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Nutritional attributes of food legumes

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The food legumes, economical sources of protein, calories, certain vitamins and minerals, are an essential component of the diet of 700 million people of the world. However, the significant role they play in the diets of many developing countries appears to be limited by their scarcity caused mainly by their present low yield, consequent cost and certain defects in their nutritional and food-use qualities. The food legumes have primary importance for:

- Complementing and supplementing the protein-deficient diets, generally prevailing among population in urban, suburban and rural areas, including subsistence farmers.
- Providing economical protein concentrates as ingredients for processed, nutritious foods, including foods for weaning and pre-school children.
- Raising the income of agricultural producers by making these crops competitive with other food staples.

The per capita production of non-oilseed pulses is the highest (28.7 kg/capita) in the USSR and the lowest (4.8 kg/capita) in the USA. By virtue of being the richest sources of protein among vegetable foods, they are consumed in relatively large amount where foods of animal origin are expensive or in short supply. Out of 13,000 species of the family leguminosae, 18 legumes are extensively cultivated today for the purposes of human consumption. Certain types of legumes are preferentially cultivated and consumed in certain parts of the world and there are wide variations in the amount of legumes eaten, depending on the agricultural conditions and income levels. There appears to be an inverse relationship between the availability of legumes and animal foods. In Asian countries like India and Japan, the consumption of legumes tends to increase with inçreasing income, while in the USA and Italy, the opposite trend has been noted.

Figures of daily per capita consumption of legumes are reported to be 24 grams for Pakistan 65.71 grams for India, 23 grams for Indonesia, 42 grams for China, 30-40 grams for Africa, 25-50 grams for Middle East, 20-60 grams for Central and South America and 16 grams for Europe.

Unfortunately, the protein in grain legumes are regarded as dietetically inferior to animal protein because of their low sulphur amino caid concentration. This limitation in quality, coupled with the relatively small and notoriously variable yields of many grain legumes crops, represent two major areas for improvement in the future. The present paper deals with the nutritional properties of food legumes and breeding strategies aimed at improving the nutritional quality of these grains.

NUTRITIVE VALUE

The chemical composition of some common legumes is given in Table 1. In general, legumes contain 18 to 25 percent protein, about double that of the cereals and slightly higher than that of meat, fish and eggs. Soybean and groundnut are exceptional in containing about 38 and 26 percent, respectively. The pulses yield almost as many calories per unit of weight as cereals.

The quality of pulse protein depends on the relative proportions of essential amino acids it contains. Pulses are good source of lysine but are deficient in methionine and cystine. The protein quality is measured in

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Table 1. Composition of some food legumes

Food	Protein (g/100 g)	Carbo-hydrate (g/100 g)	Fat (g/100 g)	Fibre (g/100 g)	Calories kcal/100g	Calcium (mg/100 g)	Iron (mg/100 g)	Thia-mine (mg/100 g)	Ribo-flavin (mg/100 g)	Niacine (mg/100 g)
Chickpeas	20.0	61.0	5.0	2.8	368	120	9.0	0.5	0.2	1.5
Lentils	24.0	59.0	1.0	4.0	339	70	7.0	0.5	0.2	2.0
Mung	22.0	57.0	1.0	4.7	324	100	8.0	0.5	0.2	2.0
Mash	24.0	56.0	1.0	4.5	329	150	9.0	0.4	0.2	2.0
Common beans	22.1	57.0	1.7	4.0	339	110	8.0	0.5	0.2	2.0
Peas	25.0	57.0	1.0	4.5	337	70	5.0	0.8	0.2	2.5
Cowpeas	22.0	60.0	1.5	4.0	340	90	5.0	0.9	0.2	2.0
Lathyrus (Khesari)	25.0	46.0	1.0	15.0	293	110	5.6	0.1	0.4	—

Source: Platt, B.S. 1975. Special Report Series No. 302. Her Majesty's Stationery, London

terms of biological value (B.V.) i.e. percentage of nitrogen absorbed from the intestinal tract that is actually retained in the body for maintenance and growth. The B.V. of pulses varies from 45 to 73 percent. The true protein digestibility of properly cooked legumes falls between 85 and 95 percent. The net protein utilization of various pulses ranges from 38 to 66 percent. The biological utilization of the nutrients is interferred by various anti-nutritional factors present in legumes. The poor digestibility of food legume proteins is due to residual proteinase inhibitors not affected by heat or to reactions between the proteins and compounds such as polyphenols or to the tertiary structure of protein bodies which prevents proteolytic enzymes from acting effectively.

Food legumes contain about 60 percent of carbohydrate, mainly starch which, in general, is well absorbed and utilized. Soybean, however, contains a considerable amount of carbohydrates such as galactans, pentoses and hemicelluloses which are poorly utilized. Legume fats, in general, are rich in the essential fatty acids. Fresh legumes are dietary sources of thiamine, niacin, riboflavin, calcium, folate, iron and vitamin C. The dry legumes, however, show little or no ascorbic acid, while sprouting legumes have an increased content of thiamine and riboflavin as well as vitamin C.

The legumes contain considerable amount of phytic acid which may affect the absorption and utilization of calcium, iron and zinc. Although some interesting positive attributes such as hypo-cholesterolaemic effects (lowering serum cholesterol) and diabetic management have recently been associated with food legume consumption, they still cause undesirable side-effects in many situations.

FACTORS AFFECTING NUTRITIVE VALUE

The nutritive value of food legumes may be affected by the following factors:

- Production environment
- Anti-nutritional factors

- Processing
- Storage conditions

Production Environment

Differences in chemical composition and the efficiency of utilization of food legumes may be attributed to the effects of soil, climate, strain of seed and fertilizer treatment.

Anti-nutritional Factors

A wide variety of toxic and potentially toxic substances are found among the pulses. These include trypsin inhibitors, phytohemagglutinins, goitrogens, cyanogenetic glycosides, anti-vitamin factors, metal binding constituents, estrogenic factors, toxic amino acids, lathyrogens, favogens and unidentified growth inhibitors. Despite this formidable list, pulses have been used for food since time immemorial. Fortunately, cooking destroys many of the toxicants. Others are present in small concentration, therefore, not deleterious in a varied diet. Only a relatively small proportion of the world population is highly susceptible to favism from *Vicia faba*. Nevertheless, there is the ever-present possibility that the prolonged consumption of a particular legume that may be improperly processed could bring to the surface toxic effects that otherwise would be apparent.

There is sufficient evidence now available to indicate that many food legumes contain polyphenolic compounds (tannins) which decrease protein digestibility by about 10 percent. Tannins also affect the availability of dietary iron and may cause anaemia in children. When legumes are consumed in large quantities, especially by young children, flatulence due to the presence of oligosaccharides may cause considerable inconveniences. This limits their consumption but if the legumes are well cooked, children can eat them.

Processing

The main effects of processing on legumes, other than detoxification, are to increase palatability, decrease dry matter content, alter the bio-availability of nutrients and reduce the rate of formation of beany flavour.

Dehulling: This leads to a considerable loss in dry matter, but has the advantage that with the seed coat removed, pulses cook more quickly. The dehulled seed is known as *dhal*. From nutritional point of view for chickpea, the main nutrient loss in this process is calcium. As tannins are mainly confined to the hull, they are also removed during dehulling.

Soaking: Soaking is commonly used before cooking as it reduces the cooking time. During this process, there is a loss of solids and trypsin inhibitors in certain species of pulses leach out. Addition of papain or sodium bicarbonate (0.5 percent) in the soaking water can further reduce the cooking time.

Germination: The main effect of germination besides the loss of dry matter is to increase the content of Vitamin C. This makes legumes an important source of Vitamin C in some communities during winter when fresh vegetables are in short supply. Moreover, the phytic acid content of seed is reduced during germination. Germination increases the protein quality of cereal. However, it has not been shown to have this effect on legumes.

Cooking: This appears to be the universal and preferred way of preparing legumes for consumption. The conditions and extent of heating procedures may affect foods adversely or beneficially with respect to their physical and organoleptic characteristics, as well as in regard to the utilization of the nutrients they contain. The nature and the extent of these changes depend mainly on the temperature and heating time, exposure and moisture content. The heat treatment applied to food legumes does improve their texture and palatability and also helps to destroy or inactivate some heat-labile toxic compounds such as trypsin inhibitors hemagglutinins and other enzyme inhibitors, thus improving the nutritional value of the food legumes. However, excessive heat treatment may cause a reduction in their nutritive value. Most legumes require three-four hours of ordinary boiling to cook properly; others are adequately prepared in half that time. The long cooking required for most legumes necessitates the expenditure of fuel, which is frequently scarce and probably causes significant destruction or modification of nutrients.

Storage

Undesirable changes in some legumes result from prolonged storage. Among these are (i) significant alteration in colour, (ii) reduced digestibility and acceptability, (iii) hardening of seed which requires increased cooking time and (iv) insect infestation decreases the nutritive value of legume proteins.

SUPPLEMENTARY EFFECT OF LEGUMES

The legumes protein is a rich source of lysine. Its major deficiency lies in the sulphur containing amino acids. Furthermore, legumes contain relatively high amount of protein as compared to other common foodstuffs. On the other hand, cereals have a low protein content, are, in general, lysine deficient, but have adequate amount of the sulphur containing amino acids. These chemical and nutritive characteristics of legume foods place them as natural complement to cereal-based diets. It is logical to conclude that legume protein should complement the protein in cereal grain. In fact, studies carried out by several investigators, have indicated that the protein value of a mixture of legume and cereal grain is superior to that of each of these components fed individually. The best supplementary effect of legume is observed when 50 percent of the legume protein is replaced by cereal protein.

LEGUME IN CHILD FEEDING

The legumes used in young child feeding should depend initially on those available in the particular area; selection should be based on cultural preferences, knowledge of nutritional composition, culinary attributes and apparent digestibility. Evidence suggests that young children of about one year of age can tolerate from 25 to 60 gram/day of well-cooked chickpeas. It is probably wisest to introduce legumes in a relatively dilute way to start with, say 1:4 mixture with the staple and gradually increase the content of legume as the child becomes adapted or accustomed to the new food. The available data provide information on two important aspects of legume feeding:

- That legumes are accepted, tolerated and utilized satisfactorily even by the children who are acutely ill and who are severely malnourished.
- That there is perhaps virtually no limit to the amount of legume that can be safely given to children provided it is suitably processed.

Legumes are primarily used as supplementary sources of protein to balance the protein quality of the staple. Legumes could be used safely in amounts to provide as much as 50 to 60 percent of total protein in the diet. Satisfactory improvement in nutritional quality of cereal-based diets has been achieved, when legumes are included, as they provide 30 percent of protein intake.

There is undoubtedly a great need for applied, domestic or a "grassroot" food technology with regard to the home processing and cooking of legumes in such a way that they are highly digestible and cause the least expenditure for fuel and the least destruction of nutrients.

BREEDING FOR NUTRITIONAL VALUE

Larger and more stable yield should be the primary objective of legume improvement programmes. When the available land is limited and competition from other crops is intense, increased productivity is essential to make legumes as economically attractive as the productive cereals and to obtain the seeds necessary for food and feed.

Protein yield per unit area can be increased either by increasing overall yield whilst at the same time keeping the percentage protein content of the grain approximately constant, or by increasing the percentage of protein in the grain keeping overall yield approximately constant. The breeders have reported either none or a weak negative correlation between protein yield and overall yield in legumes, indicating that both could be improved simultaneously. Furthermore, improving overall yield would allow greater leeway for subsequent improvement of protein content.

The poor nutritional value

of grain legumes is usually attributed to insufficient sulphur amino acids, the presence of anti-nutritional compounds and to poor protein digestibility. To increase the amount of methionine and cystine to nutritionally adequate levels, requires an approximate doubling of the current concentrations. Lectins and proteinase inhibitors are usually present in small quantities and are inactivated with proper heat treatment. However, prevailing cooking patterns may be inadequate and genetic reductions would be useful. Therefore, when breeding programmes are evolving improved strains, they should include better cooking qualities and acceptability. The newly developed strains also should meet the organoleptic (taste and flavour) requirements of the population. New varieties with short cooking time are desirable. In such efforts, plant breeders should work in close association with food technologists.

Milling characteristics and yield are also better with loose – husked varieties. There seems to be a need in areas where legumes are consumed in the form of flour or *dhal*, to develop strain with better milling characteristics, specifically large, uniform seeds.

Flatulence can be reduced by processing, using methods such as alcohol extraction, germination, soaking prior to cooking and enzymatic techniques. Since there is genetic variability in the relative abundance of these compounds, it may be possible to eliminate or, at least, minimize their effects by breeding.

Attempt should be made to breed varieties that show minimal undesirable changes during storage. Breeding for resistance to insect and mold attack should be considered in cooperative efforts between entomologists and plant pathologists. Control of mycotoxine development, such as aflatoxins, may be possible by genetic means. Breeders may need to ensure that proteinase inhibitors, haemagglutinins and tannins which may increase as a result of selection for resistance to pests and disease, does not do so to the level that adversely affects the digestibility and nutritional quality of legume grains.

If rapid progress is to be made in such breeding programme, there is a need for quick, simple and reliable method for assaying protein content, protein quality and anti-nutritional factors. For preliminary screening purposes, non-destructive tests adaptable to small sample are highly desirable.

PRODUCTION ECONOMICS AND UTILIZATION

Successful expansion of food legume production will depend ultimately on incentives for producers, marketing economics, product demand and utilization factors. These may be components of specific national policies relating to food production and nutrition objectives. Indirect benefits may include effects on soil fertility and tilth, crop rotation advantages, control of weeds and availability and use of by-products for animal food production. Economic studies should be carried out on cultural practices, including utilization of fertilizers, pesticides, and other direct inputs, relative to returns obtained from different legume genotypes grown in different environments and locales. Reassessments will need to be made for new varieties as these are developed.

The introduction of new crops and new types of familiar species will succeed only if these fit into local consumption patterns and food preferences. The exception would be those grown specifically for industrial purposes or export. Thus, it is most important, if not essential, to determine local consumer acceptability for these new food crops and varieties. In analyzing these findings, a basic understanding of sociological factors is imperative.