CP 628

1472

The Role of Pigeonpea in Human Nutrition

Umaid Singh[1]

Abstract. *Pigeonpea is used in various human foods in several developing countries, particularly in India as a source of dietary protein,. Like other food crops, the nutritional potential of pigeonpea as a human food is primarily determined by its chemical composition, bioavailability of nutrients, and the levels of various antinutritional factors. Proteins and carbohydrates are the principal constituents of pigeonpea seeds, and a variety of factors influence the nutritive value of these constituents. At ICRISAT, high protein lines of pigeonpea are available, and these lines are nutritionally better than the commonly grown cultivars. Pigeonpea seed contains noticeable amounts of antinutritional factors, such as protease inhibitors, oligosaccharides, and polyphenols, but these constituents can be wholly or partially removed by suitable processing methods. Globulins that are deficient in sulphur amino acids, methionine and cystine, constitute nearly 65% of the total seed proteins of pigeonpea, and hence play an important role in determining its protein quality.*

India accounts for about 80% of the total world pigeonpea production. For human consumption a large proportion of this produce is dehulled to convert whole seed into dhal. *Quantitative and qualitative nutritional losses occur during dehulling. Cooking of* dhal *and whole seed affects the palatability and bioavailability of nutrients. Various physico-chemical characteristics and environmental factors affect cooking quality. Traditional processing practices used to convert pigeonpea into consumable forms include soaking, fermentation, boiling, roasting, frying, and steaming, and all these practices influence nutritive value.*

Developing green seeds are consumed as a vegetable. Their nutritional composition is better than that of mature seed, as their protein and starch are more digestible, and they contain lower amounts of protease inhibitors, polyphenols, and the flatulence-causing sugars; raffinose, stachyose, and verbascose.

1. Biochemist, Crop Quality Unit, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, A.P. 502 324, India.

ICRISAT Conference Paper no. CP 628.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1991. Uses of tropical grain legumes: proceedings of a Consultants' Meeting, 27-30 Mar 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

Introduction

Grain legumes are traditionally consumed as human foods, along with cereals in various forms. Among food crops, legumes contain the highest amount of protein, generally twice the level found in cereal grains. Grain legume proteins are rich sources of lysine, but are usually deficient in sulfur-containing amino acids, methionine, and cystine. Cereal-grain proteins are low in lysine, but have adequate amounts of sulfur amino acids. Therefore, the supplementation of cereals with legumes has been advocated as a way of combating protein-calorie malnutrition problems in developing countries.

Pigeonpea is an important grain legume commonly grown and consumed in tropical and subtropical regions of the world. India accounts for over 80% of the world's supply of pigeonpea (ICRISAT 1986). Other countries where pigeonpea is an important food legume are Sri Lanka, Myanmar, the Philippines, Indonesia, Kenya, Malawi, Tanzania, and some Caribbean countries. In India, pigeonpea is processed into *dhal*, which is consumed after cooking in water to a desirable softness, but in some African countries, whole pigeonpea seeds are consumed after boiling. The developing green seeds shelled out of harvested green pods are also used as a vegetable in India, and in some African, Latin American, Caribbean, and Asian countries. This paper describes various aspects of the nutritional quality of pigeonpea for use as a human food.

Chemical Composition

Pigeonpea cotyledons constitute about 85% of total seed mass. The embryo contributes only 1% to the total seed mass and the seed coat, 14% (Singh and Jambunathan 1982). Therefore, the chemical composition of the cotyledons greatly influence the nutritive value of whole pigeonpea seed. Pigeonpea cultivars are broadly classified into three groups: early (90-150 days), medium (150-180 days), and late (180-200 days), based on their maturity durations. The starch content of pigeonpea cultivars belonging to different maturity groups ranged between 50.6% and 57.6%, with the mean being 55.0% (Singh et al. 1984a). This study also showed that seasons did not have a large effect on pigeonpea starch and protein contents. Pigeonpea contains considerable amounts of unavailable carbohydrates that are known to reduce the bioavailability of some nutrients (Kamath and Belavady 1980). Crude fiber, ash, and fat contents of various cultivars did not show wide variation (Singh et al. 1984a). Differences in the mineral composition of whole grain and *dhal* were marginal, except for calcium (Sankar Rao and Deosthale 1981).

Nutritional Quality of Vegetable Pigeonpeas

For use as a vegetable, pigeonpea is normally picked when the seeds reach physiological maturity, i.e., when they are fully grown, but just before they lose their green color (Faris et al. 1987). At this stage, the green seed is more nutritious than the dry seed because it contains more protein, sugar, and fat than the mature seed. In addition, the protein and starch digestibility of green seed is better than that of the mature seed. The green seed also contains lower quantities of flatulence-causing sugars, and trypsin and amylase inhibitors (Singh et al. 1984b). Green pigeonpea is a good source of iron (Singh et al. 1984c). Further, these studies reported that since the mature seed of pigeonpea is normally eaten after the removal of its seed coat which provides about 70% of the total seed calcium, green seed, which is normally eaten with its testa, can provide a very good source of calcium. However, it is important to study the bioavailability of dietary nutrients of green pigeonpea seed to determine their nutritional impact on the human diet.

Protein Quality

The protein quality of pigeonpea is primarily expressed in terms of its protein content, the levels of amino acids, and protein digestibility (Singh and Eggum 1984). In most food crops, genetic variability for protein content is considered an important factor for improving protein quality by selection and breeding. The protein content of *dhal* samples of cultivated and wild species of pigeonpea varies widely. At ICRISAT Center, efforts have been made to use genetic variability to improve the protein content in pigeonpea, and high-protein lines with acceptable seed size have been developed (Saxena et al. 1987). However, environment and agronomic practices influence the protein quality of pigeonpea to a considerable extent, and this should be noted while breeding for protein quality.

The sulfur amino acids, methionine and cystine, are the most limiting amino acids of legumes, and very low values for these amino acids were reported in pigeonpea (Eggum and Beames 1983). In legumes negative relationships are usually found between protein percentage and methionine content per unit of protein (Bliss and Hall 1977). However, there was no strong relationship between methionine (g 100 g^{-1} protein) and protein (%) in pigeonpea, indicating that both protein and methionine could be improved (Singh and Eggum 1984). The effect of cooking on protein quality, in terms of amino acids and bioavailability of legume proteins, is important. A slight reduction in lysine content was observed as a result of cooking (Singh et al. 1990). Seed protein fractions play an important role in determining the overall amino acid composition of seed proteins. As in the case of other legumes, storage proteins and globulins constitute about 65% of the total seed protein of pigeonpea (Singh and Jambunathan 1982). Further, the globulin proteins are deficient in sulfur amino acids. Although present in a small proportion, albumin fractions, are a very rich source of methionine and cystine. Glutelin fraction is also a better source of su'fur amino acids than globulin, and hence may be nutritionally desirable.

Protein bioavailability is of increasing interest in grain legumes in general, and in pigeonpea in particular. For this purpose, the biological evaluation of seed protein is essential, as chemical analysis does not always reveal how much of a protein is biologically available. Unfortunately, pigeonpea has the lowest biological value among legumes (Eggum and Beames 1983). Biological value, protein digestibility, net protein utilization, and utilizable protein of cooked whole seed and *dhal* samples of high protein (HP) and normal protein (NP) genotypes of pigeonpea have been reported (Singh et al. 1990). Criteria based on these characteristics have been suggested as useful for evaluating the protein quality of cereals and legumes, and are commonly followed, because human feeding trials are always difficult and time consuming.

True protein digestibility (TD) significantly increased with cooking, and the effect was more pronounced in whole seed than in *dhal* samples. Interestingly, the biological value (BV) of the cooked sample decreased in both whole seed and *dhal*, whereas net protein utilization (NPU) of the cooked samples increased, possibly due to an increase in protein digestibility. A decrease in the BV of cooked samples, of both whole seed and *dhal* might be attributed to heat treatment, which causes considerable nutritional damage to methionine, the most important amino acid in grain legumes (Shemer and Perkins 1975). A comparison of TD of whole seed and *dhal* samples of these genotypes indicated large differences. Average TD was about 60% for whole seed, whereas it increased to over 70% in *dhal* samples. A reduction in TD of whole seed may be due to higher concentration of polyphenols and fiber content, as a majority of these compounds are concentrated in the seed coat. Although TD, BV, and NPU values have shown differences among genotypes, no noticeable differences in the protein-quality attributes of high protein (HP) and normal protein (NP) genotypes were observed. More importantly, the values for utilizable protein (UP) were considerably higher in HP than in NP genotypes of pigeonpea, indicating that HP genotypes are nutritionally better than NP genotypes (Singh et al. 1990).

Antinutritional Factors

Of the various antinutritional factors that are found in grain legumes, trypsin and chymotrypsin inhibitors, amylase inhibitors, polyphenols (commonly referred to as tannins), and oligosaccharides are important in pigeonpea (Singh 1988).

The protease (trypsin and chymotrypsin) inhibitors of legumes have been extensively studied, and their mode of action established. In comparison with soybean, pea, and common bean, pigeonpea offers fewer antinutritional factor problems. Pigeonpea contains considerably higher levels of protease inhibitors than the other commonly consumed Indian grain legumes, but much lower levels than those of soybean (Sumathi and Patabhiraman 1976). Pigeonpea contains considerable amounts of polyphenolic compounds that inhibit the activity of digestive enzymes, trypsin, chymotrypsin, and amylase. These are higher in pigeonpea cultivars with dark seed-coat colors (Singh 1984). Phytolectins are toxic factors that interact with glycoprotein on the surface of red blood cells, causing them to agglutinate. Pigeonpea contains phytolectins which are highly sensitive to heat treatment and hence may be of little nutritional significance. Pigeonpea contains traces of glycosides but not at toxic levels (Singh 1988).

Food legumes are well known for causing flatulence when consumed in large quantities. This property is mostly attributed to high levels of oligosaccharides: stachyose, raffinose, and verbascose. These three sugars together constitute about 53% of the total soluble sugars in pigeonpea, but they show a large variation (Singh 1988). Pigeonpea, chickpea, urd bean, and mung bean, in order of decreasing volume, produced flatus in rats (Kantha et al. 1973). These studies suggest that pigeonpea and chickpea may cause discomfort because of higher flatus production, if consumed in large quantities.

The Effect of Processing on Nutritive Value

Pigeonpea is traditionally processed into consumable forms by methods that can be broadly divided into two categories: 1) primary processing, also called dehulling; and 2) secondary processing, which involves three major treatments, namely, cooking, fermentation, and germination. Dehulling pigeonpea improves its palatability and digestibility. The dehulling process is commonly referred to as the removal of seed coat, and may take place either with the dry, raw, whole seed as dry dehulling, or with soaked grains as wet dehulling. Most common methods of dehulling remove the germ along with the husk and cause noticeable losses of protein, calcium, iron, and zinc, the important dietary constituents (Singh et al. 1989). This study suggested that efforts should be made to develop suitable methods of dehulling to reduce quantitative and qualitative losses in pigeonpea grains.

Of the various secondary processing practices, cooking improves the bioavailability of nutrients, and also wholely or partly destroys some antinutritional factors (Salunkhe 1982). The starch digestibility of pigeonpea and other commonly consumed Indian pulses is improved by moist heat treatment. The enhancement of carbohydrate digestibility in cooked legumes is generally attributed to the swelling and rupturing of starch granules. Although cooking improves nutritional quality, prolonged cooking results in a decrease in protein quality and loss of nutrients such as vitamins and minerals. In this context, soft-cooking cultivars of pigeonpea are preferable. A major beneficial effect of cooking is the destruction of protease inhibitors, which interfere with protein digestibility. Pigeonpea protease inhibitors are completely destroyed when subjected to heat under acidic conditions (Sumathi and Patabhiraman 1976). Preliminary soaking followed by dry heat treatment also results in the partial inactivation of the trypsin inhibitor activity (Contreras and Tagle 1974).

Germination can reduce or eliminate appreciable amounts of phytic acid of legumes, and hence improves mineral bioavailability (Salunkhe 1982). The nutritive values of legume-based fermented foods have been shown to be higher than those of their raw components. Laboratory results at ICRISAT have shown that fermentation increased the levels of soluble nitrogen and soluble sugars in pigeonpea, implying that the digestibility of protein and starch might be improved by fermentation. Trypsin and chymotrypsin inhibitor activity in pigeonpea was significantly decreased by fermentation (Rajalakshmi and Vanaja 1967).

Future Research Needs

Chemical composition in terms of nutritional and antinutritional constituents is the primary determinant of the nutritional potential of pigeonpea. Although there appears to be a small variation in chemical composition among pigeonpea cultivars, little effort has been made to show the effect of environment on such constituents. An attempt should be made to establish whether the phenomenal differences are consistent across a variety of environments. This information would be useful in assessing the potential of pigeonpea in human nutrition. The effects of improved agronomic practices should be more carefully studied, particularly with reference to vitamin and mineral content. In addition, research on bioavailability of various dietary nutrients of pigeonpea should receive increasing attention.

Antinutritional factors of pigeonpea have been extensively studied. Studies are needed on other antinutritional and toxic factors such as hemagglutenins, cyanogenic-glucosides, antivitamins, esterogenic compounds, metal-binding constituents, and toxic amino acids, if these are present in pigeonpea. It is recognized that cooking destroys antinutritional factors, notably trypsin and chymotrypsin inhibitors. It is pertinent to study the biochemical changes in proteins and carbohydrates that result from cooking. Protein digestibility and bioavailability of amino acids remain low even after cooking. Factors that affect protein digestibility need be systematically studied.

Since pigeonpea is consumed in various food forms, the intensity and duration of heat treatment it receives during cooking depends on the method of preparation. A knowledge of the nutritional changes that are caused by various types of heat treatments and other pretreatments such as fermentation and germination, would also be very useful.

Postharvest processing of pigeonpea has received little attention in the past. The methods of storage, and the effect of storage on chemical composition and nutritional quality of pigeonpea have not been thoroughly investigated. Efforts should be made to study these aspects. Desirable grain characteristics of pigeonpea cultivars need to be identified to reduce quantitative and qualitative losses during dehulling. The effects of commercial dehulling (*dhal* mill) and village-level dehulling (stone *chakki*, quern) on nutrient losses should also be studied.

References

Bliss, F.A., and **Hall, T.C.** 1977. Food legumes : compositional and nutritional changes induced by breeding. Cereal Foods World 22:106-112.

Contreras, S., and **Tagle, M.A.** 1974. Toxic factors in Chilean legumes. Archivos Latinoamericanos de Nutricion 24:191-199.

Eggum, B.O., and **Beames, R.M.** 1983. The nutritive value of seed proteins. Pages 499-531 in Seed proteins: biochemistry, genetics, nutritive value. (Gottschalk, W., and Muller, H.P., eds.). The Hague, Netherlands: Martinus Nijhoff/W. Junk.

Faris, D.G., **Saxena, K.B.**, **Mazumdar, S.**, and **Singh, U.** 1987. Vegetable pigeonpea: a promising crop in India. Patancheru, A.P. 502 324, India: ICRISAT.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1986. Page 175 in Annual Report 1985. Patancheru, A.P. 502 324, India: ICRISAT.

Kamath, M.V., and **Belavady, B.** 1980. Unavailable carbohydrates of commonly consumed Indian foods. Journal of the Science of Food and Agriculture 31:194-202.

Kantha, S.S., **Sundaravalli, O.E.**, and **Desai, B.L.M.** 1973. Effect of cooking and germination on the flatus inducing capacity of some legumes. Pages 133-137 *in* Nutritional aspects of common beans and other legume seeds as animal and human foods: proceedings of a Meeting, 6-9 Nov 1973, Ribeirao Preto, S.P., Brazil (Jaffe W.G., and de Oliveira, J.E.D., eds.). Caracas Venezuela: Archivos Latinoamericanos de Nutricion.

Rajalakshmi, R., and **Vanaja, K.** 1967. Chemical and biological evaluation of the effects of fermentation on the nutritive value of foods prepared from rice and legumes. British Journal of Nutrition 21:467-473.

Salunkhe, D.K. 1982. Legumes in human nutrition: current status and future research needs. Current Science 51:387-394.

Sankar Rao, D.S., and **Deosthale, Y.G.** 1981. Mineral composition of four Indian food legumes. Journal of Food Science 46:1962-1963.

Saxena, K.B., **Faris, D.G.**, **Singh, U.**, and **Kumar, R.V.** 1987. Relationship between seed size and protein control in newly developed high protein lives of pigeonpea. Plant Foods for Human Nutrition 36:335-340.

Shemer, M., and **Perkins, E.G.** 1975. Degradation of methionine in heated soybean protein and the formation of B-methyl mercaptopropionaldehyde. Journal of Agricultural and Food Chemistry 23:201-205.

Singh, U., and **Eggum, B.O.** 1984. Factors affecting the protein quality of pigeonpea (*Cajanus cajan* L.). Qualitas Plantarum Plant Foods for Human Nutrition 34:273-283.

Singh, U., and **Jambunathan, R.** 1982. Distribution of seed protein fractions and amino acids in different anatomical parts of chickpea (*Cicer arietinum* L.) and pigeonpea (*Cajanus cajan* L.). Qualitas Plantarum: Plant Foods for Human Nutrition 31:347-354.

Singh, U., **Jain, K.C.**, **Jambunathan, R.**, and **Faris, D.G.** 1984c. Nutritional quality of vegetable pigeonpeas (*Cajanus cajan* L.): minimal and trace elements. Journal of Food Science 49:645-646.

Singh, U., **Jain, K.C.**, **Jambunathan, R.**, and **Faris, D.G.** 1984b. Nutritional quality of vegetable pigeonpeas (*Cajanus cajan* L.): dry matter accumulation, carbohydrates and proteins. Journal of Food Science 49:799-802.

Singh, U., **Jambunathan, R.**, **Saxena, K.B.**, and **Subrahmanyam, N.** 1990. Nutritional quality evaluation of newly developed high-protein genotypes of pigeonpea (*Cajanus cajan*). Journal of the Science of Food and Agriculture 50:201-209.

Singh, U., **Kherdekar, M.S.**, **Sharma, D.**, and **Saxena, K.B.** 1984a. Cooking quality and chemical composition of some early, medium and late maturing cultivars of pigeonpea (*Cajanus cajan* L.). Journal of Food Science and Technology 21:367-372.

Singh, U., **Rao, P.V.**, **Seetha, R.**, and **Jambunathan, R.** 1989. Nutrient losses due to scarification of pigeonpea (*Cajanus cajan* L.) cotyledons. Journal of Food Science 54(4):974-976, 981.

Singh, U. 1984. The inhibition of digestive enzymes by polyphenols of chickpea (*Cicer arietinum* L.) and pigeonpea (*Cajanus cajan* L.). Nutrition Reports International 29:745-753.

Singh, U. 1988. Antinutritional factors of chickpea and pigeonpea and their removal by processing. Plant Foods for Human Nutrition 38:251-261.

Sumathi, S., and **Patabhiraman, T.N.** 1976. Natural plant enzyme inhibitors. Part II. Protease inhibitors of seeds. Indian Journal of Biochemistry and Biophysics 13:52-56.