BIOCHEMICAL AND NUTRITIONAL EVALUATION OF THE WINGED BEAN *Psophocarpus tetragonolobus* (L.) DC

by

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TITLE

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Dedicated to

Georgina, Maurice, Anthony and Thelma

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Introduction

Throughout history, man has utilized about 3000 plant species for food. Today, only about 20 major crops feed the world's constantly increasing population. The crisis of the world's population explosion, accompanied by dwindling renewable food supplies, natural disasters, ignorance and disease, has contributed to the rapid decline in food supplies of nutritional significance in countries of the third world. In these countries, there is too much concentration on the cultivation of a few major and possibly cash crops, which has led to the neglect and extinction of some crops which might be of major nutritional significance. Historically, this system has been associated with the demands of the former colonial masters during the era of colonization when foreign consumer demands dictated the choice, cultivation, sales and industrial processing of and further research into certain tropical crops such as rubber, oil-palm, groundnuts, cocoa, coconut, cashew and a few others. The lack of local manpower and adequate facilities for research into the main food crops of local communities added to the problem.

The diet of the populations of developing nations of Latin and South America, Asia and Africa is based primarily on crops with high carbohydrate content. These staple diets with high starch content include tubers and cereals like yam, cassava, cocoyam, taro, sweet potatoes, rice, millet, maize and plantains.

The lack of proteins and minerals is compensated for by a high consumption of a large variety of leafy vegetables whose protein levels

have been shown to range between 1 and 10% (Terra, 1966). Although these vegetables have these levels of protein and a high content of vitamin C, they have low caloric values, and even the vitamin C is lost during excessive and extended cooking.

In West Africa, foods providing caloric value come from starchy crops such as cassava, plantain, yam, cocoyam, sweet potatoes (53-81%), fruits and vegetables (1.9-4.4%), oil plants (5.3-18.4%), and animal products (2.9-6.8%) and foods with any good amount of proteins account for less than 10% of the caloric value of African diets (Pospisil, 1978). In the humid tropics, therefore, shortages of protein foods are more pronounced among the vulnerable groups of the population. Children are most often affected, which accounts for a number of infantile deficiency diseases. Kwashiorkor, which leads to weakening, secondary infections and in many cases death, is most prevalent. It is necessary then to increase the level of proteins in the diet of the populations in the tropics. This can be achieved either by increased animal production or by crop production involving genetic improvement of the level and quality of proteins in these crops.

Unfortunately, these crops supply about 70% calories of the daily diet but are very low in vitamins, minerals and especially proteins. A few contain about 1.5% or less proteins (plantains and cassava); rice and maize about 8-10% proteins and the tubers contain about 2% proteins. The nutritional superiority of animal proteins over vegetable proteins has been well established. Proteins of animal origin supply all the essential amino acids required by man and contribute adequate amounts of

the essential minerals and vitamins. However, in developing countries, the availability of proteins of animal origin is limited. In recent times attention has been diverted into utilizing and improving by agricultural and genetic means the nutritional value and particularly the protein quality of staple food crops. It has also been found necessary to search for and improve on staple foods with a high protein content made from underexploited tropical plants with promising nutritional and economic value.

As the prospect of food shortages and protein deficiencies becomes more pronounced, populations in affected nations must depend increasingly on plants rather than animals to meet their protein needs. Plant sources indigenous to these countries (most probable center of geographical origin or at least a center of germplasm diversity) include the large family of the Leguminosae. Grain legumes are important sources of dietary proteins and oils, forming one of the main protein supplies of people in areas where animal protein sources are either scarce or very expensive. The FAO publication (1964) has demonstrated the world need for increased food supplies. Grain legumes are among the oldest of crop plants both in the Old and New Worlds; remains have been found in cave sites dating back to more than 6,000 years ago (Aykroyd and Doughty, 1964). Of the large number of legumes in history, about 20 species are used in sufficient quantities in the human diet.

Food legumes can play an increasing role in meeting the protein needs in areas of food scarcity, widespread protein-calorie malnutrition and expanding population. They have, on the average, twice as much

protein as cereals, are consumed at an insignificant level in Europe but to an average of 400 to 500 g daily in some parts of Africa and Asia (Aykroyd and Doughty, 1964). In terms of production, the top six grain legume crops are the soybean, peanut, dry bean, chickpea, pigeon pea and cowpea (Hymowitz and Boyd, 1977). Also, there are more than 50 other minor tropical legumes that have received very little attention and remain unexploited. Research information is lacking on their specific contribution to human nutrition and the possibility of certain of their intrinsic properties producing other useful by-products. Among the minor grain legumes, little known and much unexploited, is *Psophocarpus tetragonolobus* (L.) DC, or the winged bean.

The experiments reported in this dissertation were conducted to determine:

1. the biochemical composition of the winged bean
2. the nutritional value of the winged bean.

Experiments were conducted to determine the presence of anti-nutritional factors, the amino acid profile of the different parts of the plant, protein extraction and precipitation, some chemical differences between varieties, the digestibility levels of the different plant parts and the effects of different processing methods of the bean on protein digestibility.

TAXONOMY OF THE WINGED BEAN

The winged bean belongs to the family of the Leguminosae, genus *Psophocarpus*. There are about six species, all of which are indigenous to Africa. Some of these are wild African plants, unknown and so far not cultivated.

Species of the Winged Bean

P. tetragonolobus. A twinning, glabrous, perennial herb grown as an annual which climbs to a height of 3 to 4 meters. The roots are somehow modified and have tubers. The pods vary in size and length and have characteristically four longitudinal wings from whence the name is derived (figure 1). The pod length ranges from 8 to 36 cm with 5 to 20 seeds per pod. This species is very vigorous, productive and more useful than others. It is confined to the humid tropics where at least 150 cm of precipitation is required and up to 250 cm of precipitation beneficial (Masefield, 1973). This species has been widely grown and distributed in Asia (Hymowitz *et al.*, 1977). It is found in India (Hosker, 1879; Maheshwari *et al.*, 1965; Russel, 1952), Burma (Fairchild, 1917), Malaya (Burkhill, 1935; Massart, 1895), the Phillippines (Fairchild, 1944; Merrill, 1903, 1912, 1923), Papua New Guinea (Girard *et al.*, 1957; Ryan, 1972; Warburg, 1899), China (Loureiro, 1789), Ceylon (Hyland, 1968; McKee, 1928; Morrison, 1940), and Thailand (Craib, 1931; Fairchild, 1923).

P. palustris Desv. (*P. longepedunculatus, Hassk.*). Next to *P. tetragonolobus* is *P. palustris Desv.* *P. palustris* is a semi-wild plant

Figure 1 Pod of Winged bean showing "wings"

used mainly in times of food scarcity in Ghana and neighboring countries (Anon., 1975). It is a twinning, perennial herb with tuberous roots, winged pods 12 to 20 cm long. The seeds are much smaller than those of *P. tetragonolobus*. It is native to West Africa (Hutchinson *et al.*, 1958). It is reported by Hymowitz *et al.* (1977) that Verdcourt (1968) recently divided this species into *P. palustris* and *P. scandens* (Endl.) Verd., the latter being distributed in East Africa and cultivated in Indonesia, Brazil, Jamaica, Ceylon, India and Burma (Paul, 1953; Russell *et al.*, 1957; Verdcourt, 1968). It is widely cultivated in Africa and sparingly introduced into other countries (Burkill, 1966).

P. lancifolius Harms. Not much is known about this species. The leaves are lanceolate and it grows in swampy grasslands and forest edges from 1,100 to 2,500 m above sea level. It is found widely grown in Congo, Malawi, Kenya, Uganda, Nigeria, Tanzania and Zambia (Prain, 1921; Verdcourt, 1971).

P. lukafuensis. Much smaller in size. It has been noticed in Northern Rhodesia (Masefield, 1961) growing in open grassland on seasonally wet sites near the edges of swamps, twining round the stems or leaves of grasses.

P. monophyllus. A little known species found in Sudan, Ivory Coast and Portuguese Guinea (Chevalier, 1920).

P. grandiflorus. Also a little known species found wild in Uganda, Congo and Ethiopa. It grows in upland bushland, forest and grassland from 1,800 to 2,100 m above sea level (Verdcourt, 1971).

Nomenclature

Some confusion has existed so far between the winged bean of the genus *Psophocarpus* and that of the genus *Lotus* that grows in temperate regions. Hymowitz *et al.* (1977), in quoting Merrill (1917), gives the following synonymy:

Psophocarpus Necker (Retained name, Vienna Code: *Botor Adansis* is older (1963).

Psophocarpus tetragonolobus (L.) DC. Podr. 2 (1925) 403

Dolichos tetragonolobus L. Stickman Herb. Amb. (1754) 23, Amoen. Acad. 4 (1759) 132, Syst. ed 10 (1759) 1162, Sp. Pl. ed 2 (1763) 1020

Botor tetragonoloba Kuntze Rev. Gen. Pl. 1 (1891) 162

Lotus quadrangularis Rumph. Herb. Amb. 5:374, t. 133

Hymowitz and Boyd (1977) have given a list of language and geographical sites for vernacular names of *P. tetragonolobus*. They note that Rumphius, who lived on the island of Amboina from 1653 to 1702, wrote of this genus and that Rumphius believed that the cultigen had been introduced into the Moluccas probably from Bali or Java with an Arabic name of *botor* (Burkhill, 1935). The list of Hymowitz and Boyd (1977) shows that *P. tetragonolobus* has been given 42 different names in 18 different languages and from 12 different geographical sites. It has been called the four-angled bean, Goabean, Manila bean, Mauritius bean, murukavarai in India, see-kok-tau in China, asparagus pea in England, averrhoea bean, four-cornered bean, princess pea and others (Merrill, 1903, 1923; McMillan, 1935; Fairchild, 1917; Aykroyd and Doughty, 1964;

Purseglove, 1968; Masefield, 1973). It is believed that many more names have been given to this legume depending on the geographical area of distribution.

Merrill (1948) has shown that there is great diversity in the number of specific vernacular names given to crops in the Malaysian, Melanesian, Micronesian and Polynesian regions. In these sites there is a great multiplicity of native dialects and languages, numbering over 500 in certain areas. Each dialect or each language calls each plant by a different name so that the indigenous, introduced, cultivated and naturalized species have been assigned specific vernacular names that are typical of a particular geographical area. Little wonder then that the English language calls *P. tetragonolobus* by such names as winged bean, winged pea, princess bean, Manila bean, Maritius bean, Goa bean, four-angled bean, asparagus bean and asparagus pea while in French it is called haricot de la foret, haricot dragon and pois carre. Hymowitz and Boyd (1977) have shown this system of vernacular nomenclature to be misleading, since, as their example shows, the peanut in Indonesia is called katjang manilla where katjang is the general term for beans. It is their view therefore that oftentimes the number of vernacular names for a domesticate is a function of the number and special interest of botanists in the region.

ORIGIN OF THE WINGED BEAN

There has been a lot of speculation and now new research interest in the origin of this crop. Historically the records of Rumphius have

shown that the Arabs introduced the winged bean from Africa (Merrill, 1903, 1917, 1925). The very early work of Pickering (1879) indicated that this crop was a native of West Africa, but Hymowitz and Boyd (1977) contend that *P. tetragonolobus* has never been found wild in West Africa. Rather *P. palustris* has been indicated as the likely crop native to West Africa (Andrews, 1952; Brown and Massey, 1929; Fairchild, 1917). Other authors have reported the spontaneous occurrence of *P. tetragonolobus* in West Africa. Burkill (1935) suggested that *P. tetragonolobus* was introduced into Asia from Madagascar or Mauritius. Cobely (1956) and Vavilov (1951) claim India as the center of origin but others have shown that this species was only introduced into India (Hooker, 1879; Loureiro, 1788; Prain, 1903). Dalziel (1955) suggested that it is indigenous to tropical West Africa. Ryan (1972) concludes that New Guinea is the origin of the winged bean. Hymowitz and Boyd (1977) have unconvincingly indicated from their meagre evidence that Papua and New Guinea are the most probable center of geographical origin, or at least a center of germplasm diversity. On the contrary, Bhumiratana and Rachapaetayakom (1978) report that the winged bean originated from Africa and was later introduced into Southeast Asia and Papua New Guinea in the 17th century.

Areas of Cultivation

The winged bean is cultivated at an altitude ranging from sea level to 2,000 m and between 20°N and 10°S latitude in the Asian tropics. It is a short-day plant and when grown outside the tropics, no flowering occurs due to photoperiodic inhibition. It can be grown in dry areas as well as under irrigation.