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Vegetable pigeonpea – a review

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ABSTRACT

Among sub-tropical legumes, pigeonpea or red gram (*Cajanus Cajan* (L.) Millspaugh) occupies an important place in rainfed agriculture. This crop has a wide range of uses and its use as fresh or canned green peas is common in parts of India, Africa, Central America and the Caribbeans. Vegetable pigeonpea is characterized by large pods and seeds because of easy shelling. Some parts of India prefer green pod colour but the study revealed that pod colour does not play an important role in determining the organo-leptic qualities of vegetable pigeonpea. The anti-nutritional factors like phyto-lectins are also present in pigeonpea, but it is heat sensitive and destroyed during cooking. Vegetable pigeonpea can be grown in backyards, field bunds and also as a commercial crop. The fresh seeds can also be frozen and canned for commercialization and export. The Dominican Republic stands first in exporting commercialized vegetable pigeonpea to United States and other countries. Vegetable pigeonpea is a good source of protein, vitamins (A, C, B complex), minerals (Ca, Fe, Zn, Cu), carbohydrates and dietary fibre. In comparison to green peas (*Pisum sativum*), the vegetable pigeonpea has five times more beta carotene content, three times more thiamine, riboflvin and niacin content and double vitamin 'C' content. Besides it has higher shelling percent (72%) than that of green peas (53%). These all factors indicate that pigeonpea is nutritionally rich vegetable and it can be used in daily cuisine.

Key words: Vegetable pigeonpea, Antinutritional factors, Beta carotene, Shelling percent

Pulses are known to be rich in edible proteins. In India, the most commonly grown pulses, in order of their importance, are chickpea, pigeonpea, green gram, black gram, peas, common beans, and cowpea. In spite of their high nutritive value and being important part of daily cuisine, most farmers give low priority to pulses in cultivation and are assigned to rainfed and relatively less productive portions of their fields. However, recent escalation in prices of pulses has brought about some changes in the mind set of some farmers and they are taking the cultivation of pulses more seriously than before. At present, protein availability among rural masses in the developing world is less than one - third of its normal requirements and with continuously growing population and stagnation of productivity, and expensive animal protein, the nutritional programmes associated with protein supply are facing tough challenges to meet the demand of unprivileged group of masses. Since in most households, food production priority lies in the calorie-filled cereals, the issue of protein availability assumes a greater significance from health point of view.

Among legumes, pigeonpea or red gram [*Cajanus cajan* (L.) Millspaugh] occupies an important place in rainfed agriculture. Globally, it is cultivated on 4.67 million ha, out of which, 3.30 million ha is confined to India alone. Although the crop is known to be grown in 22 countries, the major producers are only a few. In Asia besides India, Myanmar (570,000 ha), China (150,000 ha), and Nepal (20,988 ha) are important pigeonpea producing countries; while in Africa, Tanzania, Kenya, Malawi, Uganda, and Mozambique produce considerable amounts of pigeonpea. The Caribbean islands and some South American countries also cultivate a reasonable area with pigeonpea.

Pigeonpea is cultivated in a wide range of cropping systems and so is its usage. In the northern India, its de-hulled split cotyledons are cooked to make *dal* while in the southern parts of the country, its usage as *sambar* is very popular. Also in some parts of India including Karnataka and Gujarat, the use of immature shelled seeds is very common as fresh vegetable. Besides this, in the tribal areas of various states, the use of pigeonpea as green vegetable is very common. The recipes prepared with green pigeonpea seeds are nutritive and tasty and are consumed with rice as well as *chapati*. During the off-season in southern and eastern Africa, southern America, and the Caribbean islands, the whole dry seeds are used in making porridge while in the crop season, its immature seeds are used as fresh vegetable. Green peas in the form of frozen or canned products are also available for use as vegetable in the markets of USA and Europe. Its nutritious broken seeds, husks, and pod shells are fed to cattle and the dry stems make it a popular household fuel particularly in rural areas. Pigeonpea is credited to be the most suitable crop for subsistence agriculture that needs minimum external inputs. It is known to produce reasonable quantities of food even under unfavorable production conditions mainly due to its qualities such as drought tolerance, nitrogen fixation, and deep root system. Its seeds contain 20-22% protein and reasonable amounts of essential amino acids.

A. Important attributes of vegetable pigeonpea

Fresh Pod colour: There is a large variation for fresh pod colour in pigeonpea and for vegetable market, green podded pods fetch better price in the market. Saxena *et al*. (1983) studied the effect of pod colour on important organo-leptic properties of vegetable pigeonpea. They found that fresh seeds harvested from purple pods had poor texture, flavour, and taste as compared to those of green seeds; but after cooking operation such differences disappeared, suggesting that the pod colour does not play any important role in determining the organo-leptic qualities of vegetable pigeonpea. In a survey conducted in Gujarat state of India, where vegetable pigeonpea is consumed on a large scale, it was found that the rural consumers preferred pods with green base colour with minor or dense streaks on its surface. In contrast, the urban consumers preferred green colour pods. Yadavendra and Patel (1983) reported that the pods produced on cultivar 'ICP 7979' were the most preferred because of their good taste, attractive green colour, less stickiness, and easy shelling.

Pod and seed size: For vegetable purposes, generally large pods are preferred for they are attractive and relatively shelled easily. Although seed number/pod in the germplasm ranges between 2 and 9, but on an average, the optimum seed number/ pod that is easily marketed is 5-7. Recently, the new vegetable types have been developed with up to 8 – 9 seeds/pod. In pigeonpea, seed and pod size is invariably correlated with large podded types having large immature as well as dry seeds. On the contrary, in some vegetable type lines, the immature seeds are large but their size reduces gradually with approaching maturity. Saxena (2008) observed that in the long podded genotypes, all the ovules did not develop properly to their full size due to ovule abortion. The exact reason for the loss of ovules is not fully understood but there appears to be some sort of blockage in the supply of carbohydrates and other vital nutrients to the growing ovules resulting in their pre-mature cessation.

Important Quality Parameters: The green pigeonpea seeds are considered superior to *dal* in general nutrition. The observations recorded at ICRISAT and some other laboratories show that pigeonpea *dal* is better than vegetable with respect to starch and protein (Table 1). On the contrary, the green pigeonpea grains have higher crude fibre, fat, and protein digestibility. As far as trace and mineral elements are concerned, the green peas are superior in phosphorus by 28.2%, potassium by 17.2%, zinc by 48.3%, copper by 20.9%, and iron by 14.7% (Table 2). The *dal* however, has 19.2% more calcium and 10.8% more manganese. Singh *et al*. (1977) reported that the vegetable type pigeonpea had higher amount of poly-saccharides and low crude fibre content than *dal* irrespective of their seed sizes. They also reported that crude fibre content in vegetable pigeonpea was similar to that of garden pea (*Pisum sativum*).

Table 1. Comparison of green pigeonpea seeds and *dal* for important quality constituents

Constituent	Green seeds	*Dal*
Starch content (%)	48.4	57.6
Protein (%)	21.0	24.6
Protein digestibility (%)	66.8	60.5
Soluble sugars (%)	5.1	5.2
Crude fibre (%)	8.2	1.2
Fat (%)	2.3	1.6

Table 2. Trace and mineral elements (mg/100g) identified in green seeds of a vegetable variety 'ICP 7035' and *dal* of a pigeonpea variety 'C11'

Element	Green seeds ('ICP 7035')	*Dal* ('C 11')	SEm	Superiority of vegetable grains (%)
Phosphorus	264*	206	± 3.95	28.2
Patassium	1498*	1279	± 12.74	17.1
Calcium	92.3	114.3*	± 1.98	(–) 19.2
Zinc	3.07*	2.07	± 0.01	48.3
Copper	1.39*	1.15	± 0.08	20.9
Iron	5.16*	4.50	± 0.06	14.7
Manganese	0.99	1.11*	± 0.02	(–) 10.8
Magnesium	108.3	108.5	± 0.86	--

*Adopted from Singh *et al*. (1984)

Like other legumes, pigeonpea seeds also contain some anti-nutritional factors. In dry pigeonpea seeds, poly–phenol compounds are present which inhibit the normal activity of some digestive enzymes. These include trypsin, chymotrypsin, amylase, poly-phenols, and tannins (Table 3). According to Kamath and Belavady (1980), pigeonpea seeds have appreciable amounts of unavailable carbohydrates which adversely affect bio-availability of certain vital nutrients. Some of the anti-nutritional factors such as phyto-lectins are heat sensitive and are destroyed during cooking. Some of the flatulence causing oligo-saccharides such as staychyose, raffinose, and verbascose are also present in pigeonpea seeds.

Table 3. Major anti-nutritional factors and toxic substances identified in pigeonpea seed

Constituent	Range	Mean
Protease inhibitors (units/mg)		
Trypsin	8.1-12.1	9.9
Chymotrypsins	2.1-3.6	3.0
Amylase inhibitors (units/g)	22.5-34.2	26.9
Oligo-saccharides (100/g)		
Raffinose	0.24-1.05	0.47
Stachyose	0.35-0.86	0.49
Poly-phenols (mg/g)		
Total phenols	3.0-18.3	10.7
Tannins	0.0-0.2	0.03
Phyto-lectins (units/g)	400	400

Source: Singh (1988)

Seed development in relation to chemical changes: Pigeonpea plants produce profuse flowers and pods under normal growing environments. The number of pods on the plants is also genetically related to their pod size. It has been observed that in small seeded varieties, pod load on an individual plant is much higher than those of large seeded varieties. Under sub-tropical growing conditions, it takes about 45 - 50 days from pollination to seed maturity. During this period, both pods and seeds pass through a number of physiological, morphological, and chemical changes. It has been observed that three days after fertilization, the floral petals wither completely and the ovary starts emerging. A young pod of about one centimeter long is generally visible after one week. Such pods grow rapidly and reach their full size in about 25 days. During this period of pod growth, the young seeds (ovules) inside pods remain alive and intact but do not gain noticeable size and weight. Soon after achieving the potential pod size, a greater proportion of food reserves of the plant start diverting into the ovules and rapid increases in seed sizes and weights are observed for the next 10 - 12 days.

From nutrition and marketing view points, it is essential that the growing pods are harvested at a right stage to optimize the gains with respect to their yield and quality. To determine the optimum pod age for harvesting, two commercial vegetable pigeonpea cultivars ‘ICP 7035’ and ‘T 15-15’ were selected and the changes in the levels of principal dietary constituents and minerals were studied (Singh *et al.* 1991) at different stages of seed development. To record observations, over 3000 flowers of the same age were tagged and hand pollinated in a single day. The crossed pods were sampled on different dates for chemical analysis of their seeds. It was found that the two cultivars differed grossly in their dry matter accumulation rate with ‘ICP 7035’ being faster than ‘T 15-15’, and it was attributed to their respective seed sizes. In the growing seeds, starch content was negatively associated with their protein and sugar contents. The amount of crude fibre content in the growing seeds increased slowly with maturation, while soluble sugars and proteins decreased proportionately. The starch content recorded rapid increases between 24 and 32 days after flowering. ‘ICP 7035’ exhibited relatively high soluble sugars in each sample that was studied (Singh *et al.* 1991). Meiners *et al.* (1976) also showed that minerals and trace elements such as calcium, iron, zinc, magnesium, and copper did not produce significant changes during seed development in pigeonpea. It was also found that these minerals play an important role in improving cooking quality of pigeonpea seeds (Sharma *et al.* 1977).

B. Breeding vegetable pigeonpea

Popular vegetable pigeonpea varieties are characterized by their large pods and large seeds. It has been generally observed that in most germplasm, these two traits are linked together and such lines are invariably photo-sensitive, late maturing (>180 days at 17^{o}N), and perennial in nature. These cultivars flower at the onset of short photo-periods and produce fresh vegetable pods for about 40 - 50 days, allowing a maximum of 2-3 pickings. However, to ensure good profits and run the processing factories for longer periods, a regular supply of quality green pods for extended periods is essential. Besides this, the vegetable pigeonpea should have good appearance, taste, and other organo-leptic properties. The breeding objectives in a vegetable pigeonpea breeding programme revolve around such traits.

Breeding objectives: In an ideal vegetable pigeonpea breeding programme, in general, the prime objectives include early podding with round-the-year production, annual as well as perennial varieties, high multiple harvest potential, long attractive green pods with fully grown ovules, non - sticky pod surface with easy shelling, good taste, large white dry seeds, and long shelf life.

Available germplasm: ICRISAT has a global responsibility for collection, characterization, maintenance, and distribution of pigeonpea germplasm, and at present a total of 13,632 accessions representing 76 countries are available for use in breeding programmes. Since long pod size is the most important characteristic of vegetable pigeonpea, the accessions with more than 5.5 mean seeds/pod are considered in this group. At present, there are 231 such accessions in this group. In this material, 50% flowering ranged from 80 to 229 days. The plant height ranged from 85 to 285 cm, while pod length varied from 3.2 to 11.6 cm (Table 4). It was also observed that the majority of long - podded accessions originated from Africa, South America, the Caribbean islands, and tribal areas of India, where traditionally large - white seeded cultivars and landraces are cultivated.

Table 4. Variation for some important traits within vegetable type pigeonpea germplasm

Region	No. of accessions available	Days to		Plant height (cm)	Seeds/ pod	Pods/ plant	Pod length (cm)
		Flowering	Maturity				
Eastern Africa	106	117 - 229	166 - 270	130 - 270	5.4 – 6.7	26 – 406	5 - 12
Southern Africa	17	131– 194	163 – 260	185 - 260	5.4 – 6.1	33 – 154	5 - 11
Central Africa	4	141 –166	215 – 232	200– 230	5.4 – 5.6	74 - 130	7 - 9
Western Africa	13	142– 156	194 – 218	17 – 250	5.4 – 5.6	67 – 246	7 – 10
Central America	26	106– 151	167 – 202	85 – 240	5.4 – 7.2	19 – 160	7 – 11
South America	16	132– 158	182 – 230	100– 285	5.4 – 6.1	27 – 420	5 – 11
South Asia	39	80 – 175	133 – 235	85 – 230	5.4 – 7.2	55 – 830	3 – 9
South-east Asia	8	134– 201	190 – 264	140– 210	5.4 – 5.9	24 – 119	5 – 9
Europe	2	156 - 174	222 - 237	210 - 260	5.4 – 5.8	137	9
Total	**231**	**80 – 229**	**133 – 270**	**85 – 285**	**5.4 – 7.2**	**19 – 830**	**3 - 12**

Genetics of important traits: For productive plant breeding, a good understanding of the genetic systems controlling important qualitative and quantitative characters is essential. The presence of both additive and non-additive gene actions for yield and other characters have been reported in literature (Saxena and Sharma 1990). D'Cruz *et al.* (1970) reported that streaked pod colour was dominant over green, and that a single gene was responsible for streaked pods. A dihybrid F_2 segregation was reported by de Menezes (1956) and D'Cruz and Deokar (1970), while Deokar *et al.* (1972) found that the colour development in unripe pigeonpea pods was due to interaction of four genetic factors. Saxena *et al*. (1984) for the first time reported intra-plant pod colour variation in a pure breeding pigeonpea germplasm 'ICP 3773' and postulated that the pod colour variation and its unpredictable expressivity were governed by the presence, absence, or interaction of one or more unstable genes. The genetics of seed colour in pigeonpea is complex and is reported to be influenced by some basic and inhibitory genes, and modifiers.

Deokar *et al*. (1972) reported the dominance of brown seed colour over white and it was controlled by a single gene. But, Deokar and D'Cruz (1971) observed a di-hybrid F_2 ratio of 9 brown: 7 white seed colour. Similar results were also recorded by Chaudhary and Thombre (1977), Marekar and Chopde (1985). Patil *et al*. (1972) reported that brown seed colour was governed by three duplicate dominant genes.

Gene action and heritability of key traits: In pigeonpea, both additive and non-additive gene actions control grain yield and other quantitative characters, but critical information on the extent of non-additive effects, particularly dominance and epistasis components is not very decisive. Saxena *et al*. (1981) observed predominance of additive gene action for yield and yield components. Reddy *et al*. (1981) and Sidhu and Sandhu (1981) reported the importance of both additive and non-additive gene actions, while the predominance of non-additive gene action was observed by Dahiya and Brar (1977). Sharma *et al*. (1972) reported predominance of additive gene action for seed size and the genes controlling smaller seed size were found to be dominant over the large seeds. Gupta *et al*. (1981) also confirmed additive gene action and reported that seed size differences were determined by only 2 or 3 genes. For days to flower, Dahiya and Satija (1978) reported additive genetic variance with partial dominance for earliness, while Gupta *et al*. (1981) reported predominance of additive gene effects.

The heritability estimates provide a guideline on the efficiency of selection as they refer to the proportion of the phenotypic variance that is due to genetic factors. A high heritability estimate suggests that the concerned character can be selected easily in a given test environment. In pigeonpea, a number of reports on heritability estimates for various quantitative traits have been published. Together these estimates provide a good idea about the ease of selection for a particular character. In pigeonpea, a large variation in the estimates of heritability has been reported for all the important agronomic traits. However, most of the studies suggest that characters such as seed yield, pods/plant, and protein content have low heritability. On the contrary, days to flower, plant height, and seed size have high heritability estimates (Saxena and Sharma 1990).

C. Breeding Methods

Globally, very little work is being undertaken to breed vegetable type pigeonpea. However, some efforts were made in the West Indies, Dominican Republic, and ICRISAT to breed new varieties that produce vegetable pods early in the season and produce several flushes of flowers and pods. Vegetable pigeonpea breeding programmes in most countries are predominantly based on selection and purification of native germplasm.

Selection from germplasm: The local landraces are generally well adapted in the area but the natural out-crossing has made them genetically impure. With 25-30 per cent natural out-crossing, the pure lines become heterozygous and heterogeneous. Breeders generally select individual plants of interest within such materials with due consideration to plant type, pod colour, seed colour, and the like. One or two branches of such plants are bagged. At maturity, these selfed branches are harvested separately and their seed is used for evaluation in progeny rows in the subsequent season. Selection should be made among lines and in each selected progeny, five plants should be bagged again for raising their single plant progenies. In the subsequent generation, again 4 - 5 plants are selfed in each selected progeny. The self seeds are used as nucleus seed for further multiplication.

Hybridization and selection: To breed varieties with definite objectives in mind, the selection of parents for hybridization is the first step towards breeding. For example, early maturing varieties should be used as female parents. This will help in identifying the self plants present in an F_1 population. Emasculation should be done carefully and fresh pollen buds be collected for pollination and a piece of thread is tied on the pollinated flowers. In the F_1 generation, the selfed plants that would resemble early maturing parent should be removed. Plants flowering around mid-parent value should be selfed. Selection in F_2 generation should be exercised for pod colour, seed colour, and their size and maturity. These plants can be handled further using classic pedigree selection method.

D. Available Varieties

India: The most popular vegetable pigeonpea cultivars have long pods and large seeds (weighing at least 15 g/100 seeds when dry). These cultivars are grown as a normal field crop, but immature pods are harvested at an appropriate stage for use as vegetable. This practice is more prevalent around cities where green pods can readily be marketed at attractive prices. After harvesting green pods, the crop is left for producing dry seeds. Such dual purpose varieties are very profitable for peri–urban farmers. Cultivars with white seed coat are preferred because the cooking water remains clear when such seeds are cooked. Sweetness of fully grown immature seed is also a preferred trait. Normal sugar levels in green pigeonpea seeds are around 5.0 %; but researchers at ICRISAT have identified a line 'ICP 7035' with a sugar content as high as 8.8 %. This germplasm was collected from *Bedaghat Township* located near Jabalpur city in Madhya Pradesh, India. Its flowers are dark red that produce purple colour pods. The seeds of 'ICP 7035' are large and purple with a mottle pattern. It produces an excellent quality of vegetable. Its pods are 7 - 8 cm long and, on an average, each pod contains six seeds (Fig. 1). Another cultivar 'T 15 – 15' is widely grown in Gujarat

Fig 1. Green pods and seeds of 'ICP 7035', a popular vegetable variety

state for both green and dry seed harvests. In southern India, the large - seeded lines such as 'HY - 3C' and 'TTB - 6' are also popular as vegetable. In hilly tribal areas of India, a large number of large - seeded landraces are traditionally grown for vegetable purpose. Scientists at ICRISAT have also bred an early maturing determinate variety 'ICPL 87' which is also used for dual purpose. It produces pods for relatively longer time and allows 2 - 4 pickings within a year.

Africa: The first early maturing variety 'ICPL 87091' was released in Kenya, Malawi, Uganda, and Tanzania for vegetable as well as dry seed production. In eastern and southern Africa, about 20% of the farmers have adopted new medium maturing pigeonpea varieties like 'ICEAP 00554' and 'ICEAP 00557' both for grain as well as green vegetable purposes. In Tanzania, about 50% of the farmers in *Babati* district have adopted new varieties and pigeonpea production area has now extended to the neighbouring districts of *Karatu* and *Mbulu* (SN Silim, personal communication). The adoption of a late maturing, market preferred variety 'ICEAP 00040' in northern and central Tanzania, Kenya, and Malawi has resulted in increased grain yields.

Southern and Central America and the Caribbean regions: In these regions, Dominican Republic is the highest pigeonpea growing country (17000 ha) with an average yield of 945 kg/ ha (FAO, 2008). The other pigeonpea growing countries are Panama, Venezuela, Jamaica, Trinidad & Tobago, Puerto Rico, and Grenada. Pigeonpea in these countries is essentially a small farmers' enterprise but at national levels, it is an important crop. The first vegetable type variety released in the West Indies was 'Prensado'. It was early in maturity and determinate in growth habit. Subsequently, three more varieties 'Tobago', St.Augustine', and 'Lasiba' were released, which were similar to traditional types in their phenology and are still under cultivation.

In Dominican Republic, pigeonpea is mainly grown by small farmers and about 80% of the annual harvest is exported in the form of canned or frozen green peas. According to Mansfield (1981), in Dominican Republic four pigeonpea varieties are recognized. These are 'Kaki', 'Pinto Villalba', 'UASD', and 'Year-round'. All these varieties have long pods with large and white seeds. In Puerto Rico, 'Kaki' is the most popular pigeonpea variety (Aponte 1963) and '2B Bushy' is another early maturing semi-dwarf variety. Subsequently, a few vegetable type varieties such as 'Panameno', 'Amarillo', 'Kaki', 'Saragateado', and 'Totiempo' (Rivas and Rivas 1975) were also released. Also, there have been recent releases of pigeonpea varieties in Puerto Rico and Dominican Republic. These include 'Guerrero' and 'Cortada', and 'Navideño'. According to Rivas and Rivas (1975), in Venezuela a cultivar 'Panameno' was released in 1972.

E. Cultivation of vegetable pigeonpea

Pigeonpea is known to be highly sensitive to major environmental factors such as photo-period and temperature which influence the development of plant phenology. Late maturing non - determinate types require 40,000 – 50,000 plants/ha for optimum yields.

Backyard and bund cultivation: For domestic use, many families grow pigeonpea plants in their backyards (Fig. 2).

Fig 2. Vegetable pigeonpea plants in the backyard

Such plants are maintained up to 4 - 5 years and they attain a height of over 3 m. The plants start flowering at the onset of short days and pods are picked for house-hold use as and when required. Under normal moisture conditions, new flowers are produced for extended periods and one can see buds, flowers, young, mature, and harvestable pods on the same branch. No specific agronomic practices are followed for this system of cultivation. For local market, relatively large populations are grown on field bunds, mainly around rainy season paddy fields (Fig. 3). In this system, generally 3 - 4 seeds are sown in a single hill. Plants produce a large number of branches on either side of the bunds. In such plantings, if a few plants die due to any reason, the branches of other plants compensate for the loss of biomass. The green pods are picked manually and sold in market either as whole pods or shelled seeds.

Fig 3. A vegetable pigeonpea plant growing on rice bund in Kerala

Peri-urban commercial crop: Since pigeonpea cannot withstand water-logging, low - lying fields should be avoided for vegetable pigeonpea production. Application of 100 kg/ha of di-ammonium phosphate and other soil amendments for the known soil deficiencies is advisable. Green pods are harvested for sale as fresh vegetable in nearby township and cities. Since for vegetable purpose, fully grown bright green seeds are preferred, the pods are harvested just before they start loosing their green colour.

F. Production and maintenance of quality seed

Maintenance of genetic purity of elite genotypes is essential to get high quality performances repeatedly. In a crop like pigeonpea where cross-pollination takes place (Saxena *et al*. 1990), the maintenance of seed quality is not only difficult but also expensive. Therefore, adoption of appropriate isolation distance is essential, and it requires extra precautions to maintain variety purity. Some of the important steps that would help in quality seed production include purchasing good quality seed from a reliable source, adoption of normal sowing time, selection of good field, maintenance of isolation distance of at least 200 m, roguing of all the off-types at flowering or as soon as they are spotted, sun drying of seeds for a few days to bring down seed moisture level to 9.0%, treating seed with fungicides and packing it in small polyethylene bags for storage.

G. Commercial processing of vegetable pigeonpea

Commercial vegetable pigeonpea is commonly processed into canned or frozen peas. Among the countries involved in commercialization of vegetable pigeonpea, Dominican Republic stands first from where vegetable pigeonpea is exported to the United States and other countries. The literature on various aspects of processing is scanty and the author could access only one good publication (Mansfield, 1981), which gave details of vegetable pigeonpea processing technology. The following steps are essential in canning and freezing procedures of vegetable pigeonpea.

Vining and cleaning: To maintain freshness of harvested green pods, they should be shelled as quickly as possible. This will not only avoid fermenting but also make available necessary oxygen to maintain the quality. Vining (shelling) of small lots of pods is usually done manually and the shelled peas are generally consumed in local market either as fresh or frozen peas. The bigger lots are used for commercial purpose where vining and cleaning are performed mechanically (Fig. 4). Most commercial canners feed the green pods directly into the vining machine while some use a pre-treatment of heat for better yields and clear brine. For local market, the shelled peas are washed and cleaning operation is carried out to remove unwanted peas and inert materials. The mechanically vined peas are cleaned soon after shelling. For this purpose, the shelled peas directly fall onto conveyors for cleaning and washing. The dry cleaning operation is performed by passing the shelled peas through an air blast which helps in removing small pieces of pods or vine, dust, *etc*. The cleaned lot passes through a mesh screen that allows

Fig 4. Mechanical shelling of vegetable pigeonpea in China

the peas to drop through it but retains large size peas and extraneous materials. Subsequently, the product passes through a fine mesh that retains shelled peas but removes fine dirt and splits. This dry cleaning operation is followed by washing for removing floating dirt, skins, split peas, and worms. The washing is carried out more than once in various types of flotation washers with cold running water. After washing, the shelled peas are forced to pass through rotary rod washers where splits, undersize, and mashed peas are separated. The washed peas fall on a belt where off-colour and remaining worm - damaged, and broken peas are removed manually for further processing (Mansfield 1981).

Blanching: Heat treatment or blanching is an essential treatment for both freezing as well as canning. This helps in stabilizing colour and flavour besides improving the texture of seeds. According to Mansfield (1981), the blanching operation also helps in producing clear brine by discarding mucous substances, starch particles, and inter-cellular gases. The best blanching is done by heating the peas to 185^{o} F for five minutes in hot water followed by cooling in cold (80^{o}F) water (Sanchez Nieva *et al.* 1961). Melmick *et al.* (1944) showed that steam is excellent in preserving nutrients of fresh peas but in most cases this process is not cost effective. After the above mentioned series of treatments, the processed peas could be used either for canning or for freezing. These two follow-up treatments are summarized below:

(a) Freezing: According to Mansfield (1981), the following two methods of freezing peas are used in Dominican Republic. In the automated freezing system the peas are cooled in water at ambient temperature soon after blanching and then taken to fluidized bed freezer. In this freezer, operating between -10^{o} F to -20^{o} F, the peas are quick-frozen individually while moving inside a vibrating conveyor screen which receives a rapid moving current of cold air from the lower side (Mansfield, 1981). The frozen peas are then hand picked and kept in wax treated cartons. These cartons are stored at 0^{o} F. In batch freezing system, a blast freezer is used for small quantities of shelled peas. The blanched peas are dropped in cold water tanks and then the peas are hand picked in polyethylene bags and placed for freezing in a batch freezer between -2^{o} F to -10^{o} F for 4 to 10 hours. These packets are stored at 0^{o} F (Mansfield, 1981).

(b) Canning: For canning purpose, the blanched peas are taken to volumetric filler through an elevator. Here the cans are filled with peas and 2% brine at near-boiling (195-200^{o} F) temperature. No additives are used for canning (Mansfield, 1981). For closing the cans, if near-boiling brine is maintained, then the exhaust or steam closure is not adopted. This follows a thermal processing to check the growth of any thermo-philic bacterium. After the thermal processing, the cans must be cooled immediately to reduce the thermal quality losses by putting the cans in cool water ponds to bring down their temperature to 90-105^{o} F.

H. Marketing of vegetable pigeonpea

In southern America, green pigeonpea pods are collected from the farm gate by the representatives of canning plants. The processed cans are sold to wholesalers for export to the United States, Puerto Rico, and other Latin American countries. In India and Africa, the marketing of vegetable pigeonpea is not well organized. Generally, local venders buy the product from whole-sale vegetable market and sell in local retail market.

I. Conclusions

The importance of vegetables in human diet can not be under-emphasized. Vegetable pigeonpea can be good sources of valuable proteins, vitamins, carbohydrates, and dietary fibre for humans. Vegetable pigeonpea complements the nutritional profile of cereals, and is a good source of protein, vitamins (A, C, B complex) and minerals (Ca, Fe, Zn, Cu). Vegetable pigeonpea scores manifold advantages over green peas (*Pisum sativum*). It has more than five times beta carotene content, three times more thiamine (vitamin B_1), riboflavin (Vitamin B_2), and niacin. The ascorbic acid content is more than two times over peas. Similarly, it scores over peas in terms of minerals such as calcium and copper (more than two times higher), and magnesium. Besides all, the shelling percentage of vegetable pigeonpea is 72% compared to 53% of green peas. All these factors render vegetable pigeonpea a highly nutritive potential crop for all ages. It can become one of the most nutritionally rich vegetables of the daily cuisine, especially for the poor in India, Nepal and Myanmar. It is already a vegetable of choice for Kenya, Tanzania, Malawi, Uganda, and the Caribbean.

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