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Research Article

PIGEON PEA (*CAJANUS CAJAN* L.) BY-PRODUCTS AS POTENT NATURAL RESOURCE TO PRODUCE PROTEIN RICH EDIBLE FOOD PRODUCTS

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ABSTRACT

Pigeon pea [*Cajanus cajan* (L.) Millsp.] is one of the important perennial food legume crop in the semi-arid tropics acting as an important source of protein, dietary fiber, vitamins and minerals. It is low in saturated fat, cholesterol and sodium, accomplishing it as a suitable healthy substitution to meat. Normally, pigeon pea is consumed in the form of dehulled splits, which are obtained after milling or processing. During this process various by-products are released, which found to contain 20 % of the protein, can be blended with other flour to produce protein rich edible food products. So, pigeon pea by-products in combination with grains constitute a well-balanced human diet and can be used as a potential protein source to reduce the protein deficiency and malnutrition. The present article describes the use of pigeon pea by-products as low cost alternative protein source to improve the nutritional value of human diet.

INTRODUCTION

Pigeon pea or red gram (*Cajanus cajan* (L) Millsp.,) (Family: Fabaceae) is a protein-rich grain legume crop of the semi-arid and sub-tropical regions of the world, ranks third in Asia and sixth in the global pulse production after beans (*Phaseolus* spp.), pea (*Pisum sativum* L.), chickpea (*Cicer arietinum* L.), broad bean (*Vicia faba* L.) and lentil (*Lens culinaris* Medik.). Pigeon pea probably evolved in South Asia and appeared in West Africa around 2000 BC, which is considered as its second major center of origin. Later, it was taken by the slave trade to West Indies in 1692 to use it as a bird feed, which led to the name "pigeon pea". All over the world, India is the largest producer (81.49 %) and consumer of pigeon pea, which is contributing 80 % of the global production.

This leguminous shrub grows to a height of 5 m and its leaves are trifoliate and spirally arranged on the stem (Figure 1). Flowers occur in terminal or axillary racemes, which are 2-3 cm long and are usually yellow in color. Pods are flat, usually green in color, but sometimes they are hairy, dark purple or streaked, with 2-9 seeds/pod. It is mainly cultivated as a food crop (dried peas, flour or green vegetable peas) and also used as a forage / cover crop. The harvesting period of pigeon pea crop is 6-9 months. Due to its multiple uses, it is considered as a multi-purpose legume, which not only provides food, fodder and domestic fuel wood, but also fixes 40 kg ha^{-1} atmospheric nitrogen that adds valuable organic matter to the soil through fallen leaves. Its foliage is an excellent fodder with high nutritional value (Onim *et al*., 1985), which contains 24 % crude protein, 36 % crude fiber and significant amount of minerals. In addition, the roots help in releasing soil-bound phosphorus to make it available for plant growth and also enrich the soil by improving water infiltration and conserve valuable nutrients and water.

Figure 1 Flowering pigeon pea plant with pods

In India, compared to other legumes, pigeon pea (*Cajanus cajan* L.) is predominantly grown as a multi use grain crop, which is also known as red gram, arhar, tur dal, congopea, gungopea etc.

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Figure 2 Harvested matured pigeon pea seeds

Its seeds (Figure 2) are important source of proteins, energy and other nutrients in the diets of large population groups around the world, forming an excellent source of lysine, methionine and tryptophan and other water–soluble vitamins (riboflavin, niacin and folacin) and minerals (phosphorus, iron and magnesium) (Ramcharran and Walker, 1985). The whole dry seed of pigeon pea may be cooked alone or with other vegetables, where 90 % of the crop is consumed mainly as de-hulled splits (Figure 3), which is obtained after the process of dehulling. But, the splits produced after appropriate processing or milling show a consequential decrease in nutritional value as the nutrient rich edible parts are separated from the starchy endosperm. The by-products released during the dehulling process includes processed grains, brokens, hull and powder, which are potential source of the protein and fiber.These nutritionally rich by-products can be combined with other cereal flour to produce protein rich edible food products and to supplement the protein need in the diet. The food items that can be prepared from pigeon pea are fresh sprouts, tempe,

Figure 3 Pigeon pea split dal produced after dehulling process

ketchup, noodles, snacks and various extruded food products (Saxena *et al*., 2002). In addition, the by-product of split and shrinked seeds are also used as a cheap livestock feed as a substitute to high cost animal feed sources such as bone meal and fish meal (Phatak *et al*., 1993; Chisowa 2002). Similarly, the by-products of pigeon pea such as seed coats, brokens and powder obtained from the dhal mill are also used as a feed for cows, poultry and pigs (Saxena *et al*., 2002; Sugui *et al*., 2007).

In India, several pulses have been used as a traditional supplement to staple cereals in the form of splits (Ghadge *et al*., 2008) or whole seed cooked rice, chapattis and poories (Kachroo, 1970) to have a complementary nutritional effects and their consumption fulfills the need of a balanced diet. Pigeon pea has been reported to contain 21-26 % protein (Abdel and Rahman, 2010; Okpala and Okoli, 2011), 1.2 % fat, 65 % carbohydrate and 3.8 % ash (FAO, 1982). Trinidad *et al*. (2010) stated that pigeon pea could be considered as a functional food due to its dietary fiber content, which provides potential health benefits in the prevention of chronic diseases.

Besides its nutritional value, pigeon pea also possesses various medicinal properties due to the presence of a number of polyphenols and flavonoids. It is an integral part of traditional folk medicine in India, China and some other nations (Saxena *et al*. 2010). In India, leaves of pigeon pea are used for curing wounds, sores, abdominal tumors and diabetes (Odeny, 2007). Fresh seeds are used to help from incontinence of urine in males, while immature seeds are suggested for treatment of kidney ailments (Duke, 1981). Scorched seeds are added to coffee to relieve from headache and vertigo (Saxena *et al*., 2010). Dried roots of pigeon pea are used as an alexeritic, anti-helminthic, expectorant, sedative and therapeutic agents (Saxena *et al*., 2010).

However, like other legumes, the nutritive value of pigeon pea is masked by the occurrence of anti-nutritional factors (ANFs) (Grimaud, 1988; Francis *et al*., 2001). So to improve its nutritional profile and ensure its utilization as formulated diet, different processing methods like boiling in water followed by subsequent seasoning with oil and spices and toasting of seeds (Ghadge *et al*., 2008) are employed. Plant protein provides nearly 80 % of the protein intake in developing countries as compared to developed ones, where it is about 43 % (Paroda, 1995). But, the utilization of this legume has been relegated to low-income families, despite its high nutritive and satiety value, unique good taste and cheapness (Fasoyiro *et al*., 2010). Food supplementation is the process to increase the level of essential nutrients lacking in a particular source by adding a source rich in those nutrients. This is practiced in developing countries to prevent the malnutrition, especially among the children. The supplementation of cereal-based foods with legume proteins like hydrolysate could result in improved nutrition both in quality and quantity. Kokoro is a ring-like, maize-based, ready-to-eat snack food of Nigeria. There were reports on supplementing Kokoro with legumes like pigeon pea as protein-rich source (Adegunwa, 2015; Adeola *et al*., 2011). Consumption of legumes and their components along with grains in various food formulations have been increased now a days in developing countries (Boye *et al*., 2010). In Eastern part of Nigeria, a well-

balanced pigeon pea food product known as "Fiofio" was prepared in combination with cereals for human consumption. Daniel *et al*. (1970) reported that supplementation of cereal diets with various proportions of pigeon pea in rats significantly enhanced the nutritive value of diet. Based on earlier studies, the quality of food products can be significantly improved by supplementing the maize diet with pigeon pea (Kurien *et al*., 1971).

Mostly, in developing countries of the world, hunger and malnutrition are increasing due to population explosion, shortage of fertile land and high food prices (FAO, 1980; Pelletier *et al*., 1995). Globally, it is the most important risk factor for illness and death of hundreds of millions of pregnant women and young children. Many countries are adopting different strategies to overcome this problem. To improve the nutrient intake, food preparation technologies are recommending food supplementation to increase the nutrient availability of vegetable diets effectively. These technologies must be simple and easily affordable in terms of economy and labor. Among the food legumes, red gram or pigeon pea (*Cajanus cajan* L.) occupies a very important place in human nutrition in many developing countries (Duhan *et al*., 2001; Mulimani *et al*., 2003). So, formulation of nutrient rich food items from an economic and cheap source like pigeon pea offers an efficient alternative strategy to combat the problem of malnutrition effectively. Based on this, pigeon pea flour can be recommended as an effective ingredient to increase the nutritional value of various food products. For example, enrichment of pasta with cereal germ or leguminous material increases the nutritional quality due to its larger amount of protein, vitamins and minerals, without affecting its sensory properties (Torres *et al*., 2007). The level of substitution depend on the formulation, preparation and processing of pasta products (Quaglia, 1997).

In the present study, use of pigeon pea by-products as an alternative potential source of protein to minimize the defects of malnutrition due to protein deficiency was discussed.

Milling and Processing of Pigeon pea

Pigeon pea seeds have some anti-nutritional factors, which must be removed by processing before consumption. Some simple and inexpensive domestic processing techniques, such as soaking, sprouting, germination and cooking are commonly employed to remove them in case of legumes (Prodanor *et al*., 2004). Tabekhia and Luh (1980) studied the effects of soaking, cooking on phytate retention in dry beans and reported that, heat processing can lower the phytate level and increase the availability of minerals present in pigeon pea. Blanching is the heating of legumes for a short period of time with either steam or water for 1.5 to 5 min at 77-82°C to remove tannins and phytic acid (Erdman and Pneros-Schneier, 1994; Yeum and Russell, 2002; Yadav and Sehgal, 2002). Cooking is the oldest method of bean processing that improves the nutritive value of the protein in legumes and inactivates heat sensitive anti-nutritive factors. This process reduces the tannins and other anti-nutritional agents and improves the appearance and texture of the grains. The phytate content of legume seeds decreases during cooking (Crean and Haisman, 1963).

The most commonly used method of pigeon pea processing is dehulling to improve its nutrient value. In India, every year approximately 2.5 million tons of by-products (Figure 4) are being produced from legume processing industries.

Figure 4 Pigeon pea by-product flour

These by-products consist of under processed grains, brokens, hull and powder, which are commonly used as cattle feed. The proportion of seed coat, cotyledons and embryo during the processing of pigeon pea are in the ratio of 15.50 %, 83 % and 1.50 %. Depending upon the machinery and the processing techniques, the total content of by-products obtained from the processed grains will be approximately 20-30 % (Bressani and Elfas, 1980). A process was investigated by Narasimha *et al*. (2004) to retrieve the cotyledonary material from commercial dhal mill by-products, which contain approximately 50 % of the cotyledonary material that finally amounting up to 1 million ton. The steps involved in this process are destoning, size separation and air classification followed by refining and thermal stabilization of the edible material. Using the above process, approximately 30-35 % of the cotyledonary material was retrieved from the by-products and used further for the preparation of traditional pulse based products. According to their studies, cotyledonary material can be used up to 50 % in traditional pulse based products like vada, papads, rasam/sambar powder etc.

The hull produced during this process contains significant portion of the insoluble dietary fiber, free and hydrolysable phenolic acids (Naveena and Bhaskarachary, 2013). These polyphenols are reported to have many health benefits, due to their anti-inflammatory and antioxidant nature (Scalbert *et al*., 2005). In the case of pigeon pea the content of phenolic acids present in 100 g of flour was 2 to 3 mg (Naveena and Bhaskarachary, 2013). Various experiments conducted on human cell lines and animals demonstrated that these polyphenols play an important role in the prevention of cardiovascular diseases and cancer (Singh and Jambunathan, 1982).

Nutritional losses during dehulling

Commercially, dehulling of pigeon pea is done by using big machines, while in rural areas the same process is done by using traditional grinding stones called chakki. In pigeon pea the cotyledons are attached tightly with seed coat by gums, so it's dehulling is difficult comparative to other legumes, which involves the loss of seed mass. The processing involves loosening of husk followed by dehusking and splitting of the cotyledons. The recovery of dhal after processing is around 70 % by machines and 60 % by chakki excluding the husk. According to Singh and Jambunathan (1982) by using advanced and traditional methods the loss of grain mass is about 15 -17 % and 20-25 %.

Table 1 The dietary nutrients of pigeon pea (Source: Faris *et al.* 1987)

Components	Immature seed	Mature seed	Dhal
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 (%)	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 100 g^{-1} soluble sugar)	10.3	53.5	-
Crude fiber (%)	8.2	6.6	1.2
Fat (%)	2.3	1.9	1.6

Nutritional value of pigeon pea

Pigeon pea due to its high protein content, it is desirable to use as a protein supplement to cereal-based diets. Its seeds show lower lipid content and are free of cholesterol and possess different minerals and vitamins. (Sebastia *et al*., 2001; Deka and Sarkar, 1990; Khandelwal *et al*., 2009; Elhardallou and Walker, 1994). It is a good source of amino acids and is significantly higher in sulphur-containing amino acids (cysteine and methionine) (Saxena *et al*., 2002; Elegbede, 1998; Singh *et al*., 1990). The essential amino acids like methionine, cystine, tryptophan and threonine are limiting in pigeon pea are present in cereals. So, it is ideal to compensate pigeon pea with cereals, where the ratio of weight for cereals to legume is roughly 70:30 (Hulse, 1977). Pigeon pea contains more minerals (Table 2), like iron (Fe), sulphur, calcium, potassium (K), magnesium, copper, zinc and five times more vitamin A, water soluble vitamins (Table 3), especially thiamine, riboflavin, niacin (Faris *et al*., 1987; Saxena *et al*., 2010; Sinha, 1977; Singh *et al*. 1994), three times more vitamin C and is also a good source of crude fiber than ordinary peas (Foodnet, 2002).

Table 2 Minerals and trace elements of pigeon pea (mg/ 100^{-1} g dry matter) (Source: Faris *et al.* 1987)

Minerals	Immature seed	Mature seed	Dhal
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

Table 3 Vitamins present in pigeon pea (mg /100- 1 g fresh weight of edible portion) (Source: Faris et al. 1987)

Vitamins	Immature Seed	Mature Seed
Carotene (Vit A)	469	28 IU
Thiamine (Vit B1)	0.3	0.643
Riboflavin (Vit B2)	0.3	0.187
Niacin	3.0	2.965
Ascorbic acid (Vit C)	25.0	0. 00

Pigeon pea seeds are made up of 85 % cotyledons, 14 % seed coat and about 1 % embryo and contain a variety of dietary nutrients (Faris and Singh, 1990). Cotyledons of seed are rich in carbohydrates (66.7 %) and one-third of the seed coat is made up of fiber, while a major proportion (about 50 %) of seed protein is located in the embryo. The quantities of sulphur-containing amino acids such as methionine and cysteine present in cotyledons and embryo range around 1% (Singh and Jambunathan, 1982), while calcium is predominantly present in seed coat and embryo. The proportion of prolamin is low, where as the proportion of sugars such as stachyose and verbascose is high in pigeon pea seeds (Nigam and Giri, 1961).

The total protein content in red gram ranges from 19.73 to 24.44 % (Manimekalai *et al*., 1979). Onweluzo and Nwabbugwu (2009) and Rana (2006) reported that pigeon pea flour contains 22.04 to 22.68 % of protein. Singh and Jambunathan (1982) analyzed protein content in different parts of pigeon pea and reported that the embryo has high albumin concentration compared to the other parts of the seed. Faris *et al*. (1987) studied the protein content of pigeon pea at different stages and reported that green seed, mature seed and dal contains 21.0, 18.8 and 24.6 % of protein (Table 1)

Reddy *et al*. (1979) reported that compared to inner layers of cotyledons, the outer layers are rich in protein content. But, during the process of dehulling, removal of seed coat eliminates the protein-rich germ and some portion of the outer layers of the cotyledons. The husk, which is released during pigeon pea seed processing as a by-product is also an economic and readily available natural rich source of protein and polyphenols. It has the capacity of scavenging a variety of free radicals like $ABTS^{+}$, DPPH and obtains reducing power ($FeCl_3$ and NBT).

Moreover, it exhibits anti-oxidant activity (ABTS oxidation) and the ability to prevent free radicals induced damage to biomolecules like 2-deoxy-D-ribose and hemoglobin (Tiwari *et al*., 2013).

The pigeon pea brokens contain different minerals like calcium, phosphorous and iron in the quantities of 237.3, 457.2 and 8.2 (mg/100 gms) and also contains fat around 1.7% (Singh, 1993). As per the reports of Narasinga Rao *et al*. (1989) the content of calcium, phosphorous and iron in pigeon pea brokens were 73, 304 and 2.7 (mg/100 grams) respectively. The distribution of magnesium, calcium, iron, zinc and copper in 100 gm of mature pigeon pea seed were reported as 122.0 mg, 120.8 mg, 3.9 mg, 2.3 mg and 1.3 mg respectively (Saxena *et al*. 2010).

Application of pigeon pea by-products and flour in various food formulations

Use of pulses and their components in the preparation of various food products has been increased in developing countries. In the world, about 70 % of the protein need for human consumption is being obtained from the plant sources, where as in India, it is about 90 %. Previously conducted experiments revealed that, cereal based food products fortified with leguminous products will enhance the nutritional quality (Blandino *et al*., 2003; Kerr *et al*., 2001; Ranjana *et al*., 2000; Rao and Surpalekar, 1996). Several researchers recommended the use of legume flour as a source of protein in the preparation of bakery products (Cady *et al*., 1987; Eneche, 1999; Hegaz and Faheid, 1990; Mustafa *et al*., 1986; Sathe *et al*., 1981; Lorenz, 1983). To prevent protein-calorie malnutrition in the developing world, the supplementation of cereals with protein rich legumes is considered as one of the best solutions (Chitra *et al*., 1996). Pigeon pea flour has been tested and found to be suitable for consumption as bread, cookies and chapattis due to its high level of protein, iron (Fe) and phosphorous (P) content (Harinder *et al*., 1999). So, it has been recommended in school feeding programmes and to the vulnerable sections of the population in developing nations. The protein-rich pigeon pea seeds have also been incorporated into cassava flour to produce acceptable extruded products (Rampersad *et al*., 2003; Ae *et al*., 1990).

In Bakery, cereal based traditional products like biscuits, cookies (Figure 5) and bread prepared from the grains are mixed with legume flour or milk to increase their nutritional value (Adeyemi *et al*., 1989; Patel and Rao, 1995).

Figure 5 Cookies prepared with pigeon pea by-product supplemented with refined flour

With the similar approach, biscuits have been prepared by using chickpea and broad bean flour (Rababah *et al*., 2006). Tiwari *et al*. (2011) reported that, contents of protein and fiber were increased in biscuits prepared by substitution of wheat flour with pigeon pea by-product in different ratios. The high protein and fiber content was observed in biscuits prepared with wheat flour and pigeon pea by-product in 75: 25 ratios. Similarly, enhanced protein content was noticed in biscuits prepared by blending refined flour with pigeon pea brokens flour, where the content of protein was observed to be increased by 20 % with the addition of pigeon pea flour to refined flour (Silky, 2014). Few researchers recommended the use of pigeon pea flour to improve the nutritional quality in the preparation of cookies, where it was blended with cocoyam and sorghum flour (Okpala and Okoli, 2011). Ashaye *et al*. (2015) stated that a significant increase in the crude protein content was observed in the biscuits prepared from pigeon pea and cassava flour compared to other types of biscuit samples. The underutilized by-product of pigeon pea (20 % protein content) with great potential as a valuable protein can also be used as drug/nutraceutical carriers, which would be safe for human consumption compared to synthetic materials (Tapal and Tiku, 2013). The agricultural by-product used as a protein source would indirectly resolve environment related problems caused by their dispersion.

CONCLUSION

Pigeon pea is a rich source of food proteins and occupies an important place among the pulses. Based on its amino acid profile and biological value, it was considered as the best natural source of essential nutrients and recommended as a balanced diet. Pigeon pea can fulfill the nutritional gap of proteins, when it was mixed with cereals in the poorer section of developing economies that cannot afford a non-vegetarian diet. At present, the protein availability in developing countries is about one third of the normal requirements due to the ever-growing population. So, various nutritional development programs prevailing at present are facing a tough challenge to meet the protein demand. Hence, the use of pigeon pea derived by-products can be an alternative source to combat the problem of the protein deficiency by cereal legume mutual supplementation principle. These by-products also possess therapeutic properties, which can be branded as a food with neutraceutical properties. So, preparation of food products using an economic and cheap source like pigeon pea by-products offers an efficient alternative strategy to reduce the malnutrition at global level.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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