dopa, researchers have suggested levels below 1% (Versteeg *et al*., 1998) or that the daily consumption should not exceed 1500 mg per person (Lorenzetti *et al*., 1998).[18] In this volume, N. Szabo and I. Tebbett discuss the possibility of determining safe consumption levels of L-Dopa, while several articles explore the impact of different processing methods on the level of L-Dopa (e.g., Myhrman; Flores *et al*.; Del Carmen *et al*.; Burgos *et al*.; Balaban and Teixeira; Diallo *et al*.; Gilbert).

In summary, *Mucuna* has been utilized as a minor food crop in several countries in both Africa and Asia. Although such usage has a historical basis, *Mucuna* is still typically viewed only as a minor food crop. Usage has, however, been accompanied by some food science research efforts in a number of institutions located in these areas. Recent efforts on developing *Mucuna*'s food uses have seemingly utilized many of the principles of the traditional recipes (boiling, discarding the water, and grinding), but have not resulted in adoption at any significant scale. Questions regarding antinutritional factors have left researchers and practitioners hesitant to promote *Mucuna*'s food uses. Most of these efforts seem to have taken place in relative isolation from the food science-oriented research in areas with traditional use.

3. 2. *Mucuna*'s Use As Feed

Mucuna has good potential as animal feed. This is evidenced both by research results (Ravindran, 1988), and by its adoption as forage and feed in the first half of the 20th century in the southern USA as well as in various

[17] K. Hairiah (personal communication).

[18] According to Lorenzetti *et al.* (1998) this dose is derived from current European pharmacological literature as maximum tolerable dose without physiological complications for the chronic treatment of Parkinson's disease.

countries of the tropics. The most extensive utilization of *Mucuna* as feed occurred by the smallholder farmers of the southern United States in the first half of the 20th century. Though its feed potential became more widely known only in 1895, when it was brought to the attention of the Florida Agricultural Experimental Station researchers (Clute, 1896), already in 1902, its pods were marketed as cattle, poultry, and pig feed (Miller, 1902), and over 1.5 million hectares were grown at the peak of its utilization in the late 1910s (Buckles, 1995). Though *Mucuna*'s soil improving qualities clearly fostered its adoption, it has been suggested that its use as feed was more important (Buckles, 1995). *Mucuna* was typically intercropped with maize, and its use took on several forms, the most important one being winter grazing. The paper by Eilittä and Sollenberger (this volume) describes the systems utilized, literature on animal performance, and factors that may have made *Mucuna* so adoptable in the southern USA. In current studies, however, *Mucuna* has been observed to cause vomiting and diarrhea when fed in large quantities to pigs (Duke, 1981) and has inhibited or decreased the growth of poultry (Del Carmen *et al*., 1999; Carew *et al*., 1998a; Carew *et al*., 1998b). Studies by Del Carmen *et al*, Carew *et al*., and Flores *et al*. (this volume) all attest to such severe impacts.

Fodder use of *Mucuna* also seemingly extends back in time. Piper and Tracy (1910, citing Voigt, 1845), in reviewing nine *Mucuna* accessions cultivated in the Florida Experimental Station, mention that *Mucuna utilis* had been extensively cultivated in Mauritius as a fodder for cattle. A survey of the reports from the International Institute of Agriculture in the 1930s documents the use of *M. pruriens* as a fodder on the island of Madagascar (Buckles, 1995). *Mucuna* has also been widely used as hay at various locations worldwide, e.g., in Southern Rhodesia in the 1950s (FAO, 1959), and as fodder, hay, or ensilage in Brazil and Argentina (Whyte *et al*., 1953). The paper by B. Maasdorp (this volume) reviews some of these early efforts in Southern Africa where today research on *Mucuna*'s feed properties as, e.g., silage, continues (Titterton *et al*., 1997; Maasdorp *et al*., 1997).

Currently, *Mucuna* finds relatively little use as fodder or feed. However, increased interest in its feed potential has been evident in the 1990s. At the Panamerican Agricultural School, ZAMORANO in Honduras, various research projects focusing on *Mucuna*'s potential as feed for pigs and poultry have been conducted and are reported in this volume (Carew *et al*., Del Carmen *et al*., Burgos *et al*., and Flores *et al*.). Also in West Africa, research has commenced on *Mucuna*'s feed possibilities, both for cattle, pigs, and poultry (CIEPCA, 1999; Iyayi and Egharevba, 1998; Yai, 1998; Ukachukwu and Obioha, 1997a); Ukachukwu *et al*. (this volume) review some of these efforts. In Mexico, research projects on *Mucuna*'s potential as animal feed have taken place in various institutions and have focused on several livestock species. At the Chapingo University's Agroforestry Program, *Mucuna* as rabbit feed has been studied while several NGO projects in Mexico have been executed on *Mucuna* as pig feed. Above, current research efforts on *Mucuna* silage in Zimbabwe are mentioned.

In summary, *Mucuna*'s feed potential has been proven through relatively large-scale utilization throughout the tropics and subtropics; especially notable is its extremely common utilization in the early-century southern United States. Both seeds and pods, as well as the foliage have been utilized in various systems. Currently, *Mucuna*'s utilization as feed is far more limited, though research efforts have been renewed to explore its potential.

4. Limitations to *Mucuna*'s Use as Food and Feed: Anti-Nutritional and Toxic Compounds

Impacts of anti-nutritional and toxic compounds in *Mucuna* range from the mild (such as dizziness) to the drastic, as e.g., in the report of Infante *et al*. (1990) of a 1989 outbreak of acute toxic psychosis during drought in Mozambique, when local people drank *Mucuna* cooking water instead of discarding it. Negative impacts on animals have also been reported. In the study by Salmon (1922), pigeons fed ground *Mucuna* or an aqueous extract of *Mucuna* developed dry and rough-looking feathers and drawnup, sleepy appearance, and many of them died. In another study, Afolabi *et al*. (1985), all rats died within 72 hours when fed a diet containing 10% crude protein from *Mucuna*. Duke (1981) reports that if fed in excessive quantities, *Mucuna* may cause vomiting and diarrhea in pigs. In this volume, various papers describe the negative impact of *Mucuna* on non-ruminant animals (Flores *et al*., Del Carmen *et al*., Carew *et al*.).

It has been commonly assumed that many of the negative impacts from *Mucuna* consumption are caused by the presence of L-Dopa, but *Mucuna* is known to also contain a number of other anti-nutritional compounds. Such compounds, as well as their possible uses, are reviewed below.

4.1 Common Anti-Nutritional Factors

As is common with legumes, a relatively large number of anti-nutritional substances have been found in *Mucuna* seeds. Such compounds include polyphenols or tannins, which can bind with proteins, lowering digestibility (Janardhanan and Lakshmanan, 1985; Mary Josephine and Janardhanan, 1992; Siddhuraju *et al*., 1996; Ravindran and Ravindran, 1988; Laurena *et al*., 1994; Rajaram and Janardhanan, 1991; Guevara Hernández *et al*., n.d.). In *Mucuna*, however, most of the tannins are seemingly located in the seed coat, which are typically discarded in food preparation, rather than in the endosperm (Mary Josephine and Janardhanan, 1992; Ravindran and Ravindran, 1988). Phytic acid, a component of all plant seed, can reduce bioavailability of certain minerals and reduces the digestibility of proteins; several researchers have quantified phytic acid levels in *Mucuna* seed (Ravindran and Ravindran, 1988; Siddhuraju *et al*., 1996; Laurena *et al*., 1994). Cyanogenic glycosides liberate hydrogen cyanide–a well-documented toxin–upon hydrolysis; but fairly low to zero levels of hydrogen cyanide have been found in *Mucuna* (Ravindran and Ravindran, 1988; Siddhuraju *et al*., 1996; Laurena *et al*., 1994). Finally, trypsin inhibitor activity and

L-amylase inhibitor activities have been found in *Mucuna* (Siddhuraju *et al*., 1996; Laurena *et al*., 1994; Ravindran and Ravindran, 1988; Rajaram and Janardhanan, 1991; Del Carmen *et al*., 1999), and *Mucuna* had the third highest level of oligosaccharides of seven legumes evaluated in the Philippines (Revilleza *et al*., 1990). Little research has been conducted on the presence of such factors in *Mucuna* parts other than seeds, though Laurena *et al*. (1994) found very low concentrations of cyanogenic glycosides in immature leaves, and none in mature leaves.

Seemingly, a consensus on these anti-nutritional factors exists among the food scientists who have studied *Mucuna*: due to their relatively low levels as well as heat lability, they do not seem to pose a danger to humans, if proper cooking takes place prior to eating (Siddhuraju *et al*., 1996; Laurena *et al*., 1994; Ravindran and Ravindran, 1988; Janardhanan and Lakshmanan, 1985; Rajaram and Janardhanan, 1991; Mary Josephine and Janardhanan, 1992). In this volume, R. Bressani reviews many of these anti-nutritional factors in *Mucuna* and compares their concentrations to those found in other edible legumes.

4.2 Toxic Substances

Both L-Dopa and other toxic compounds have been found in *Mucuna*. In the following, each will be reviewed from a broad perspective, including its utilization for medicinal purposes.

4.2.1 L-Dopa

L-Dopa (3,4-dihydroxy-L-phenylalanine) is a non-protein amino acid used chiefly in the treatment of Parkinson's disease. Its effects can be both gastrointestinal, including nausea, vomiting and anorexia, and neurological, including aggression, paranoid delusions, hallucinations, delirium, severe depression, and unmasking of dementia (Reynolds, 1989, cited in

Lorenzetti *et al.*, 1998). Physiological effects of L-Dopa are further discussed by Szabo and Tebbett in this volume.

A seeming consensus exists among the food scientists familiar with *Mucuna*, as well as with the recent developers of *Mucuna* recipes, that the intoxication associated with eating *Mucuna* seed is mainly related to L-Dopa (Siddhuraju *et al.*, 1996; Ravindran and Ravindran, 1988). The work by Carew *et al.* (1998a; 1998b; this volume) clearly demonstrates that while L-Dopa ingested at high levels does reduce appetite and growth of chickens it does not produce the other impacts, e.g., on organ growth or blood chemistry, that were observed when raw *Mucuna* was fed to chickens. These effects may be attributable to the mix of antinutritional factors present in the raw bean. Until now, little information has existed on the concentration of L-Dopa in plant parts other than seeds, but two recent reports indicate that such concentrations are relatively low. Prakash and Tewari (1999) measured L-Dopa concentrations in Lucknow, India, which ranged between 0.17-0.35% in leaves, 0.19-0.31% in stems, and 0.12-0.16% in roots of *M. nivea* and *M. utilis*. Similar results were obtained by Szabo and Tebbett (this volume).

The relatively large and consistent L-Dopa concentration in *Mucuna* beans has been well verified. In fact, Daxenbichler *et al.*, (1971, 1972) surveyed a total of 1062 plant species in 160 families, and determined that only *Mucuna*'s L-Dopa content was sufficient to merit extraction for medicinal purposes. In this survey, *Mucuna* seed L-Dopa concentration varied between 3.1 % (in a variety from Georgia) and 6.7 % (in wild *M. holtonii* in Guatemala). Similarly, Bell and Janzen (1971) measured L-Dopa content in six *Mucuna* accessions collected from different locations; their L-Dopa concentration ranged between 5.9 and 9.0%. In a recent review of 36 *Mucuna* accessions collected from India, Benin, Honduras, Mexico and Georgia, USA, the seed L-Dopa content varied from 2.18% to 6.17% (Lorenzetti *et al.*, 1998). Variability was seemingly of both environmental (more L-Dopa near the Equator) and genetic nature (similar concentrations in accessions with same seed color). In India, L-Dopa concentrations up to

9.16% have been measured (Siddhuraju *et al.*, 1996; Janardhanan and Lakshmanan, 1985; Mary Josephine and Janardhanan, 1992), but interestingly, Rajaram and Janardhanan (1991) found low level of L-Dopa, at 1.50%, in the wild *M. gigantea* seed utilized as a food source by several ethnic groups in the south. An L-Dopa concentration of 2.6% has been measured in India for another wild species, *M. atropurpurea* (Mohan and Janardhanan, 1994). In this volume, St-Laurent *et al.* discuss recent findings of the variability in L-Dopa production in different accessions of *Mucuna.*

Researchers in the early 20th century USA pursued issues related to biochemistry of L-Dopa. They understood and were interested in the action of tyrosinase enzyme on L-Dopa (Balaban and Teixeira, this volume), and isolated tyrosinase in the seed coat of *Mucuna* (Miller, 1929). They were also interested in the content of vitamin B in *Mucuna* (Read, 1923), perhaps understanding the alleviating impact that vitamin B has on the symptoms produced by L-Dopa (see Szabo and Tebbett, this volume). These early reports are worthy of an in-depth review to clarify the state of knowledge of the time.

4.2.2. Other Potentially Toxic Compounds

Despite reports on other toxic compounds in *Mucuna*, far less information is available on their presence in different plant parts or species and cultivars. Several researchers have pointed out a need for a study of the toxic compounds present in *Mucuna* (Afolabi *et al.*, 1985; Janardhanan and Lakshmanan, 1985; Lorenzetti *et al.*, 1998). Reports of such toxic compounds include the following:

- Duke (1981) lists nicotine, physostigmine, and serotonin as compounds present in *Mucuna*, without identifying in which fractions such compounds may be present.
- Ghosal *et al*. (1971) reports a number of toxic compounds in a mixture of pods, seeds, leaves, and roots of *M. pruriens*, including bufotenine,

choline, N,N-dimethyltryptamine, two unidentified 5-oxy-indole-3-alkylamines, an unidentified indole-3-alkylamine, and an unidentified B-carboline.

- Lorenzetti *et al*. (1998) found no tryptamines present in the seed of any of the 36 *Mucuna* accessions analyzed.
- In a USDA-led review of the medicinal potential of legumes (Bauer, 1996), *Mucuna* was reported to have bufotenine (reduces cholinesterase enzyme), mucunain (treats parasitic intestinal worms; pesticide), and seratonin (reduces cholinesterase enzyme and intestinal gas; relaxes muscles; clotting agent).
- Prakash and Misra (1987) report serotonin in *Mucuna* pod hairs.

In this volume, Szabo and Tebbett review and present data on the presence of some of these compounds.

4.2.3. Uses for L-Dopa and Other Toxic Compounds

The compounds presented above have given rise to a number of potential applications of *Mucuna*, particularly medicinal. In the following pages, such uses are reviewed with a particular focus on L-Dopa, for which more information is available.

It is widely speculated that L-Dopa confers a pest and disease resistance to *Mucuna* (Rehr *et al*., 1973; Bell and Janzen, 1971) and L-Dopa has been shown to decrease survivability of southern armyworm (Rehr *et al*., 1973). Indeed, despite use throughout the tropics, pests and disease have in most locations had only minor impact on *Mucuna*, such as in Zimbabwe, where vine rot has been reported (Faridah Hanum and van der Maesen, 1996), or in Nigeria, where in a field of the International Institute of Tropical Agriculture (IITA), a fungal disease, *Macrophomina phaseolina*, occurred in 1991 (Berner *et al*., 1992). Diseases on *Mucuna* have also been identified in Malawi

[19] R. Gilbert, University of Florida (personal communication).

(Gilbert[19]) and in Mexico. The most severe pest infestation reported anywhere occurred in Florida and the southern USA, where the velvetbean caterpillar, *Anticarsia gemmatalis,* at times devastated *Mucuna* crops in the early part of the century (Scott, 1911); the caterpillar is still a common pest of *Mucuna*.[20] Another role that has been suggested for L-Dopa is that it supplies the developing embryo with a high concentration of nitrogen (Rehr *et al*., 1973), a result supported by Prakash and Tewari (1999) who reported percentage L-Dopa loss at 17, 31, 45, and 72% at 1, 3, 5, and 7 days of *M. pruriens* germination.

The large L-Dopa content in *Mucuna* has given rise to a number of medicinal uses throughout history and regions. Chief among them has been Parkinson's disease that apparently was already been treated with *Mucuna* in the ancient Indian medical system *Ayurveda* (Manyam, 1995); in fact, out of the 35 formulations for Parkinson's disease reported in *Ayurveda*, at least 18 contained *Mucuna* (Manyam and Sánchez-Ramos, 1999). Later, this ancient use was adopted at a more global level as a consequence of three findings: (1) isolation of L-Dopa from *Vicia faba* over 80 years ago (Brain, 1976, referring to Guggenheim, 1913); (2) isolation of L-Dopa from *Mucuna*; and (3) discovery that L-Dopa provides symptomatic relief for Parkinson's disease by decreasing the dopamine deficiency of certain areas of the brain, and the normalization of such treatment during the 1960s (Yahr, 1973).[21] Though Manyam (1995, citing Damodaran and Ramaswamy, 1937) states that L-Dopa was first isolated from *Mucuna* in 1937 by Indian scientists in fact, Alabama scientist, E.R. Miller (1920) reports an amino acid, dihydroxyphenylalanine, which had been previously identified in *Vicia faba*.[22]

[20] Curiously, it has been reported that *Anticarsia gemmatalis* damaged only *Canavalia ensiformis*, not *Mucuna*, in the experimental fields of ZAMORANO in Honduras (M. Flores, personal communication).

[21] In 1961-62, independently Austrian and Canadian scientists found that L-Dopa provides symptomatic relief for Parkinson's disease by decreasing the striatal dopamine deficiency that happens with the disease, and in 1967 it was found out that large, orally administered doses of DL-Dopa combined later with L-Dopa could give more sustained suppression of Parkinson's symptoms (Yahr, 1973).

[22] Miller and other scientists of his time (Miller, 1922; Miller, 1928; Read, 1923; Salmon, 1922) went on to study effects of L-Dopa on humans and animals, as well as the impact of tyrosinase on L-Dopa and the vitamin B content of *Mucuna;* some of these works have been reported in this paper.

Due to the resulting demand for large quantities of L-Dopa at an economic price, reinvestigation of plant sources of L-Dopa was initiated (Brain, 1976), including extensive plant surveys and the development of extraction methods (Daxenbichler *et al*., 1972). Methods for L-Dopa extraction from *Mucuna* were even patented (Wysong, 1966; cited by Daxenbichler *et al*., 1972). By the mid-1970s, however, Brain (1976) observed that due to the large quantities of raw materials required for production–a problem exacerbated by the high dosage required in the treatment–and by the difficulty of cultivating the twining plants, a recent trend to investigate synthetic and microbial transformation methods of production had emerged.

Although L-Dopa medicines are synthetically manufactured today, *Mucuna* as a source of L-Dopa continues to receive attention from two sources: from those interested in developing low-cost medical treatments for Parkinson's disease (Hussain and Manyam, 1997) and from those interested in natural and alternative medicines (Hussain and Manyam, 1997; Manyam, 1995). Clinical trials and other research work on *Mucuna* for Parkinson's has been conducted, suggesting a higher effectiveness of *Mucuna* powder over synthetic L-Dopa (Hussain and Manyam, 1997) and *Mucuna*-derived L-Dopa products, such as *Kapi Kacchu*, are available through the Internet. In this volume, Szabo and Tebbitt review information from medical and pharmacological journals on the impact of L-Dopa on humans.

In addition to relieving symptoms of Parkinson's disease, *Mucuna* has been used for various other medicinal purposes. The pod hairs have been used for treating snakebites in India (Siddhuraju *et al*, 1996) and the plant has also been used against snakebites in West Africa (Houghton and Skari, 1994). It has also been used for increasing sexual potency (Siddhuraju *et al*., 1996), its pod hairs have been used for deworming purposes (Faridah Hanum and van der Maesen, 1996) and as an expectorant to treat cough, asthma, and tongue infection (*M. monosperma*) (Prakash and Misra, 1987). Even criminal purposes have been reported in the use of the pod hairs: they have been secretly fed to persons whose death has been desired (Quisumbing, 1951). *Mucuna* has also been used as a uterine stimulant and as an aphrodisiac (Lorenzetti *et al.*, 1998). Interestingly, Ajiwe *et al*. (1997) report that in Nigeria *M*. *sloanei* has been cooked for pregnant women to avoid miscarriage. In their paper, Ukachukwu *et al*. (this volume) further discuss *Mucuna*'s uses in Nigeria and elsewhere in West Africa.

Currently, products containing *Mucuna* are being sold for a number of purposes through the Internet, including increased muscle mass and strength, male vitality, enhancement of mental alertness and coordination, as well as for an alleged anti-aging effect. We have no literature backing up these claims except for one study showing that *Mucuna* increased sexual activity of rats (Amin *et al*., 1996). When inquired, one such company told that its *Mucuna* seed comes from India.[23]

In conclusion, some work has been conducted on *Mucuna*'s anti-nutritional compounds but information is patchy. *Mucuna*'s profile of common anti-nutritional factors does not greatly vary from that of other beans, but the body of knowledge to draw from is relatively limited and studies that have documented the impact of different processing methods on the factors are few. While the high concentration of L-Dopa in *Mucuna* seeds has been verified, it is clear that this concentration is variable, and could form the basis of any future efforts to reduce L-Dopa concentration through germplasm improvement. The current confusion with *Mucuna* taxonomy impedes future work on reducing L-Dopa concentration, as little is known of the accessions whose L-Dopa concentration is measured. A number of other secondary compounds have been measured in *Mucuna* and the diverse and frequent medicinal uses to which *Mucuna* has been put lend support to the presence of such compounds. Only a few individuals have identified such compounds, and their levels have often not been determined, nor have their potential impacts on human and animal health. Much therefore remains to be discovered about the anti-nutritional and toxic factors of *Mucuna*.

[23] Sabinsa Corporation, http:/www.sabinsa.com.

5. Conclusions

As discussed above, several factors positively impact *Mucuna*'s potential as a food and feed, and a limited amount of research does exist on the topic. However, as the review above clearly indicates, there is a great deal of ambiguity surrounding the state of knowledge on the toxic compounds present in *Mucuna*, their impact on *Mucuna*'s potential as a food and feed, as well as ways to reduce such compounds through processing. Such ambiguity calls for both research and development efforts.

Given its high yield, good growth in diverse environments, and proven potential both as a food and feed crop and as a green manure/cover crop, *Mucuna* has been underrepresented in the research agendas. Foundations for *Mucuna* research have, however, definitely been laid by researchers that have either worked in areas where *Mucuna* was a prominent feed crop–such as the early-century USA–or in areas where *Mucuna* has been a minor food crop but where researchers have seen that it may hold greater potential. A number of research institutions in Asia (especially in India) and Africa (especially in Nigeria) have been strongly involved in food-and-feed-related research on *Mucuna*. Moreover, development-oriented organizations have been involved in *Mucuna* research during the past two decades. Future work on *Mucuna*'s food and feed uses can initiate from these efforts.

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Session I.
A View From the Field

Mucuna pruriens in Malawi: A Promising Legume with
a Troubled History

Increasing Farmer Adoption of *Mucuna pruriens*
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The Many Uses of *Mucuna:* Velvetbean in the Southern
United States in the Early 20th Century

The L-Dopa Problem as Viewed by Community
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