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PROBLEMS OF NUTRITIONAL QUALITY OF PIGEON PEA AND CHICKPEA AND PROSPECTS OF RESEARCH

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Presented to the

INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS, HYDERABAD

WORKSHOP ON GRAIN LEGUMES
JANUARY 13-15, 1975

012487

ARCHIV
HULSE
no. 20

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ABSTRACT

Food legumes in general and chickpea and pigeon pea in particular have been neglected as good potential sources of edible protein by agricultural, food and nutrition scientists. Both chickpea and pigeon pea are comparatively deficient in methionine-cystine and tryptophan but both are complementary to cereal proteins in amino acid composition. Neither appears to contain either toxic substances or nutritional inhibitors of any major consequence.

Many authors have published protein and amino acid analyses of the two legumes but it is difficult in most cases to decide to what extent different analyses are attributable to genetic differences. The need for international methods of analysis and standardized conventions of reporting results and of identifying the source of the legumes analyzed is recommended.

Though increased yields must be the first objective of legume breeding programs, the genetic diversity in terms of biochemical composition should not be overlooked. A more imaginative approach to technological research could benefit the nutritional value, acceptability and utility of chickpea and pigeon pea.

November 18, 1974

PROBLEMS OF NUTRITIONAL QUALITY OF PIGEON PEA AND CHICKPEA AND PROSPECTS OF RESEARCH

Because of the extent of the relevant published literature the principal difficulty in preparing this paper has been to decide what to omit rather than what to include. Many worthy papers are missing from the list of references because of the limits of space and time. However copies of all those cited are available at IDRC and can be made available to anyone seriously interested.

Though the two food legumes under discussion appear under a variety of names, throughout this paper "*Cicer arietinum*" will be referred to as chickpea and "*Cajanus cajan*" as pigeon pea.

Since the volume of published scientific literature which describes chickpea appears much larger than that on pigeon pea, the subsequent text may appear somewhat unbalanced in relative content.

Food legumes can be described as potentially the most valuable yet probably the least developed of the naturally occurring sources of food protein. The nutritional value of legumes was recognized by the author of the book of Daniel (Daniel I verse 12) who wrote:

> "Prove thy servants I beseech thee ten days; and let them give us pulse to eat and water to drink then let our countenances be looked upon before thee and the countenances of the children that eat of the portion of the King's meat ....At the end of 10 days their countenances appeared fairer and fatter in flesh than all the children which did eat the portion of the King's meat. Thus Melzar took away the portion of their meat and the wine that they should drink and gave them pulse."

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Chickpea appears to have originated in the fertile crescent of the Mediterranean. Though Arnon (1972) suggests the crop had its earliest origins in the Himalayas, recipes including chickpea are to be found in "De Re Coquinaria" one of the earliest known cookbooks which was written by the Roman gourmet Apicius, in "The Deipnosophists" by Athenaeus and by Pliny the Elder in his "Historia Naturalis". Athenaeus describes dishes containing boiled and roasted chickpeas and the use of the tender and mature seeds in several desserts. Pliny recommends chickpea as a diuretic, to stimulate lactation and also to prevent skin diseases.

While the results of archaeological excavations around the Mediterranean appear to have firmly established the origin of chickpea, the birthplace of the pigeon pea, so called because it is said to be a favorite of the wild pigeon, appears less certain. In 1908 Watts ("The Commercial Products of India") reported that pigeon pea grew wild in China and in the countries of Indochina. In 1904 De Candole ("The Origin of Cultivated Plants") reported that pigeon pea was to be found in Africa from Zanzibar to the coast of Guinea and at about the same time pigeon pea was said to be growing wild in the region of the Upper Nile.

From earliest times the food legumes in general and chickpea in particular have been stigmatized as the food of the poor and even today in Latin America it is descriptive of a poor man to state that he is "counting his garbanzos".

....3

One could write a major work on the various ways in which chickpea and pigeon pea are cooked and eaten in different parts of the world. They may be eaten raw as immature green seeds, or as cooked or milled dried pulses. The seeds may be parched, or roasted over open fires, in metal pans or on hot sand.

In India probably more than 75% of the chickpeas produced are milled to produce dhal. In several Middle Eastern countries milled chickpeas are mixed with wheat and other cereal flours to make a variety of fermented breads and sweet breads, in addition to being combined with meat, vegetables and/or spices in many very delicious dishes.

The total world production of the major legumes is given in Table 1. If we exclude soya beans and groundnuts, chickpea falls third and pigeon pea fifth in order of production. Table 2 presents production data for 1972 by major regions and it can be seen that Asia and the Far East provide roughly 90% of both the world's chickpea and pigeon pea production. Mauritania (24g/person/day) is the largest per capita producer of chickpea with Togo and India (20g/person/day) in second place. The Dominican Republic (15g/person/day) is the largest and India (8g/per/day) the second largest per capita producer of pigeon pea.

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In terms of total production, India is the largest producer of both pigeon pea and chickpea. According to Swaminathan and Jain (1972) chickpea represented 51.0% and pigeon pea 11.2% of India's total pulse production of approximately 11.7 million tons in 1969-70.

Table 3 presents the percentage change in (a) population, (b) total food production, (c) food per capita and (d) chickpea production for the world as a whole and for the principal developing regions of the world.

In the world as a whole, the population has increased by roughly 40% while chickpea production has increased by 38%. In Latin America and the Near East chickpea production has risen faster than the population but in Asia legume production in general, and chickpea production in particular, have fallen markedly behind the rate of population increase and at a noticeably lower rate than the percentage increase in total food production.

Cereal protein and legume protein are nutritionally complementary; those amino acids which are deficient in the one being generally adequate in the other. As a broad generalization, a diet in which protein derived from cereals and protein derived from food legumes are in approximately a 70-30 ratio comes very close to nutritional adequacy.

....5

According to FAO (1972) based on total production statistics, only in Latin America does the ratio of cereal protein to legume protein approach a 70:30 ratio. In Africa and the Near East the ratio is 75 cereal to 25 legume whereas in Southeast Asia it is closer to a 90:10 ratio. World cereal production is increasing at a much faster rate than world legume production, consequently the need to increase legume production on a world wide basis and in particular in South and Southeast Asia must be regarded as a matter of vital urgency.

In the FAO Publication "Amino Acid Content of Foods" (FAO 1970) the average protein content of chickpea (Nx6.25) is quoted as 20.1 and of pigeon pea (Nx6.25) as 20.9%.

Swaminathan and Jain (1973) give the results from 16 varieties of chickpea grown at 12 locations and 11 varieties of pigeon pea grown at 5 locations. They state the range of protein in chickpea from 12.4 to 28.1 with a mean of 19.5 and in pigeon pea from 18.5 to 26.3 percent with a mean of 21.5.

Since many of the protein contents quoted in the literature are based on a wide variety of sources and various methods of analysis, they are not all readily comparable. Many may prove to be of little practical value to the plant breeder, since in comparatively few instances are the identity and origin of the samples analyzed clearly defined.

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In The Pulse Crops of India (ICAR, New Delhi 1970) Argikar reports protein contents (Nx6.25 on a moisture free basis) from 17.5 to 27.9, the results being from different strains grown at different localities. Also in the same publication the author quotes analytical results from a range of eight different strains of chickpea. (See Table 4)

In the same publication it is suggested that soil condition may influence protein content in that of chickpea which ranged in protein content from 17.5 to 27.9 percent, the highest tended to be those strains grown on alluvial soils. Protein contents of those grown on black cotton soils were 17.5%, 17.9%, 19.7%, 20.0%, 22.0% and 26.3%. Those grown on alluvial soils were 22.7%, 26.3%, 27.7% and 27.9%. However since in this case the strains were all different it may be difficult to isolate environmental from genetic influences.

Lal et al. (1963) analyzed 47 pure strains of chickpea, 24 of which were described as Common and 23 Kabuli. Common strains varied in protein content from a low of 17.38 (strain BR17 from Bihar) to a high of 23.8 (strain G2 from Madhya Pradesh). The Kabuli strains ranged from a low of 19.65 (strain NP7 - IARI) to a high of 25.41 (strain Rabat from the Punjab). The authors believe that Kabuli strains are genuinely and significantly higher in protein, ether extract and iron content. They claim the Common strains to be higher in crude fibre and calcium.

....7

Chandra and Arora (1968) analyzed 40 varieties of chickpea all of which were grown in the Punjab. They identified four high protein varieties (Nx6.25 = 29.8%). The names and sources of origin of the four high protein varieties were: (a) Algeria 3444-Algeria; (b) Frontier 8A-Pakistan; (c) Gram Cross A- India: (d) Gadag S2-India. The low protein varieties (Nx6.25 = 18.4%) were (a) Tehran 29 and (b) Ahmedabad S1.

Dr. Hugh Doggett kindly supplied us with the results of protein nitrogen analyses carried out at ICRISAT by (a) Micro-kjeldahl and (b) the Udy dye binding method on 29 samples of chickpea, 85 samples of pigeon pea and 14 dehusked samples of pigeon pea. The results are given in Table 5.

In "New Vistas in Pulse Production" (IARI 1971) the yields and protein contents of "high yielding" varieties of chickpea and pigeon pea are quoted. The chickpea varieties range in protein content from 22.4% to 24.7%, the yields from 917 to 1053 kg/ha, and the protein yields from 215.5 to 260 kg/ha. Pigeon pea ranges were: protein 20.7-21.1%; yield 1250 to 1682 kg/ha, protein yield 259 to 340 hg/ha.

Zimmerman et al. (1967) fractionated, by hand scalping, the cotyledons of random samples of chickpea into an inner and outer portion and analyzed for protein, lysine and methionine. (See Table 6).

....8

The weight(%) represent the proportions of the whole seed. The balance of 10.2% represents the combined weight of hulls and embryo.

Many authors have published the results of their analyses for essential amino acids in chickpea and pigeon pea. A selection of these results are presented in Tables 7 and 8.

Hanuamantha Rao and Subramania, N. (1970) (See Column A of Tables 7 and 8) quote the range of results from 15 different papers. They also quote (Column G) results which they determined using paper chromatography. Later in Column E and F respectively are (E) the range of results from various sources reviewed by FAO and (F) the average of the same FAO data. The variability of results among different authors is readily apparent. To what extent the variation reflects genuine differences among samples and to what extent it is attributable to inconsistencies in methodology and experimental error it is difficult to say. In any event, very few of the results quoted will be of great help to plant breeders since rarely do the authors state precisely the nature, biological history and source of the materials analyzed. The Column labeled "WHO" in both Tables quote the World Health Organization's recommended reference amino acid pattern: what might loosely be described as "an ideal proportion of essential amino acids".

Table 9 presents the author's (J.H. Hulse 1974) calculated amino acid scores for chickpea and pigeon pea based upon (a) the FAO average values and (b) Hanuamantha Rao and Subramanian's analyses.

The amino acid score is the quotient of the amount of each amino acid reportedly present divided by the WHO reference pattern level for the same amino acid. The first and second limiting amino acids are those with the lowest and second lowest score respectively. According to the FAO results, the sulphur amino acids, methionine plus cystine,-are first limiting in both chickpea and pigeon pea. Tryptophan or valine is the second limiting in the case of chickpea and tryptophan second limiting in pigeon pea. From Hanuamantha Rao and Subramanian's results, tryptophan appears clearly as first limiting and methionine plus cystine as second limiting in both cases. Braham et al. (1965) claim that in autoclaved pigeon pea meal "methionine and tryptophan were equally deficient".

In "New Vistas in Pulse Production" (IARI 1971 p.66) the results of methionine analyses on a large number of pulse crop samples are quoted. The data for chickpea and pigeon pea are given in Table 10. Unfortunately, the results are quoted as mg methionine per gram of sample and hence cannot be compared with the amino acid results presented in other tables.

....10

To what extent the variation in methionine is influenced by variability in protein content is not indicated. In any event, the range of results suggests that variability in methionine content may exist in significant degree and may be genetically influenced.

The total lipid (ether extract) content of chickpea appears in general to lie between 3 and 6 percent and in pigeon pea between 1 and 2 percent. The fatty acid composition of both legume lipids is nutritionally favourable with more than 50% of the lipid consisting of polyunsaturated fatty acids.

The carbohydrate content which consists mainly of starch is variously reported between 50 and 65% in both legumes.

In common with most other legumes, chickpea and pigeon pea contain only modest amounts of Vitamin A, approximately 300 International Units per 100 g in chickpea and 150 IU in pigeon pea. Thiamine content in both legumes is approximately 0.5 mg/100g. Both contain comparatively little riboflavin (approximately 0.15 mg/100g) but both are fair sources of niacin (1.5 to 2.5 mg/100g). All three vitamins are present in roughly the amounts found in whole cereal grains. Both chickpea and pigeon pea are comparatively good sources of iron (6-9 mg/100g) and contain 5 to 10 times the concentration of calcium found in the major cereals. (Daniel and Norris 1945 and Aykroyd and Doughty 1964).

Since in a number of countries chickpea and pigeon pea are allowed to germinate before being eaten, a number of authors have reported on the influence of sprouting on a number of essential nutrients (De and Barai (1949), Bannerjee and Bannerjee (1950), Chattapadhyay and Bannerjee (1951), De and Datta (1951), Chattapadhyay and Bannerjee (1952), Belavady and Bannerjee (1953), Chattopadhyay and Bannerjee (1953), Bannerjee et. al. (1954), Bannerjee et. al. (1955), Singh and Bannerjee (1955)). Ascorbic acid, niacin, available iron, choline, tocopherol, pantothenic acid, biotin, pyridoxine, inositol and Vitamin K all reportedly increase in both chickpea and pigeon pea during germination.

Patwardhan (1962) states that the Biological Value (BV) (an estimation of the proportion of absorbed nitrogen that is retained in the body for maintenance and/or growth) ranges in chickpea from 52 to 78 percent and in pigeon pea from 47 to 74 percent; that the Coefficient of Digestibility ranges from 76 to 92 percent in chickpea and 59 to 90 percent in pigeon pea; that the Protein Efficiency Ratio (PER) ranges from 1.3 to 2.1 in chickpea and from 1.3 to 1.6 in pigeon pea (See Table 11). Elsewhere Patwardhan (1961) quotes a PER of 1.1 for chickpea and 0.7 for pigeon pea.

The variance cited by Patwardhan (1962) is illustrated in other results from various authors. It is probable that these variable results reflect a combination of (a) differences in methodology, (b) intrinsic differences and, (c) differences in methods of processing the various samples reported on.

The comparatively low values of the various PERs quoted reflect the lack of balance in the amino acid content of these legumes. At the same time, in rat feeding studies used to evaluate nutritional value, the results tend to be based upon isonitrogenous rather than isocaloric diets.

Some authors claim that cooking or autoclaving raises the nutritive value of both chickpea and pigeon pea (Gaitonde and Sohoniek (1952) and Hirwe and Magar (1951)). Graham et. al. (1965) claim that after autoclaving for 20 minutes the PER of chickpea meal was increased from 0.46 to 1.52.

Kande (1967) states that normal cooking does not alter either the digestibility or the nutritive value of chickpea.

Chitre and Vallury (1956b) compared the plasma protein levels of rats fed both raw and autoclaved chickpea and pigeon pea. There was no significant difference between raw and autoclaved chickpea but the plasmaprotein levels were lower in rats fed autoclaved than rats fed raw pigeon peas. They concluded that chickpea was one of the most efficient sources of protein in maintaining blood protein plasma levels.

....13

Ochse (1931) claims that raw seeds of pigeon pea contain an unidentified narcotic which if eaten in quantity induces sleepiness. Ochse concludes that pigeon pea seeds are a harmless soporific. No one else to the author's knowledge has pursued this subject.

Kuppuswamy et al. (1958) report findings in Central America which indicate that chickpea when fed as the sole source of protein to experimental animals produced toxic symptoms attributable to "cicerism". It is claimed that the "toxicity" could be ameliorated by the addition of methionine or choline. No toxin was however identified and interest in "cicerism" seems to have died since 1951.

Three other undesirable characteristics associated with some food legumes are: 1) the presence of substances which agglutinate red blood cells; 2) trypsin inhibitors and 3) a tendency to induce flatulence. The first two factors have been studied by Liener (1973). Liener's results are given in Tables 12 and 13. Haemagglutinating activity appears to be zero in chickpea and pigeon pea and, compared with black bean and kidney bean, the anti-tryptic value in chickpea and pigeon pea appears to be of little consequence.

....14

It is perhaps worth pointing out that most of the comparative work on trypsin inhibitors has been done with bovine trypsin. It is well known that bovine trypsin is more significantly affected by anti-trypsins than is human trypsin and since most of the trypsin inhibitors present in legumes appear to be comparatively thermolabile it is doubtful if they are of any great importance in human diets. Certainly they appear to be of little consequence in cooked chickpea and pigeon pea.

Though in adults flatus production is probably more of social than clinical importance, severe flatulence can give rise to acute discomfort in infants. Narayana Rao et al. (1973) produce evidence to indicate that the following legumes induce flatus in the decreasing order indicated; chickpea being highest and green gram lowest: Chickpea; black gram (Phaseolus mungo); pigeon pea; green gram (Phaseolus radiatus). Though the substance(s) in chickpea and other legumes which leads to flatus has not been positively identified, it does appear that the effect is reduced by cooking. Sirkantia (1973) describes experiments in which groups of children received 50% of their total protein from pigeon pea while another group received the same amount from milk. The growth of the children in the two groups was identical suggesting that the legume protein was a satisfactory replacement for milk.

....15

The author goes on to state "legumes could be used safely in amounts to provide as much as 50-60% of the total protein in the diet (of children)".

Hulse and Laing (1974) and Urie and Hulse (1952) have reported upon the importance of phytic acid in human nutrition which depends upon its property of forming insoluble compounds with essential minerals such as calcium, iron, magnesium and zinc. Phytic phosporus appears to be present in chickpea at levels in excess of 200 mg/100g. It is also present in significant levels in pigeon pea. The level in chickpea approximates to that present in whole wheat. Since the calcium content of chickpea and pigeon pea is significantly higher than the calcium in cereals the phytic phosphorus may not seriously interfere with calcium absorption in human diets. The phytin levels may however be sufficiently high to interfere with iron, magnesium and zinc absorption.

Though the polyphenols (often described as "tannins") are known to be widely distributed among the leguminosae, little appears to be known about the polyphenol content of chickpea or pigeon pea. It seems highly probable however that, particularly in chickpea possessing near-black,

....16

purple, brown or maroon seed coats and chickpeas with brown and orange testas that polyphenols are present. The biochemical mechanism whereby polyphenols interfere with protein metabolism in humans and animals has yet to be determined but there is evidence to suggest that polyphenols can be correctly described as anti-nutrients. It would be worth discovering whether there is a significant difference in biological value between the dark and light seed coated pigeon pea and chickpea varieties.

Hulse and Laing (1974) have commented upon the shortcomings in the manner in which analytical results related to the cereal grains are reported in the literature and the need for a universally standardized methodology by which the biochemical composition and the biological value of the cereal grains are determined and rationally presented.

Similar criticisms might be advanced concerning the published analytical and nutritional data relevant to the food legumes. The Protein Calorie Advisory Group (PAG) of the United Nations System has recently prepared, in PAG Guideline 16, "Protein Methods for Cereal Breeders Related to Human Nutritional Requirements". While many of the recommendations in this publication are applicable to legumes, it is hoped in the not too distant future a similar PAG Guideline will be prepared for legume breeders. Some of the inherent difficulties and approaches to the subject are discussed in another PAG Publication (PAG 1972) "The Nutritional Improvement of Food Legumes by Breeding".

....17

It is possible that chemical analysis is a less precise science than plant breeding. Williams (1974) lists 27 sources of error in the Kjeldahl testing procedure for protein content and 18 sources of error in the Udy dye binding system of protein testing. It is worthy of note that a significant error can result from dye binding analyses carried out on immature grains since the dye stuffs used are readily absorbed by chorophyll and thus immature grains tend to give an exaggerated high value for protein content. In addition, grains high in cellulose may also present exaggeratedly high protein values. One of the greatest sources of error in amino acid analysis results from a lack of care and careful standardization of the method of hydrolysis.

Daniels (private communication 1974) carried out analysis of variation on the protein contents of various chickpea and pigeon pea samples analyzed by Microkjeldahl and Udy (dye binding) methods at ICRISAT. The results are given in Table 14.

Though significant the coefficients of correlation are comparatively low. This, at least in part, may be attributable to the narrow range of results over which the analyses were made. Since Udy is intended as a comparatively rough screening test, it would be useful to repeat the comparison over a much wider protein range.

In any event, it is suggested that in selecting for increased protein, differences of less than 1 full percent in percent protein (0.16%N) between the test and the standard can be discarded for all practical purposes.

As suggested in PAG Guideline 16, it is urged that all analytical laboratories in plant improvement research centres establish collaborative protein and amino acid testing programs with other laboratories and retain homogeneous reference samples stored below freezing in sealed containers by which to check equipment calibrations from time to time.

The biological methods of protein evaluation include those which depend upon body weight gain and those which depend upon nitrogen retention in the test animals. Most recommended test methods are based upon an isonitrogenous diet. It is readily demonstrable that the results with rats and other animals may be highly dependent upon the proportion of protein in the test diet. For example, proteins generally considered nutritionally inferior such as wheat gluten, will appear more satisfactory at low levels of intake than at high levels of intake when compared with a standard protein such as casein. The PAG Guideline 16 therefore recommends a slope growth method in which all proteins are tested at at least three different levels against a standard, the rat being recommended as the preferable-test animal. The Relative Protein Value (RPV) is then expressed as:

$$\frac{\text{Slope of the test protein}}{\text{Slope of the standard protein}} \times 100$$

....19

A brief word on the standardization of conventions by which results are recorded is perhaps in order. It is recommended that "protein" values be quoted as total nitrogen on a dry weight basis. If it is considered desirable to quote the results as "protein" these results should also be expressed on a dry weight basis and the conversion factor from "nitrogen" to "protein" clearly stated.

In the case of cereals it is recommended to breeders looking for "high protein" lines that they express their results as mg nitrogen/seed rather than as nitrogen or protein on a total dry weight basis. In the cereal grains protein content and composition vary among different fractions of the seed and protein as percent dry matter is influenced by seed weight and the relative proportion of the various seed fractions present. These in turn are influenced by environment and agronomic conditions. Similarly, the protein nitrogen present in the legumes is not uniformly distributed throughout the seed (Zimmerman et al. 1967) and therefore results expressed as mg nitrogen/seed is again recommended when selecting for higher protein breeding lines.

Amino acids have also been expressed in a variety of ways. It is recommended that no matter what the method of determination the results should be expressed as mgAA/per gram nitrogen. Minerals and vitamins are best expressed as mg or g/100g of material with the exception of vitamins A and D which are customarily expressed in International Units.

....20

It would appear that if resources are to be used with greatest effect a great deal more cooperation between plant breeders on the one hand and analytical chemists and nutritional biochemists on the other hand is essential. It is my view that the latter have served the breeders very poorly in their attempts to develop plants of superior nutritional values. Perhaps an elementary course in botany would prove valuable for food chemists and biochemists.

In seeking genotypes capable of synthesizing higher than average levels of protein nitrogen some attention might be given to the duration of nitrogenase activity. Hardy et al. (1968) and (1971) and LaRue and Kurz (1972) have described a method for determining the duration of nitrogenase activity which depends upon the ability of the nitrogenase present in the legume root nodule to reduce acetylene to ethylene. The results of the workers at the Prairie Regional Laboratory in Saskatoon indicate significant variations among different Pisum sativum lines in the length of time during which the nitrogenase is active. It is their belief that those lines of longer nitrogenase activity possess a higher potential capacity for synthesizing seed protein.

In its publication "Nutritional Improvement of Food Legumes by Breeding" (1973) a PAG Working Group recommends a long list of considerations to which the plant breeder should give attention.

....21

Time will not permit a detailed commentary upon the individual recommendations within the PAG document but suffice it to say that, since pigeon pea and chickpea appear to be comparatively free from major toxic factors and nutritional inhibitors, the plant breeder's primary concern should be to increase the yield potential of these crops and to explore the range of genetic variability related to seed nitrogen content and perhaps amino acid composition. What is required is a significant increase in protein production per unit area of land per unit of time. As a secondary objective, and when time and facilities permit, it would be useful to determine whether the proportions of sulfur-containing amino acids and tryptophan are genetically controlled. If either of these limiting amino acids is increased it should not be at the expense of lysine. The cereal grains are first limiting in lysine and since cereals and legumes are in many diets eaten together, the lysine contribution by the legume is of primary importance. Where the legumes are eaten with maize there may be a good case for attempting to raise the tryptophan content though this may be more readily achieved by genetic manipulation of the maize than of the legumes.

....22

Where chickpeas and pigeon pea are the principal source of protein nitrogen calories in the diets of people who subsist largely on root crops, the sulfur amino acid content is of significant importance since the cyanogenic glycosides present in cassava combine with and reduce the absorption of methionine and other sulfur amino acids.

It is my opinion that a great deal more attention could be given to the processing of legumes. As stated earlier, food legumes tend to be regarded as poor man's meat but this image could be significantly changed by imaginative technological research and development. Particularly to be recommended are technological systems which permit the processing of cereals and legumes using the same equipment. Such technology has been developed in Canada and is now installed in a small rural mill in Northern Nigeria. It consists of simple abrasive decortication using rotary carborundum discs in a rubber case followed by hammer mills or mosaic grinders, screening and packaging facilities. Technology of this kind permits inexpensive foods in which the optimum ratio of cereal and legume protein is combined together. Such foods are particularly advantageous for infants and young children, nursing mothers and other nutritionally vulnerable groups.

The techniques of protein concentration in cereals by fine grinding and air classification have been known for many years. The principle is that in a finely ground flour the carbohydrate preponderates in the heavier particles. Consequently, protein fractionation can take place by applying a centrifugal force to the fine flour particles opposed by a centripetal drag. The heavier particles of higher effective mass will move in one direction and the finer protein rich particles in the other direction. In theory air classification is easier to achieve with legume flours than with cereal flours since legume flours contain, in general, significantly larger starch granules. That this theory is sound has been demonstrated at the Prairie Regional Laboratories in Canada (private communication) where field pea flour (Pisum sativum) has been thus converted to significantly higher protein contents than occur naturally in the cotyledon.

While this technology is not as inexpensive as simple milling, it is simpler, less expensive, and less hazardous in tropical countries to operate than the "wet" systems of producing protein concentrates.

In summary, it can be said that the chickpea particularly and also the pigeon pea, represent valuable but considerably underexploited sources of edible protein. Greater attention needs to be given to their genetic diversity to determine the

....24

range of variability related to their biochemical composition. However, as stated at the outset, breeding for improved nutritional quality should not be undertaken at the expense of all those factors which contribute to improved yield.

Footnote: In the interests of brevity only a comparatively few relevant references have been cited in the text. An additional longer bibliography is provided and copies of all of the publications quoted are available at IDRC in Ottawa.

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TABLE 1 WORLD PRODUCTION (1972) OF MAJOR LEGUMES

	'000 M.T.
SOYBEANS	52712
GROUNDNUTS	16532
PHASEOLUS VULG.	11010
PISUM. SAT.	10731
CHICKPEA	7415
VICIA FABA	5286
PIGEON PEA	1648
COWPEA	1146
WORLD TOTAL	106480

(SOURCE UN PAG BULLETIN 3 (2) 1973)

TABLE 2 CHICKPEA AND PIGEON PEA PRODUCTION 1972

'000 M.T.

	CHICKPEA	PIGEON PEA	ALL MAJOR PULSES[1]
DEVELOPED COUNTRIES	132		8713
LATIN AMERICA	186	34	4345
NEAR EAST	235		788
ASIA AND FAR EAST	6530	1548	19854
AFRICA	332	66	3536
ALL LDCs	7283	1648	28523
WORLD	7415	1648	37236

[1] Phaseolus vulgaris; Vicia faba; Pisum sativum; Cicer arietinum; Cajanus cajan; Vigna spp.

TABLE 3 % CHANGE IN POPULATION AND LEGUME PRODUCTION 1952-1972
(Based upon FAO statistics)

	POPULATION	TOTAL FOOD	FOOD PER CAP	CHICKPEA
DEVELOPED COUNTRIES	+ 22	+60	+32	− 42
LATIN AMERICA	+ 62	+65	+ 2	+78
NEAR EAST	+ 57	+65	+ 2	+64
ASIA AND FAR EAST	+ 51	+65	+ 9	+40
AFRICA	+ 52	+47	− 3	+55
ALL LDCs	+ 53	+62	+ 6	+42
WORLD	+ 40	+61	+15	+38

(SOURCE FAO STATISTICS OF PRODUCTION AND POPULATION 1972)

TABLE 4 ANALYSES OF WHOLE AND DEHUSKED CHICKPEA

	WHOLE	DEHUSKED
Ether Extract (%)	3.9-6.2	4.6-6.9
Nx6.25%	20.8-25.9	25.3-28.9
Soluble carbohydrate %	60-63	63-65
Crude fibre %	8.0-8.7	1.0-1.5
Ash %	3.0-3.3	2.5-2.9

G.P. Argikar "Pulse Crops of India" ICAR 1970

TABLE 5. ANALYSES OF CHICKPEA AND PIGEON PEA BY MICROKJELDAHL AND UDY (ICRISAT RESULTS)

	MEAN	VARIANCE	RANGE
CHICKPEA			
Udy	23.77	0.79	22.58-26.56
Microkjeldahl	23.47	0.78	21.5-25.13
PIGEON PEA			
Udy	21.44	0.61	19.26-23.17
Microkjeldahl	21.04	1.02	18.1-23.31
PIGEON PEA WITH SEED COAT REMOVED			
Udy	24.87	0.89	23.64-26.24
Microkjeldahl	25.25	1.52	23.52-27.58

TABLE 6 PROTEIN, LYSINE AND METHIONINE CONTENT

%	Part of Cotyledon Inner	Outer
Weight	25.1	64.7
Crude Protein	19.4	25.7
Lysine	1.23	1.79
Methionine	0.21	0.29

TABLE 6A COMPOSITION OF VARIOUS FRACTIONS OF CHICKPEA

	PERCENT			
	SEED COAT	COTYLEDON	EMBRYO	WHOLE SEED
PROPORTION	14.5	84	1.5	100
PROTEIN (Nx6.25)	3	25	37	22
ETHER EXTRACT	0.2	5	13	4.5
ASH	2.8	2.6	5	2.7
CRUDE FIBRE	48	2	3	8
CHO	46	66	42	63
PHOSPHORUS (mg/100g)	24	290	740	260
IRON (mg/100g)	8	5	11	6
CALCIUM (mg/100g)	1000	70	110	200

TABLE 7. AMINO ACID COMPOSITION OF PIGEON PEA (mg/g Protein)

	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	WHO*
ISOLEUCINE	51-66	57	66	38	30-33	31	50	46	40
LEUCINE	61-87	70	88	72	60-66	63	59	80	70
LYSINE	62-74	64	70	68	72-83	77	59	58	55
METHIONINE	3-34	9	9	12	4-6	5	14	7)	35
CYSTINE	4-18	8	--	--	7-12	10	11	6)	
PHENYLALANINE	78-91	91	82	10	78-93	83	57	72)	60
TYROSINE	33-40	--	--	31	19-21	20	32	22)	
THREONINE	31-40	38	41	36	28-31	29	47	40	40
TRYPTOPHAN	2-9	2	2	--	4-8	6	3	--	10
VALINE	43-57	51	57	45	34-40	36	59	54	50
HISTIDINE	--	34	22	34	35-40	37	--	36	

(A) Hanuamantha Rao and Subramanian (1970) (15 papers)

(B) Rao S.V. et al (1964)

(C) Banerjee (1960)

(D) Van Etten et al (1967)

(E) FAO (1970) - Range

(F) FAO (1970) - Average

(G) Hanuamantha Rao and Subramanian (1970)
By paper chromatography

(H) Royes W.V. (1972)

*WHO - Recommended "Ideal" amino acid composition
energy and protein requirements WHO (1973)

TABLE 8. AMINO ACID COMPOSITION OF CHICKPEA (mg/g Protein)

	(A)	(B)	(C)	(D)	(E)	(F)	(G)	WHO*
ISOLEUCINE	44-60	60	57	44	42-47	44	50	40
LEUCINE	49-80	86	67	76	71-80	75	50	70
LYSINE	45-79	64	54	72	65-74	68	46	55
METHIONINE	7-31	17	9	14	5-17	10	9)	35
CYSTINE	7-18	8	--	--	8-15	12	8)	
PHENYLALANINE	30-68	50	37	66	39-78	57	53)	60
TYROSINE	20-35	--	--	33	19-34	29	23)	
THREONINE	28-48	48	32	35	35-42	38	45	40
TRYPTOPHAN	2-12	6	4	--	4-15	9	3	10
VALINE	38-63	54	45	46	34-57	45	48	50
HISTIDINE	--	23	14	23	24-30	26	--	

(A) Hanuamantha Rao and Subramanian (1970) (15 papers)

(B) Rao S.V. et al (1964)

(C) Banerjee (1960)

(D) Van Etten et al (1967)

(E) FAO (1970) - Range

(F) FAO (1970) - Average

(G) Hanuamantha Rao and Subramanian (1970)
By paper chromatography

*WHO - Recommended "Ideal" amino acid composition
energy and protein requirements WHO (1973)

TABLE 9. AMINO ACID SCORES

	CHICKPEA		PIGEON PEA	
	(a)	(b)	(a)	(b)
ISOLEUCINE	110	125	78	125
LEUCINE	107	71	90	84
LYSINE	123	84	140	107
METHIONINE & CYSTINE	63	49	43	71
PHENYLALANINE & TYROSINE	143	126	172	148
THREONINE	95	112	73	118
TRYPTOPHAN	90	30	60	30
VALINE	90	96	72	118

(a) FAO Average   (b) Hanuamantha Rao and Subramanian (1970)

TABLE 10 METHIONINE CONTENT OF CHICKPEA AND PIGEON PEA

	No. of Samples	Mean Methionine mg/g sample	S.D.	Range
CHICKPEA	84	2.08	0.334	1.10-3.00
PIGEON PEA	295	1.54	0.334	0.80-3.00

"New Vistas in Pulse Production" IARI 1971

TABLE 11. BIOLOGICAL EFFICIENCY OF CHICKPEA AND PIGEON PEA

SOURCE	Biological Value %	Coefficient of Digestibility %	Protein Efficiency	Level of Feeding %
CHICKPEA	52-78	76-92	1.3-2.1	12
PIGEON PEA	47-74	59-90	1.3-1.6	12

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TABLE 12 HEMAGGLUTINATING AND ANTITRYPTIC ACTIVITIES OF CRUDE EXTRACTS* OF RAW LEGUMES

LEGUME	HEMAGGLUTINATING ACTIVITY	ANTITRYPTIC ACTIVITY
	HU/ml	TIU/ml
Phaseolus vulgaris		
BLACK BEAN	2450	2050
KIDNEY BEAN	3560	1552
Cicer arietinum	0	220
Cajanus cajan	0	418
Phaseolus aureus	0	260

*A 10% SUSPENSION OF THE FINELY GROUND MEAL IN 1% NaCl CLARIFIED BY CENTRIFUGATION.

TABLE 13 EFFECT OF HEAT ON NUTRITIVE VALUE OF SOME LEGUMES

SOURCE OF PROTEIN	GAIN IN WEIGHT	
	g/day	
	RAW *	HEATED
Phaseolus vulgaris		
BLACK BEAN	− 1.94 (4-5)	+ 1.61
KIDNEY BEAN	− 1.04 (11-13)	+ 1.48
Cicer arietinum		
BENGAL GRAM	+ 1.25	+ 1.16
Cajanus cajan		
RED GRAM	+ 1.33	+ 1.74

*100% mortality observed during period (in days) shown in parentheses.

TABLE 14. ANALYSIS OF VARIATION ON PROTEIN ANALYSES BY MICROKJELDAHL AND UDY

	No. of Samples	Range(Protein %)	SD	COEFFICIENT OF CORRELATION
CHICKPEA (Whole)	29	21.5-25.13(MK) 22.58-26.56(Udy)	0.88 0.89	.6171
PIGEON PEA (Whole)	85	18.1-23.31(MK) 19.26-23.17(Udy)	1.006 0.78	.4152
PIGEON PEA (Seed coats removed)	14	23.52-27.58(MK) 23.64-26.24(Udy)	1.23 0.94	.7912

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