

Quality nutrition through pigeonpea—a review

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ABSTRACT

Protein mal-nutrition is widespread among poor of developing and under developed countries. Since animal protein is beyond the reach of this group, their primary protein supply comes from plant based products. Amongst these, pigeonpea or red gram (*Cajanus cajan* (L.) Millspaugh) is an important food legume that can be grown under rainfed conditions with least inputs. Pigeonpea is rich in starch, protein, calcium, manganese, crude fiber, fat, trace elements, and minerals. Besides its high nutritional value, pigeonpea is also used as traditional folk medicine in India, China, Philippines and some other nations. Literature on this aspect show that pigeonpea is capable to prevent and cure a number of human ailments such as bronchitis, coughs, pneumonia, respiratory infections, dysentery, menstrual disorders, sores, wounds, abdominal tumors, tooth ache, and diabetes.

Keywords: Protein; Pigeonpea; *Cajanus Cajan*; Nutrition; Folk Medicine

1. INTRODUCTION

Protein availability in developing countries at present is about one-third of its normal requirements and with ever growing human population; various nutritional development programs are facing a tough challenge to meet the targeted protein demand. Legumes in the developing world are known to offer food proteins that are generally grown under risk-prone marginal lands with low inputs. Among the legumes pigeonpea or red gram (*Cajanus cajan* (L.) Millspaugh) occupies an important place in rainfed agriculture. Globally, it is cultivated on 4.79 M ha in 22 countries [1] but with only a few major producers. In Asia, India (3.58 M ha), Myanmar (560,000 ha), and Nepal (20,703 ha) are important pigeonpea producing countries. In African continent, Kenya (196,261 ha), Malawi (123,000 ha), Uganda (86,000 ha),

Mozambique (85,000 ha), and Tanzania (68,000 ha) produce considerable amounts of pigeonpea. The Caribbean islands and some South American countries also have reasonable areas under pigeonpea cultivation.

The presence of high genetic diversity made [2-4], to believe that India is the primary center of origin of cultivated pigeonpea from where it spread to Africa about 4000 years ago. There are several local names of *Cajanus cajan* in different parts of the world [5]. Among these “pigeonpea” is the globally popular name that was coined by [6] in Barbados, where the crop was grown in barren lands for feeding its seeds to pigeons. In India it is popularly known as red gram, tur, or arhar. Pigeonpea is a perennial plant (**Figure 1**) and it can survive up to 3-4 years [5]. It is a short-day plant with a high sensitivity to photo-periodic changes. There are two major growth patterns in pigeonpea; the determinate types which produce pods in clusters at the top of the canopy and its further growth ceases after flowering that results in more or less uniform maturity. The other and most common growth habit is non-determinate type, where the pods are borne in axillary clusters. In general, the later types can tolerate major biotic and abiotic stresses due to their inherent capacity to regenerate. The traditional pigeonpea cultivars and most landraces are tall and take about 180-280 days to mature. However some early maturing



Figure 1. A commercial crop of pigeonpea.

cultivars are also now available [5].

In India, de-hulled split cotyledons (**Figure 2(a)**) of pigeonpea seeds are cooked to make *dal* (thick soup) for eating with bread and rice; while in southern and eastern Africa, and South America its whole dry seeds (**Figure 2(b)**) are used in a porridge like recipe. The fully grown seeds of pigeonpea when, harvested green (**Figure 2(c)**) before losing their green color, are used as fresh, frozen, or canned vegetable. Its broken seeds, skin, and pod walls are fed to domestic animals; and the dry stems are used as domestic fuel wood. In tropics and sub tropics pigeonpea is considered a life line of subsistence agriculture. Pigeonpea plant is known to provide several benefits to soil such as fixing atmospheric nitrogen, adding organic matter and micro nutrients, and breaking hard plough pan with its long tap roots and, thereby sometimes referred as “biological plough”. Pigeonpea can be grown successfully in a wide range of soil types and is capable of producing reasonable quantities of nutritive food even in the degraded soils and with minimum external inputs.

2. NUTRITIONAL QUALITY

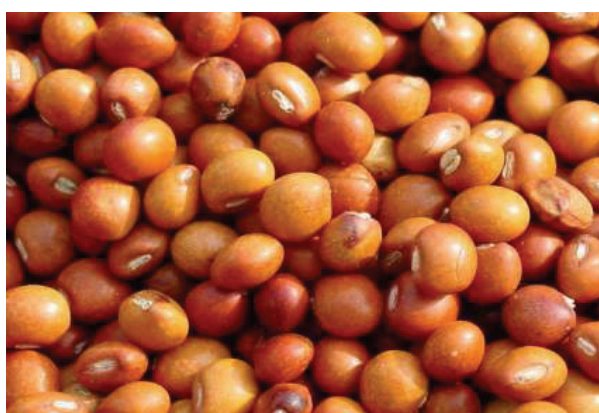
Pal [7] published the first information on biological value, net protein content, essential amino acids, and digestibility of different pulses. In this study pigeonpea was rated the best as far as its biological value was concerned; and it was recommended that for a balanced vegetarian diet pigeonpea should be eaten with rice. References [8-10] reported large variability for various chemical constituents and nutritive value of pigeonpea. It is to be noted that besides inherent genotypic differences, some degree of variation in protein content can also arise due to differences in environmental conditions where the crop was grown, methods of sampling and analyses, and seed storage conditions and its duration.

2.1. Nutritional Value of Dry Seeds

Pigeonpea seeds are made up of 85% cotyledons, 14% seed coat, and about 1% embryo, and contain a variety of dietary nutrients [11]. The cotyledons are rich in carbohydrates (66.7%) while a major proportion (about 50%) of seed protein is located in embryo. About one-third of seed coat is made up of fiber. The quantities of important sulfur-containing amino acids such as methionine and cystine range around 1% and they are present in cotyledons and embryo; while calcium is predominantly present in seed coat and embryo. Singh [12] found that the globulins constitute about 65% of total proteins. In general, pigeonpea is not rated superior for sulfur-containing amino acids [13], but it is not linked



(a)



(b)



(c)

Figure 2. (a) Dehulled split cotyledons (*dal*); (b) Whole dry seeds of pigeonpea; (c) Vegetable pigeonpea seeds.

with low methionine content [14]. In comparison to other protein fractions, globulin is rather inferior in sulfur-containing amino acids while albumin has high amino acid content. In pigeonpea seed the proportion of prolamin is low while sugars such as stachyose and verbascose are high [15].

Table 1. Distribution of nutrients in green seed, mature seed, and *dal*¹ of pigeonpea.

Constituent/cooking time	Green seed	Mature seed	<i>Dal</i> ¹
Protein (%)	21.0	18.8	24.6
Protein digestibility (%)	66.8	58.5	60.5
Trypsin inhibitor (units mg ⁻¹)	2.8	9.9	13.5
Starch content (%)	48.4	53.0	57.6
Starch digestibility (%)	53.0	36.2	-
Amylase inhibitor (units mg ⁻¹)	17.3	26.9	-
Soluble sugars (%)	5.1	3.1	5.2
Flatulence factors (g 100g ⁻¹ soluble sugar)	10.3	53.5	-
Crude fibre (%)	8.2	6.6	1.2
Fat (%)	2.3	1.9	1.6
Minerals and trace elements (mg 100g ⁻¹)			
Calcium	94.6	120.8	16.3
Magnesium	113.7	122.0	78.9
Copper	1.4	1.3	1.3
Iron	4.6	3.9	2.9
Zinc	2.5	2.3	3.0
Cooking time (min)	13	53	18

¹ = split seeds with seed coat removed; Source: [74].

Table 2. Genotypic variation for major anti-nutritional factors in pigeonpea.

Factor	Genotypes	Range
Total phenols (mg g ⁻¹)	14	3.0-18.3
Tannins (mg g ⁻¹)	10	0.0-0.2
Trypsin inhibitor (units mg ⁻¹)	9	8.1-12.1
Chymotrypsin inhibitor (units mg ⁻¹)	9	2.1-3.6
Amylase inhibitor (units g ⁻¹)	9	22.5-34.2
Raffinose (g 100 g ⁻¹)	10	0.24-1.05
Stachyose (g 100 g ⁻¹)	9	0.35-0.86
Stachyose + verbascose (g 100 g ⁻¹)	-	41.60-2.30

Source: [75].

2.2. Nutritional Value of Immature (Vegetable) Seeds

In general, green pigeonpea seeds (vegetable pigeonpea) are considered superior to dry splits in nutrition. The observations recorded at ICRISAT showed that pigeonpea *dal* was better than green peas with respect to starch and protein (**Table 1**). On the contrary, the green pigeonpea seeds had higher crude fiber, fat, and protein digestibility. As far as trace and mineral elements was concerned, the green pea was better in phosphorus by 28.2%, potassium by 17.2%, zinc by 48.3%, copper by 20.9%, and iron by 14.7%. The *dal*, however, had 19.2%

more calcium and 10.8% more manganese [11]. Singh [16] reported that the vegetable type pigeonpea had high poly-saccharides and low crude fiber content than *dal*, irrespective of their seed sizes. They also reported that crude fiber contents in vegetable pigeonpea and garden pea (*Pisum sativum*) were comparable. There was a vast range in size and color in immature pods and mostly the consumer preference was for large green pods; however, these traits were not related to any organoleptic property of seeds. In pigeonpea, seed and pod size are positively correlated and the varieties with large pods invariably have large immature and dry seeds.

2.3. Nutritional Changes in Developing Seeds

In a commercial vegetable pigeonpea crop it is essential that a balance be established between seed yield and its nutrition quality. To achieve this, the green pods have to be harvested at a proper stage of seed growth. At Patancheru (17°N), it takes about 45-50 days from flowering to seed maturity while vegetable pods are ready to harvest in about 25-35 days from flowering. In pigeonpea, the pods grow rapidly and attain their full size in about 20 days. During this period, the young seeds (ovules) inside the pod remain intact but do not attain significant weight. Soon after achieving its normal pod size, the seeds grow rapidly for the next 10-12 days to achieve their optimum size.

From nutritional and marketing points of view, it is

essential that the green pods are picked at a proper stage to reap maximum seed yield with highest nutritional quality. In this context, Singh [17] observed that in growing seeds the starch content was negatively associated with their protein and sugar contents. The amount of crude fiber content in the growing seeds increased slowly with maturation. The soluble sugars and proteins decreased in the developing seeds but the starch content increased rapidly between 24 and 32 days after flowering. Meiners [18] showed that the minerals and trace elements such as calcium, iron, zinc, magnesium, and copper remained more or less constant and did not change markedly during seed development in pigeonpea.

2.4. Nutritional Value of Split Peas (*DAL*)

Carbohydrates (67%) and protein (22%) are main constituents of pigeonpea seeds [11]. Hulse [19] reported that the seed protein among cultivars ranged around 22%. The quality of protein is determined by its quantity and digestibility, and amino acid contents. In pigeonpea the amino acid such as lysine and threonines are in good proportions, while methionine and cystine are deficient [12]. Pigeonpea cotyledons are also rich in calcium and iron.

Saxena [20] used wild relatives of pigeonpea as high protein donor parents and demonstrated that seed protein content in cultivated types can be enhanced through conventional breeding. Singh [21] assessed these high protein lines for their chemical composition. They reported large differences between the levels of protein in high-protein (28.7 to 31.1%) lines and control cultivars (23.1 to 24.8%). As expected, the starch component in high-protein lines was relatively less (54.3 to 55.6 %) than that of controls (58.7 to 59.3%). Also the high-protein lines were marginally lower (2.5 to 2.6%) in fat content when compared with control cultivars (2.9 to 3.1%). The differences in the major protein fractions of the high and normal-protein lines were also large. In comparison to controls (60.3 to 60.5%), the globulin fraction was higher (63.5 to 66.2%) in the high-protein lines and the reverse was true for glutelin.

2.5. Anti-Nutritional Factors

Like other legumes, pigeonpea seeds also contain some anti-nutritional factors (**Table 2**). These include oligo-saccharides (raffinose and verbascose), polyphenols (phenols and tannins), phytolectins, and enzyme inhibitors (trypsin, chymotrypsin, and amylase). According to Kamath [22], pigeonpea seeds also have some amounts of unavailable carbohydrates which adversely affect the bio-availability of certain vital nutrients. Some of the anti-nutritional factors such as phytolectins are heat sensitive and are destroyed during cooking.

Godbole [23] reported protease inhibitors in seven-day old seeds; while Ambekar [24] found that such inhibitors are either not synthesized or inactive up to 28 days of the seed development. No other plant part except seed exhibited trypsin or chymotrypsin inhibitors [25]. The white seeded pigeonpea cultivars contain relatively less amounts of polyphenols. Such cultivars are preferred in many countries where de-hulling facilities are not available and whole seeds are consumed. In comparison to the white seeded cultivars the red seeded types contain three times greater quantity of polyphenols [26]. Similarly, the enzyme inhibition activity was also greater in the colored seeds of pigeonpea. Since in India almost entire pigeonpea production (3.2 m tones) are de-hulled and converted into *dal* for consumption, the tannins present in the colored seed coat pose no nutritional problem.

3. COOKING QUALITY

Pigeonpea seeds in the form of either dry, green, or split peas are invariably consumed after cooking. Therefore, besides various nutritional aspects the cooking time and other related parameters assume importance. Consumers always prefer a *dal* that cooks fast and produces more volume upon cooking with high consistency and flavor. Cooking time of *dal* is independent of taste and flavor [9]. Jambunathan [27] studied various physico-chemical characters of pigeonpea, and reported that quick cooking trait of *dal* was associated with large seed size, high solid dispersal, more water absorption, and high nitrogen solubility. Narasimha [28] and Pal [7] reported a positive association of cooking time of pigeonpea seeds with their calcium and magnesium contents. According to Salunkhe [29], cooking of pigeonpea improved the bio-availability of nutrients and at the same time destroyed some anti-nutritional factors. Heat treatment of pigeonpea seeds is also known to enhance their starch digestibility. The lines, which take long time to cook, generally face the danger of losing important vitamins from food. Cooking pigeonpea seed after germination enhances their starch digestibility [30] but reduces the levels of oligo-saccharides [31]. The fermentation of seeds helps in reducing inhibitory activity of digestive enzymes [32]. Geervani [33] reported that thiamine and riboflavine were destroyed by heat but niacin content was unaltered during boiling, pressure cooking, and roasting of pigeonpea seeds. She further found that the availability of lysine and methionine decreased on roasting but the available methionine increased on boiling and pressure-cooking.

4. NUTRIENT LOSSES DURING STORAGE AND PROCESSING

Pigeonpea is predominantly cultivated by small holder

farmers and they generally store the whole seeds for over 6-12 months round-the-year for consumption. In rural areas the farmers' process small quantities of grain as and when needed, and they do de-hulling by hand-operated traditional grinding stones called *chakki* or quern. Since in pigeonpea the cotyledons are attached tightly with seed coat by various gums, the de-hulling involves the process of dissolving the gum layers by soaking whole seeds in water, heat treatment, or adding oil after surface scarification. This is followed by drying, de-husking, and splitting of cotyledons. During this process the losses of certain proportions of cotyledons are inevitable, and it is estimated that by using advanced processing technology about 15%-17% of grain mass is lost; while with *chakki* such losses may shoot up to 20%-25%.

In rural areas, the seeds are generally stored in gunny bags or bins made of mud and husk. According to Daniel [34], food grains containing more than 10 mg uric acid per 100 g of food are unfit for human consumption. Pigeonpea seeds when stored for eight months turned unfit for consumption as their total uric acid content crossed the safe prescribed limit [35]. Cooking time of pigeonpea in general increased with storage time [36]. Daniel [34] reported that lysine, threonine, and protein efficiency ratios were adversely affected in pigeonpea when the seeds were stored in jute bags. The storage of pigeonpea seeds also resulted in the loss of vitamins. Such losses were less (10%-26%) in the protected seed and high (32%-49%) in the infested seeds [37]. Thiamine and niacin contents also registered decline during storage. Factors such as moisture, temperature, relative humidity, and seed hardness determined the extent of quality losses during storage [38].

Reddy [39] reported that in comparison to inner layers of cotyledons the outer layers are rich in protein. From nutrition point of view, this is a matter of concern since de-hulling not only removes protein-rich germ but also some proportion of the outer layers of the cotyledons. Singh [40] further observed that de-hulling also removes about 20% calcium and 30% iron. According to Kurien [41], the *dal* yield under controlled conditions achieves an efficiency of 80%-84% but at commercial level the recovery remains around 70%. Therefore, with a combination of a superior variety and efficient processing technology, the nutrient availability can be maximized.

5. ENVIRONMENT AND PROTEIN

The growth and development of pigeonpea plants are known to be highly influenced by environmental factors such as temperature, photoperiod, available moisture, soil nutrition etc. The large variation observed for protein content of pure lines over locations or years is a good example of the role that environment can play in the ex-

pression of this trait. Sham [42] reported significant effects of location and fertilizer application on pigeonpea seed protein. Oke [43] found that incorporation of 20 ppm sulfur alone or in combination with phosphorus increased methionine content of pigeonpea.

Saxena [44] observed significant differences for protein content across locations and months. The same variety, when grown in different months at a particular location showed significant variation in its protein content. For example, in cultivar "Prabhat" planted at Patancheru (17°N) over 12 months, the seed protein content ranged from 21.6% to 25.2%; similarly at Pantnagar (29°N), in 10 plantings within a year, the protein content of cultivar Prabhat ranged between 24.5% and 27.9%.

6. MEDICINAL USES

Plant kingdom had been considered from a long time a reservoir of folk medicines. The herbal medicines, also called as phyto-medicines, refer to using a plant or its part such as leaves, flowers, fruits, bark, or seeds for medicinal purposes. Since ancient periods and long before any recorded history China, India, and Egypt were the leaders in folk medicines. The ancient Chinese and Egyptian papyrus writings described various medicinal uses of some plant species. The native Africans and Americans also used different herbs in a number of healing rituals. The herbal medicine system has a long tradition of usage outside the boundaries of synthetic medicine system. With the advent of improved chemical analytical methods along with quality control technologies and advances in clinical research, the value of herbal medicines increased in treating and preventing of some human diseases. Subsequently, effective traditional medical systems such as "Ayurveda" in India and "Traditional Chinese Medicine" in China were developed with a fairly good recognition. Slowly the people in different parts of the world also started using the common herbal plants for medicinal purposes.

In the early 19th century, when the first chemical analysis became available, the scientists began to extract the active ingredients from selected plant species for pharmaceutical usage and some chemists started synthesizing targeted plant compounds in their laboratories. Gradually, the usage of herbal medicines declined in favor of synthetic drugs. However, the World Health Organization estimated that 80% of people worldwide, particularly from developing and under-developed countries, still rely on herbal medicines for some part of their primary health care. In Germany, about 600-700 plant-based medicines are still prescribed by 70% of the Physicians. Recently, some of the developed countries have also shown interest in the natural or organic remedies [45].

6.1. Herbal Properties

Pigeonpea is being used as an integral part of traditional folk medicine in India, China, and some other developing countries [46]. The importance of pigeonpea plant in ethnical folk medicine is well known in the prevention and cure of certain human ailments and its brief account is given below:

Flowers: Pigeonpea floral decoctions are traditionally used for treating ailments such as bronchitis, coughs, and pneumonia. Pigeonpea flowers are also prepared into a “tea” for treating upper respiratory infections and pain. The flowers, when prepared in an infusion, are used for treating dysentery and menstrual disorders.

Seeds: Scorched seeds, when added to coffee alleviate headache and vertigo. Fresh seeds are believed to help incontinence of urine in males, while immature seeds are recommended for treatment of kidney ailments [47]. Pigeonpea seeds are infused to make a diuretic “tea” for inflammation and blood disorders. In South America pigeonpea seeds are used for febrifuge, stabilization of the menstrual period and dysentery [48]; in Africa pigeonpea seeds are used for treating hepatitis and measles [49]. In Mexico, pigeonpea seeds are used as styptic drug and laxative; while in China these are used to arrest bleeding, relieve pain, kill worms, and as an expectorant and sedative drug [50,51]. Some herbal researchers are of the opinion that pigeonpea diminishes swelling of internal organs such as liver, intestines etc. Clinical studies have also shown that the seed extract of pigeonpea helps in inhibiting sickling of red blood cells and therefore, has potential to treat the person suffering from sickle cell anemia [52].

Roots: Dried roots of pigeonpea are sometimes used as an alexeritic, anthelmintic, expectorant, sedative, and vulnerary.

Leaves: In India pigeonpea leaves are used for curing sores, wounds, abdominal tumors, and diabetes [53,54]. The leaves of the pigeonpea are decocted in Argentina for treating acute bronchial problems and genital and skin irritations. The young leaves of pigeonpea can be chewed for treating cough, diarrhea [55], traumatism, burnt infection, bedsore, toothache, mouthwash, sore gums, child-delivery, and dysentery [56,57]. It was also found that pigeonpea leaves have notable anti-inflammatory and antibiotic effects; and also inhibit capillary permeability [58]. In China, pigeonpea is considered as an excellent “Traditional Chinese Medicine” for therapy of ischemic necrosis of femoral head. The leaves are prepared in an infusion for overcoming anemia, hepatitis, urinary infections, yellow fever, and ulcers. In Brazil, pigeonpea leaves are infused for coughs, fevers, and ulcers.

6.2. Chemical Constituents of Leaves

In order to know the major chemical constituents of pigeonpea leaves, efforts were made to isolate and identify various active chemical compounds. The research efforts revealed that some polyphenols, especially flavonoids, play an important role in curing certain human ailments [59-62]. The four major flavonoids identified in the extracts of pigeonpea leaves are quercetin, luteolin, apigenin, and isorhamnetin. These compounds are known for their important pharmacological activities [56,63,64]. Flavonoids are polyphenolic compounds, which are widely found in plant kingdom. As intrinsic components of fruits, vegetables, and beverages many of the 4000 different flavonoids known to-date, are present in a common regular diet [65]. Pigeonpea leaves also contain other compounds such as hordenine, juliflorine, betulinic acid, stigmasterol, beta-sitosterol, etc. In recent years, extensive research is being carried on various antibacterial, anti-fungal, anti-viral, anti-cancer, and anti-inflammatory properties of these flavonoids [66-68].

7. GENETIC ENHANCEMENT OF PROTEIN CONTENT

In most third world countries supply of staple food has failed to keep pace with population growth and, therefore, breeding for high quality foods never received a priority and the resources were always diverted for enhancing yield of major food crops. Considering the state of protein malnutrition in most developing and underdeveloped countries, the genetic enhancement of seed protein in pigeonpea was initiated at ICRISAT.

To start a high protein breeding program, information on the genetic control of protein content is essential. Saxena [69] reported the role of both additive and non-additive gene actions in determining protein content and it was found to be controlled by 3-4 genes [70] that were recessive in nature [71]. Since the genetic variation for protein in primary (cultivated) gene pool was limited, the high-protein sources available in the secondary (wild) gene pool such as *Cajanus sericeus*, *C. lineatus*, and *C. scarabaeoides* were used in breeding. This program successfully developed some high protein (26.9%-27.4%) lines with good seed size (9.6-10.5 g 100⁻¹ seeds), and high seed yield (1660-2096 kg ha⁻¹). The evaluation of these high-protein lines revealed that from one hectare of field 350-450 kg crude protein can be harvested, reflecting an additional harvest of 80-100 kg protein ha⁻¹. Cultivation of such lines will markedly improve availability of protein to farmers without sacrificing seed yield.

The results of rat feeding trials of these high-protein lines showed that boiled *dal* was comparable to the control in true protein digestibility, biological value, and net

protein utilization [21]. They further concluded that the high-protein lines were nutritionally superior to normal-protein cultivars as the former contain quantitatively more utilizable protein and sulfur containing amino acids.

8. CULTIVATION OF PIGEONPEA

Early maturing varieties are short in stature and require high (about 300,000 plants ha⁻¹) density in contrast to late maturing types which need 40,000-50,000 plants ha⁻¹ for optimum yields. For backyard and bund cultivation the pigeonpea plants are maintained for more than one year and they attain a height of over 3 m. The pods are picked for house-hold use, as and when required. No specific agronomic practices are followed in this system. For local market relatively large populations are grown on field bunds, mainly around paddy fields. In this system, 3-4 seeds are sown in a single hill and the plants produce a large number of branches on either side of the bund. For peri-urban commercial crop, a field with known history of good soil fertility and drainage should be selected. The sowings on raised beds with appropriate slope is ideal for pigeonpea. Application of 100 kg ha⁻¹ of di-ammonium phosphate and other soil amendments for the known soil deficiencies are advisable before sowing. Sowing should be undertaken at the onset of rainy season with row-to-row and plant-to-plant spacing of 100 cm and 50 cm, respectively. The seeds are placed about 5 cm deep and covered firmly with soil. For weed control spraying of a pre-emergence herbicide such as *Basalin* @ 1.5 L ha⁻¹, followed by two hand weeding are enough to control rainy season weeds. Irrigation is generally not recommended if the crop is grown for domestic consumption on deep Vertisols. In pigeonpea insect control is very vital. Pod borers (*Helicoverpa armigera* and *Maruca vitrata*), pod fly (*Melanagromyza obtusa*), and blister beetle (*Mylabris pustulata*) are major pigeonpea insects. These may cause severe damage to seed yield and quality. To control these insects appropriate chemical control is essential. *Fusarium* wilt and sterility mosaic are two major pigeonpea diseases. Wilt is caused by a soil-borne fungus *Fusarium udum* Butler while sterility mosaic is caused by virus. At present a number of disease resistant cultivars are available and the losses can be minimized by using such cultivars.

9. PIGEONPEA IN RURAL DIETS

In pigeonpea methionine, cystine, tryptophan and threonine are the limiting essential amino acids, whereas in rice and wheat lysine is the limiting amino acid. A food combining both cereals and pulses provide a balanced diet because they complement the amino acid profiles of

each other. The mutual quality compensation is closest to the ideal value when the ratio by weight of cereals to legume is roughly 70:30 [19]. In southern and eastern Africa this ratio is 90:10, reflecting shortage of protein in the diet. Daniel [72] studied supplementation of cereal diets with various proportions of pigeonpea and reported that supplementation of ration with pigeonpea significantly enhanced the nutritive value of diet. Supplementation of rice diet with 8.5% and 16.7% pigeonpea *dal* markedly improved the quality of diet. Similarly, Kurien [41] demonstrated that a supplement of pigeonpea in maize diet significantly improved the quality of food.

Bidinger [73] observed that pigeonpea was by far the most preferred pulse crop in Indian villages and its consumption patterns differed widely by age group, farm size, and the village. The consumption rate was found linear with small farmers consuming the least amount and the large farmers the most. National Institute of Nutrition in India recommends cereal: pulse ratio of 3:1 for very young children, 5:1 for women, and 6:1 for men. In most of the cases, rural diets standards could not be met. Bidinger [73] further reported that 10% of protein and 5% of energy in the village diets came from pigeonpea. The maximum lysine provided from the diet was 21.7%. These values are low and reflect low consumption of legumes.

10. SUMMARY

Legumes are a rich source of food proteins that are generally grown under risk—prone marginal lands. Amongst various food legumes, pigeonpea occupies an important place and has been rated the best as far as its biological value is concerned. It has been recommended for a balanced diet with cereals, especially to fill in the nutritional gap for proteins amongst the poorer section in developing economies that cannot afford a non-vegetarian diet. At present, the protein availability in developing countries is about one-third of normal requirements and with ever growing population; various nutritional development programs are facing a tough challenge to meet the protein demand.

In general, pigeonpea can be grown both as annual crop or perennial plants in homestead and is consumed either as decorticated splits or green seeds as vegetables. It has been found that vegetable pigeonpea are considered superior to dry splits in crude fiber, fat, protein digestibility as well as trace elements and minerals. Besides its nutritional value, pigeonpea also possesses various medicinal properties due to presence of a number of polyphenols and flavonoids. It is an integral part of traditional folk medicine in India, China, and some other nations. Pigeonpea is known to prevent and cure human ailments like bronchitis, coughs, pneumonia, respiratory

infections, pain, dysentery, menstrual disorders, curing sores, wounds, abdominal tumors, and diabetes in traditional folk medicine.

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