Qual Plant Plant Foods Hum Nutr 35 (1985) 339–351. 339

Nutritional quality of chickpea (*Cicer arietinum* L.): current status and future research needs

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(*Received August 21, 1984; in revised form January 23, 1985*)

Key words: Chickpea, nutritional composition, processing, storage, anti-nutrients, future research

Abstract. The nutritional composition and the affects of processing and storage and anti-nutrients on nutritional value of chickpeas are reviewed. Future research needs are discussed.

Among the world's grain food legumes, chickpea (*Cicer arietinum* L.), Bengal gram or garbanzo bean is second to dry beans (*Phaseolus vulgaris*) in area grown and third in production to dry beans and dry peas (*Pisum sativum*). In India, it is the most important pulse crop. Chickpeas are two basic types - kabuli and desi. Kabuli seeds are generally large and light colored while desi seeds range from yellow to black, are generally smaller, and have a rougher surface. India grows about 75% of the world acreage and total production of chickpea. Chickpeas are also important in Burma, Ethiopia, Iran, Mexico, Morocco, Pakistan, Spain, Tanzania and Turkey. It is cultivated as a winter crop in the tropics and as a spring or summer crop in temperate clines. Most of the crop is prepared by traditional methods for human consumption. The traditional processing practices used to convert chickpea into consumable forms include soaking, sprouting, fermentation, boiling, roasting, parching, frying and steaming.

Because the supplementation of cereals with high protein legumes is one of the best solutions to world protein calorie-malnutrition, the Protein Advisory Group of the United Nations recommended in 1972, urgent research attention to the production and nutritional aspects of the eight major food legumes dry bean,(*Phaseolus vulgaris*), pigeonpea, (*Cajanus cajan* L.), cowpea, (*Vigna unguculata*), chickpea, (*Cicer arietinum* L.), broad bean, (*Vicia faba*), dry pea, (*Pisum sativum*), soybean (*Glycine max*) and groundnut (*Arachis hypogaea*)) which account for about 93% of the total world legume production (PAG, 1972). Since then, considerable research effort has been devoted to the nutritional and technological aspects of grain legumes. The consumer

Submitted as J.A. No. 431 by the International Crops Research Institute for the Semi-Arid Tropics (ICRASAT).

acceptance characteristics, and the effects of improved processing technology and storage on the overall nutritional quality of grain legumes have also received considerable attention in the past decade. This paper summarises the results of studies on nutritional aspects of chickpea in four major categories.

1. Nutritional composition

The literature on the nutritional composition and quality of chickpea is voluminous. Chickpea is a very good source of carbohydrates and proteins which together constitute about 80 percent of the total dry seed weight. Chickpea seed crude protein content ranges between 12.6 and 30.5% [2–3]. Chickpea seed contains a considerable amount of nonprotein nitrogen (NPN) [4]. Nonprotein nitrogen and total seed nitrogen in chickpea are positively and significantly correlated. Any large variation in NPN would affect the estimated protein of the sample and would consequently affect the protein intake estimate in the diet. A variety of factors may cause variation in chickpea seed protein content and its quality. Both location and agronomic practices have important effects on protein quality. Results have shown that location grown had the greatest influence on seed protein content [5]. The application of nitrogen, phosphorus and sulphur fertilizers to the growing crop considerably increased the protein and amino acids in seeds [6]. Although high protein genotypes exist, little progress has been made in developing a high protein cultivars of improved agronomic performance capable of producing more protein per unit area.

Starch is the principal carbohydrate constituent of chickpea. The starch content of whole seed samples of several chickpea cultivars ranged between 41.0 and 50.8% with a mean of 47.3%, but considerably higher values were obtained for dhal (decorticated dry split cotyledons) samples [7]. Starch values for whole seeds of desi cultivars were lower than for kabuli cultivars [7]. Total seed carbohydrates have been reported to vary from 52.4 to 70.9% [3, 8]. Chickpea starch is 20–30% amylose, depending on the analytical method used [9] and the remainder is amylopectin. Soluble sugars range from 4.80 to 8.53% [7, 9], kabuli types containing slightly higher amounts than desi [7]. The bioavailability of carbohydrates is important in terms of calorific value. Unfortunately the concentration of unavailable carbohydrates in chickpea is the highest (25.6%) among the commonly consumed Indian pulses [10]. Chickpea also has the lowest carbohydrate digestibility as determined by using in vivo and in vitro procedures [11].

Chickpea contributes a considerable amount of fat to the human diet. Its fat content ranges between 3.8 and 10.2% [7, 8, 12, 13]. The major fatty acids of chickpea flour lipids are linoleic, oleic and palmitic acids [14]. The hypochlolesterolaemic effect of chickpea is considered to be due to its high content of essential fatty acids particularly linolinic and linoleic [15]. Triglycerides and phospholipids are the predominant components of chickpea lipids. The triglycerides are the major components of neutral lipids (non-polar) and lecithin the major polar lipid component [15].

The nutritional significance of various fiber components in the human diet has been recognized in recent years. The concentration of crude fiber is directly related to the amount of seed coat in chickpea and the seed coat content of chickpea cultivars ranges from between 5.2 and 19.4% [7]. The dietary fiber components of both dhal and seed of desi and kabuli cultivars differ qualitatively and quantitatively [16]. In terms of calorific value and utilization of dietary nutrients kabuli whole seed should be preferred to desi as the latter contains larger amounts of dietary fiber particularly cellulose and hemicellulose [16]. White seeded cultivars have the best food technological qualities because of their lower seed coat content and thickness suggesting that cultivars with thinner seed coats have better grain quality [17].

Chickpea is a very good source of minerals and trace elements. With the exception of calcium the differences between the mineral composition of whole grain and cotyledons (dhal) are marginal [18 – 19]. Calcium and iron are important nutrients but are usually deficient in the diets of low income people particularly infants, preschool children, and pregnant and lactating women in many developing countries. Since the seed coat contributes about 70% of the total seed calcium, the consumption of whole seed would be nutritionally desirable where calcium deficiency exists [18]. Chickpea is a very good source of iron since its availability is higher (91%) than in other grain legumes [20].

Protein quality is primarily assessed by comparing its amino acid composition with standard reference patterns, the most limiting amino acid determining the nutritive value [21]. By applying this calculation to the essential amino acid composition of chickpea, it is clear that two sulphur-containing amino acids, methionine and cysteine/*cystine* are the primarily limiting amino acids [22, 23, 24]. Ashur et al (1973) reported that chickpea met adult human requirements for all essential amino acids except for methionine and cysteine/cystine [25]. The tryptophan score appears to be satisfactory although there is a considerable variation for this amino acid among chickpea genotypes [23]. Next to the sulphur amino acids and tryptophan, threonine and valine appear important as in the majority of cases the chemical scores for these amino acids are below satisfactory levels [24]. In view of the deficiency of threonine in some cereals, lack of this amino acid would lower the nutritive value of a chickpea-cereals based diet. Based on their amino acid composition, the proteins of chickpea seed were found to have a higher nutritive value than that of other grain legumes [26]. Biological evaluation of protein is important because chemical analysis does not always reveal how much of a protein is biologically available. The PER of chickpea protein is higher than the PER's of red gram, (*Cajanus cajan* L.), black gram (*Vigna aconitifolia*), and green gram (*Vigna radiata*) [27]. The PER values of chickpea (2.64), soybean (*Glycine max*)(2.55) and horse bean (*Vicia faba*)(1.42) were significantly less than those of casein [28].

In grain legumes the storage proteins (globulins) constitute a major proportion of the seed proteins. These are of poor nutritive value for human and other monogastric animals because of their low sulphur amino acid concentration. The amino acid composition of food crops can be altered either by varying the relative proportion of embryo and endosperm or by changing the relative proportion of metabolic and storage proteins. Chickpea cotyledons constitute about 83% of the total seed dry weight and the globulins are their predominant proteins contributing about 35% of their total sulphur amino acids. The glutelin fraction contains a greater proportion of sulphur amino acids [29, 30]. Although the proportions of these protein fractions did not greatly differ among the limited number of cultivars analysed, the identification of chickpea cultivars with higher glutelin to globulin ratios would help to improve protein quality [30]. Further, the isolation of a methionine or other essential amino acid-rich protein fraction under independent genetic control might also assist in improving the nutritional quality.

Grain legumes are most frequently considered in terms of their complementary nutritional value in cereal based diets particularly in relation to amino acids. Supplementation with 10, 20, 30, 40 and 50% chickpea flour significantly enhanced the nutritive value of Arabic bread, but 20% supplementation was satisfactory in terms of its organoleptic properties [31]. The chemical composition, amino acids and PER value of cereals (wheat, triticale and maize) - chickpea mixtures (50:50, 60:40, 70:30) were lower than those of chickpea and cereal flours alone [32]. The addition of chickpea to normal and opaque-2 maize in the ratio of 3:7 on a protein basis raised their nutritional quality comparable with that of amino acids supplemented diets [33]. Chickpea supplementation was observed to improve the nutritional quality of traditional central Asian breads (oli-non) second only to dried skim milk [34]. The maximum recomended quantity of chickpea was 11% and it considerably improved the amino acid adequacy of the mixture [34].

2. Effect of processing practices on nutritional compositions

In grain legumes, traditional processing practices not only remove toxic substances and antinutritional factors but also improve palatability and digestibility. Generally, the soaking of chickpeas before cooking is the most common practice. When cooked after soaking for 20 h and sprouting for 24 h, the PER values of chickpea were significantly increased [35]. Separately, cooking and sprouting were effective to almost the same extent [36]. Although it depends on the method of cooking, protein quality of chickpea is improved more by moist heat than by dry heat treatment, as available lysine was less in roasted as compared to boiled and pressure-cooked chickpea [37]. Heat treatment causes considerable nutritional damage to methionine, the most important amino acids in grain legumes [38, 39]. Time and temperature should not be above 10 min at 120 °C for chickpea [39, 40]. Roasting chickpea seed at 100–110 °C for 5 min and autoclaving for 20 min were observed to give comparable protein quality indices [41]. Moreover, studies indicated that 12–15% of the lysine content is rendered unavailable while in vitro digestibility is decreased by 15 to 28% by roasting at 130–135 °C for 30 min [42].

The destruction of antinutritional factors during cooking is beneficial. Denaturation by heat is reported to improve digestibility by the protease enzymes, but excessive heating reduces the nutritive value of protein possibly by promoting amide cross linkage of amino acid side-chains [38]. Losses of methionine from legume proteins during boiling are significant [39]. It is therefore desirable to determine both the optimum duration and conditions of heating to derive the maximum nutritional advantages from cooking chickpea.

Apart from changes in protein quality, the heating process brings about considerable changes in the contents of other nutrients. Roasting and puffing of Bengal gram resulted in a 15 to 18% decrease in free lipids and an increase in bound lipids. Puffing resulted in the retardation of the oxidation of unsaturated fatty acids, but roasting had no such beneficial effect [43]. Vitamins are also heat-liable and are affected by heat treatment. Roasting and autoclaving resulted in a significant reduction in the levels of thiamine and riboflavin [40]. Germination had no advantages over moist heat treatment in improving the biological quality of the protein, whereas cooking considerably increased the PER of both germinated and nongerminated chickpeas [37]. The PER of chickpeas germinated for 48 h was greater than in nongerminated samples, but decreased when the germination period was extended [36, 44]. Germination up to 48 h also improved the carbohydrate digestibility while germination beyond this period did not have any effect [45]. Germination did not materially alter the amino acids of chickpeas [46].

The possibilities of using chickpea to prepare a fermented food have been investigated and several food preparations made out of fermented chickpeas have been reported. *Tempeh*, prepared by fermentation of chickpeas by *Rhizophus oligosporus* had higher PER than autoclaved unfermented grits [47, 48]. The protein quality of fermented *dhokla*, was better than that of the unfermented preparations [49]. The improved protein quality resulting from fermentation was attributed to the increased levels of limiting amino acids, and also to the elimination of toxic substances [50, 51]. Fermentation results in increases in two vitamins, thiamine and riboflavin [47, 49].

3. Antinutritional factors and their removal by processing

Like other grain legumes, chickpea seeds contain a variety of chemical substances which have deleterious effects on the human digestive system. It has been recognized for many years that the nutritive value and protein digestibility of uncooked legumes are very poor because of heat labile protease inhibitors and other compounds. Protease inhibitors, amylase inhibitors, oligosaccharides and polyphenols have formed the subjects of several studies.

Protease inhibitors (trypsin and chymotrypsin inhibitors) have been extensively studied and their mode of action established. Among grain legumes, chickpeas offer less problem as far as these factors are concerned. Under identical assay conditions, trypsin inhibitor activity was observed in decreasing importance in soybean, common bean, broad beans, peas, lentils (*Lens culinaris*) and chickpea [52] and in another study in black gram, kidney bean (*Phaseolus vulgaris*), red gram, mung bean (*Vigna radiata*) and chickpea [53]. The levels of protease inhibitors of chickpea vary considerably in chickpea genotypes [54]. The chymotrypsin inhibitor was more heat-stable than the trypsin inhibitor. The inhibitors were completely destroyed only when subjected to heat treatment under acidic conditions [55]. Fermentation resulted in a considerable reduction in antitryptic activity [56]. Trypsin inhibitors are a rich source of cystine which is not readily available for growth unless modified by heat [57]. Legume proteins do not fulfil their nutritional potential even after cooking because the digestibility of protein and availability of amino acids (particularly sulphur-containing amino acids) are quite low (50–80%). In this context the role of protease inhibitors should be studied in detail [58].

The nutritional significance of alpha-amylase inhibitors has been realised in recent years. Pancreatic amylase inhibitor is present in many legumes, but the inhibitor activity appears to be considerably lower in chickpea than in other important food legumes [59]. Amylase inhibitor activity was more towards pancreatic amylase than human salivary amylase and this was found in both desi and kabuli cultivars [60]. The amylase inhibitors of chickpea became completely inactive when boiled for 10 min [60]. Since most chickpeas are consumed after boiling, the amylase inhibitor is not of practical importance, except in the case of unheated chickpea meal where some inhibition of starch digestion is expected.

The ability of legume seeds to stimulate intestinal gas formation has been recognized for many years. Microbial fermentation in the large intestine is responsible for flatus components such as hydrogen, methane and carbon dioxide. It has frequently been suggested that the galactose containing oligosaccharides (raffinose, stachyose, and verbascose) are the components in the legume seeds that are responsible for flatulence. Gas production is greater from chickpea than from other legumes and this may be due to its higher content of oligosaccharides [61, 62]. Although these oligosaccharides are components of water soluble sugars, it may be difficult to predict the levels of these sugars on the basis of the total soluble sugar content of the seed [60]. Germinated chickpeas produced less flatus than ungerminated seeds [61]. Raffinose, stachyose and verbascose are decreased considerably by germination [63, 64]. The decrease in raffinose, stachyose and verbascose, used as easily available sources of energy during germination, is somewhat slower in chickpea than in other legumes [75]. In contrast, cooking significantly increased the oligosaccharide contents of all pulses and this increase was greatest for chickpea [62]. Fermentation reduces the level of these sugars. Fermentation of chickpeas for four days at 25 °C significantly reduced their raffinose content [65]. Since these sugars are accumulated at the later stages of seed maturation, the consumption of chickpea as green seed reduces the problem of flatus production [66].

The adverse role of phenolic compounds, in influencing protein digestibility is well known. A highly significant inverse relationship has been reported between in vitro protein digestibility and total phenolic compounds of chickpea seed [54]. Tannins were not detected in chickpea genotypes differing in seed color and origin [67]. On the other hand, chickpea seeds contain considerable amount of polyphenolic compounds which inhibit the activity of digestive enzymes [68]. Chickpea phenolic compounds are highly associated with the seed coat [54] and this finding is of considerable importance for regions where chickpeas are mainly consumed without dehusking.

In addition to protease inhibitors, some legumes contain phytohemagglutinins, so-called lectins. These proteins interact with the glycoproteins on the red blood cell surface causing agglutination of the cells, and are therefore toxic to animals. Chickpea showed little agglutinating activity by using cow erythrocytes [53, 69]. These results contradict the earlier observation that hemagglutinating activity was absent in chickpea [58]. Moreover hemagglutinins are highly sensitive to heat treatment and the greater reduction of the agglutinating activity was obtained with moist heat at $>$ 100 °C [70].

Many plants are potentially toxic because they contain glycosides from which HCN may be released by hydrolysis. It should be noted that chickpea seeds contain traces of HCN but at levels much below the permitted toxicity range [53]. The last antinutritional factors and toxic constituents to be considered are mycotoxins which were detected in chickpea seed using thin layer chromatography [71]. Aflatoxin contamination increased when chickpea seeds were stored in gunny bags for 6 months and aflatoxin B1 was found to be the component which increased most as a result of storage [72]. The seed mycoflora of desi and kabuli cultivars were not very different [73].

4. Effect of storage on nutritional quality

Adverse storage conditions reduce the nutritional quality of food grains and products. Chickpeas is stored as either raw whole seed, dkhal or dhal flour (commonly called besan). The nutritive value of whole seed is indirectly influenced by the hardening of the seed coat during storage over long periods at high temperatures and this finally results in quantitative and qualitative milling losses [74]. The storage of chickpea dhal and flour up to 10.8% moisture at 0.57 water activity does not cause perceptible changes in flavour but at 14.0% moisture chickpeas become moldy and develop a musty odour in 8 weeks. These changes were attributed to the antoxidative and hydrolytic degradation of both free and bound lipids and changes in the carotenoid contents [75]. This study also indicated that the proportion of phospholipids in bound lipids decreases, while that of neutral lipids increases during storage at higher moisture levels. Generally high storage temperatures have a direct effect on vitamin contents. A considerable amount of thiamine and riboflavin is lost during storage [74].

Insects and molds cause physical and chemical damage to the chickpeas in conventional storage conditions. The most common storage insects that attack chickpea are the pulses beetles or bruchids. Genotypic differences in susceptibility to pulse beetle attack have been demonstrated. For example bruchids developed more rapidly on kabuli than on desi cultivars [76]. The chemical and nutritional changes in chickpea seeds caused by pulses beetles during storage have been the subject of several investigations [77, 78, 79]. Insect infestation significantly decreased the PER of chickpea dhal [80, 81]. Chickpea protein quality deteriorated in storage because of changes in the levels of certain amino acids. The amount of available lysine decreased significantly when seeds were stored for 12 months [82]. Tryptophan and methionine both decreased with infestation but the effects were more pronounced for tryptophan where a decrease of 24% was observed [78]. Trypsin inhibitors in chickpea were more resistant to changes on storage and this might contribute to poor protein digestibility [81]. There is considerable evidence that protein rich pulses are contaminated with aflatoxin while exposed to unfavourable environmental storage conditions. Chickpeas can be contaminated with mycoflora and myeotoxins as a result of storage [71, 72, 73].

Seed treatments and storage methods influence the nutritive value of chickpeas. Chickpeas stored in bags suffered greater losses of nutrients such as thiamine than those stored in bottles probably because of a freer circulation of air in the bags [78, 82]. Nutrient losses were greater for chickpeas stored in cloth bags than those in closed metal containers [78]. The niacin content of chickpea seeds remained constant when chickpea was stored by either of these two methods [78]. Lipids in heat-processed chickpea flours are fairly stable to oxidative changes. Lipids underwent greater hydrolytic and oxidative changes in the flour of raw seeds than in the flour of roasted and puffed chickpeas during storage [43]. Heat treatment resulted in retardation of the oxidation of unsaturated fatty acids and this is beneficial to storage quality.

Future research needs

The chemical constituents of chickpea seeds including both nutritional and antinutritional factors have been studied by several workers. Although there appears to be a large variation among cultivars, few efforts have 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 also be useful in implicating the dietary potential of chickpea in human nutrition. Also, the effects of improved agronomic practices should be more carefully studied particularly with reference to the vitamin and mineral contents of chickpea seed. Studies concerning the interaction between cultivars and such factors on the nutritional composition would be desirable.

As in other food crops, nutritional improvement in chickpea can be achieved in two ways: (1) breeding for improved genotypes and (2) using improved processing technology prior to consumption as a dietary item. Because of seasonal variation in protein content, efforts to improve nutritional quality in chickpea by breeding have not been successful but it would be desirable to continue efforts in this direction. Although several reports indicate the existence of high protein genotypes, sources of high methionine have yet to be identified. It is necessary to identify the nutritional potential including toxic and undesirable factors of related wild species which are useful as sources of insect and disease resistance.

The cooking quality of grain legumes has been the subject of many investigations in the past. Unfortunately, there have been few systematic studies on cooking quality of chickpea. Factors such as growing conditions, chemical composition and storage should be studied in relation to cooking quality. It is recognized that the destruction of antinutritional factors, trypsin and chymotrypsin inhibitors in particular, is an important accomplishment of cooking. It is particularly pertinent to study the biochemical changes in proteins and carbohydrates induced by cooking because digestibility of protein and availability of amino acids are low even after cooking on losses and bioavailability of vitamins and minerals.

The intensity and duration of heat treatment during cooking depends on the method of food preparation. Since chickpeas are consumed in various forms, it is desirable to identify the major forms in which chickpea is consumed in the regions where it is grown, and to study the nutritional changes resulting from the various processing practices. A knowledge of the nutritional and organoleptic properties of chickpea products would be useful in understanding the nutritional potential of chickpea and the effects of food preparation. The possibility of utilizing chickpea for the preparation of *dhokla*, *idli*, *tempeh*, and *khaman*-like products by fermentation and their effects on nutritional quality needs to be explored. In India, most of the chickpea is processed into dhal and during this process it undergoes quantitative and qualitative losses. Although there is a need to examine different processing units to develop efficient dhal milling techniques, the nutrient losses incurred during such milling procedures including the pretreatments should be studied. The effects of milling on storage stability and cooking quality needs further examination.

While some of the antinutritional factors of chickpea have been extensively studied, no data are available on hemagglutinins, cyanogenic glucosides, antivitamins, esterogenic factors, metal-binding constituents, and toxic amino acids, if these are present at all in chickpea. The flatulence causing property of chickpea is well known. Some studies have clearly shown that oligosaccharides are not the main factors to have a marked influence on gas production. Efforts should be made to identify the other reasons for flatulence caused by chickpeas.

The development of cultivars with increased resistance to postharvest infestation is a most desirable step and it must be applicable for chickpea stored as whole seed, dhal and besan (fine dhal flour). The effect of chemical treatments for control of insect infestation and microbial growth should be examined from nutritional aspects.

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