Chickpea – nutritional quality and role in alleviation of global malnourishment

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Abstract: Chickpea (*Cicer arietinum* L.) constitute a well-balanced source of carbohydrates, proteins, vitamins and minerals essential to combat malnourishment in human populations. The various seed constituents show large variations in abundance between genotypes, which allow selection of lines for both calorie-rich and calorie-reduced diets. Chickpea with a high protein content combined with high digestibility is preferred in diets where food is scarce. In diets of affluent cultures, chickpeas with good vitamin, fatty acid and mineral balance combined with low digestibility would have a preference. The major challenges in chickpea improvement are development of region-specific genotypes with reduced content of anti-nutritional constituents such as the raffinose family of oligosaccharides. This improvement would encourage a wider use of chickpea-based diets around the world.

Key words: carbohydrates, proteins, minor components, carbohydrate digestibility, malnourishment

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Introduction

Food security can be defined as a state when all the people at all times have physical, social and economic access to adequate amounts of safe and nutritious food to satisfy dietary needs and food preferences (5). However, food security is complex and has both temporal and spatial dimensions. During hunger epidemics, people do not have access to adequate amount of food to provide the necessary energy (9.2 MJ or 2,200 kCal) for normal human functions, and consequently, an increased risk of diseases caused by malnutrition emerges. However, overconsumption of food (11.3 MJ day^{-1} - 12.5 MJ day^{-1}) occurs primarily in the developed world and leads to obesity in persons with sedentary lifestyle (3). Many diseases related to diabetes and coronary health conditions are caused by bad food choices and overeating. Thus, food security, production and consumption of well-balanced diets are major challenges currently facing human well being around the world.

Globally, about 12.5% of world population can be considered undernourished with only a slightly higher incidence (14.9%) in developing countries (4). As one of the consequences of long-term consumption of foods with poor nutritional value are aberrant growth and development in humans, the need for improved diets is urgent. These diets should be nutritionally balanced and within the economic accessibility of all consumers in the world. Chickpea (*Cicer arietinum* L.) is one food ingredients that can add important nutritional value to diets. Here we will outline some of the seed components affecting nutritional value and digestibility of chickpeas and for a more detailed description of chickpea nutritional and health benefits, we refer to a recent review (6).

Chickpea is broadly classified into two types based on seed size and colour of flowers and seeds. The kabuli types produce white flowers and large cream-coloured seeds, whereas desi flowers are purple and seeds are small, dark-coloured and angular. Kabuli types are mainly produced in temperate regions, whereas desi types are grown in the warmer and dryer semi-arid tropical regions. Both kabuli and desi seeds are energy-rich with gross energy and calorific values varying from 15–18.7 MJ/kg and 334–391 kcal/100 g, respectively. The mature seeds are dominated by the large cotyledons accounting for 83% and 92% of seed weight of desi and kabuli types, respectively (7). Due to the difference in seed size, desi have a larger seed coat fraction (15%) than kabuli (6.5%). Only a small fraction of chickpea seeds is occupied by the embryo (1.5%). Chickpea is a good source of carbohydrates and protein, which are predominantly stored in the cotyledons. The embryo is rich in lipids and vitamins, whereas valuable dietary fibers and minerals are concentrated to the seed coat. The amount of each seed constituent is largely dependent on genotype, environment and their interactions; thus, large variations in seed composition occur between cultivars and production areas.

Carbohydrates

The main energy provided by chickpeas in human diet and animal feed is derived from carbohydrates, which constitute 51% - 65% of desi and 54% - 71% of kabuli seed weight. Some of the carbohydrate energy is provided by the water-soluble sugars varying from 2.2% - 10.7% in desi, and 5.5% - 10.85% in kabuli types. The oval to spherical starch granules (9-10 µm wide, 14-30 µm wide) represent the major energy source of chickpeas and comprise 30-57% of seed weight (9). Two large glucan polymers, amylose and amylopectin, combined with minute amounts of proteins and minerals make up the granules. The amylose molecules are linear α(1,4)-linked glucan polymers that are sparsely branched through α(1,6) linkages. Amylopectin polymers, in contrast, are heavily branched as a result of α(1,6) linkages positioned at every 20-30 glucose residue on the α(1,4) glucan backbone. For desi and kabuli chickpeas, the amylose concentration varies from 20-42% and 20.7% - 46.5%, respectively; thus, many chickpea genotypes have considerable higher amylose concentration than cereal starches, which are in the 25% - 28% range (2).

The seed coat consists mainly of non-starch complex polysaccharides such as cellulose, pectic polysaccharides and hemicellulose giving rigidity to cell walls. These structural polysaccharides can be loosely grouped as dietary fiber and constitutes 15% - 22 % of seed carbohydrate content in chickpea. This is a relatively high concentration of dietary fiber when compared to cereals such as wheat (12%), rice (2 - 4%) and other pulse crops such as peas (5.1%) and beans (2.7%).

In humans, carbohydrates when consumed are acted on by enzymes which degrade the complex molecules in to progressively smaller molecules and finally into glucose to be absorbed by the blood stream. The ease by which food carbohydrates are broken down and delivered into blood stream is of great importance for human health (2). For starches, the ratio of amylose to amylopectin concentration in grains and seeds affects digestibility, where the less branched amylose molecules are more resistant to degradation in the digestive tract than the heavily branched amylopectin. Based on *in vitro* enzymatic hydrolysis assays, starch can be classified as readily digestible starch (RDS), slowly digestible starch (SDS) and resistant starch (RS). The RDS fraction is broken down to constituent glucose molecules within 20 minutes, whereas it takes 100 min to break down the SDS and the amylose-rich RS fraction remains undigested after 120 minutes. In the human body, RDS and SDS are completely digested within the small intestine by enzymatic digestion, whereas RS need to reach the large intestine before degradation is initiated by bacterial fermentation. Similar to RS, dietary fibers of the cell wall are largely resistant to digestion in the small intestine, but undergo fermentation in the large intestine. Insoluble dietary fiber (e.g. cellulose and hemicelluloses) is important for the overall health of the digestive system as it supports gastrointestinal movement.

Protein and amino acid composition

The protein concentration in chickpeas ranges from 16.7% - 30.6% and 12.6% - 29% for desi and kabuli types, respectively, and are 2-3-fold higher than in cereal grains (8% - 16%). Chickpea proteins have a relatively high content of the essential amino acid lysine (4.9 g $100g^{-1}$ - 6.9 g $100g^{-1}$) as compared to cereal grains (2.8 g $100g^{-1}$). However, sulphur-containing amino acids methionine and cysteine are in lower concentration in chickpea as compared to cereals.. Protein digestibility, very important for human nutrition, is affected by various factors such as inhibitors of enzymatic breakdown of proteins. The enzyme inhibitors can be inactivated during processing or cooking but chickpea type and genotype also affect protein digestibility and in chickpea it varies from 34% - 79.4%.

Fatty acids

The fat concentration in chickpeas varies from 2.9-7.4% in desi and 3.4-8.8% for kabuli types and can be considered high when compared to other pulse crops. Polyunsaturated, monounsaturated and saturated fatty acids share about 66, 19 and 15% of the total fat content in chickpea seeds. The polyunsaturated linoleic acid is the most prevalent fatty acid in chickpea seed (46-62/16-56% in desi/kabuli types) followed by oleic acid (18-23/19-32%) and palmitic acid (9.1/9.4%). Linoleic acid is considered as hypocholesterolemic agent; thus it reduces the risk of atherosclerosis and coronary heart disease.

Minerals

On average, 100 g of raw chickpea seeds contains 4.6 – 6.7, 3.7 – 7.4, 93 – 197, 125 – 159, 732 – 1126, 0.7 – 1.1 mg of iron (Fe,) zinc (Zn), calcium (Ca), magnesium (Mg), potassium (K) and copper (Cu), respectively. A 100g serving of chickpea can meet significant requirement of daily allowances of Fe (75/33% in males/females), Zn (48/66%), Ca (13/13%), Mg (34/45%), K (21/21%) Cu (90/90%) and P (48/48%) (8). However, the mineral concentration can show large variations depending on genotype and growth conditions, and in particular soil environment. For example, chickpea grown in North America have a high selenium concentration (15.3-56.3 µg 100 g^{-1}) that is adequate to fulfill 61% of the recommended daily allowance in humans.

Vitamins and other bioactive compounds

Chickpea has a good complement of vitamins; the predominant being folic acid (~300 mg 100 g^{-1}) and tocopherol (~13 mg 100 g^{-1}). Chickpea seeds also contain antioxidants/pigments such as carotenoids, which give bright colors to plant tissues. The important carotenoids in chickpea are β-carotene, lutein, zeaxanthin, beta-cryptoxanthin, lycopene and alpha-carotene. With the exception of lycopene, wild accessions of chickpea contain higher concentrations of carotenoids than cultivated varieties. In the plants, the most prevalent carotenoid is β-carotene, which can easily be converted in to vitamin A. Chickpea seeds are rich in β-carotene and on a dry weight basis contain more than Golden rice or red-colored wheats (6).

Anti-nutritional compounds

The acceptability of chickpea in daily diets is often impeded by the presence of certain anti-nutritional factors in the seeds. Raffinose family oligosaccharides (RFO), phytic acid, saponins and enzyme inhibitors are generally included in this group of undesirable seed components. RFO play an important role for seed desiccation, germination, photosynthate translocation and stress tolerance in plants and are particularly prevalent in pulse seeds. For chickpea, the RFO content varies from 2 to 8%, and if consumed in large quantities, causes flatulence in humans. The stomach discomfort is a result of RFO fermentation in large intestine releasing carbon dioxide, hydrogen and in smaller quantities, methane gases. Phytic acid constitutes about 0.4 to 1.1 % of chickpeas and has an important cellular function for plant and seed development. The component has a negative effect on nutrition by chelating mineral nutrients, thereby lowering their bioavailability. Thus, about 60% - 90 % of all phosphorous present in legume seeds is unavailable for uptake and high presence of phytic acid in the western diet is thought to exacerbate iron, calcium and zinc malnutrition in developing countries. The saponins (56 g kg^{-1}) and inhibitors of trypsin (1 mg g^{-1} - 16 mg g^{-1}), chymotrypsin (2 mg g^{-1} - 13 mg g^{-1}) and α-amylase (5 unit g^{-1} - 11 unit g^{-1}) have been reported to reduce the bioavailability of other nutrients in chickpea seeds.

Use of chickpeas to combat nutritional deficiencies in diets

One step towards combating malnourishment in both developed and undeveloped countries could be an increased utilization of pulses such as chickpeas in the daily diet. As chickpeas have a large variation in carbohydrate and protein composition and functionality, the strategy would involve selection of genotypes with suitable digestion profile and nutrition value for each end-user group.

In developed countries with excess food supply, the focus is on optimizing vitamin, mineral and fatty acid content and simultaneously reducing digestibility and calorie uptake. For this purpose, chickpeas with a high amylose concentration and producing high content of RS or SDS upon cooking would be preferred. As RS behaves like dietary fiber in the digestive tract, it will release less calories than normal starch and the high-amylose diet would also have beneficial effects on the health of the digestive tract. Upon fermentation of RS and other dietary fibers, growth of remedial microflora, *viz.* lactic acid bacteria and bifidobacterium, is stimulated and production of short chain fatty acids like propionic and butyric acids is increased. Propionates can inhibit cholesterol and fatty acid biosynthesis and thereby lower the risk of coronary heart diseases, whereas butyrate can prevent colorectal cancer by reducing cell proliferation and inducing apoptosis.

In diets of food deprived regions, high-protein food products rich in essential amino acids and high energy content are needed to meet the daily nutritional requirements. Preferably, the pulse diet would be consumed with cereals to combine the high protein and lysine content with sulphur-rich amino acids of cereals. Chickpea genotypes with a starch structure promoting RDS, e.g. low amylose, would be preferred for complete digestion and thus full utilization of the calorific value of the food product (1).

In conclusion, chickpea is a very versatile pulse crop with large seed size, rich in dietary fiber, protein and a starch component with diversity in concentration and digestibility. Chickpea has the potential to be an integral part of human diet around the world by full utilization of its diversity. For developed world, it has potential to reduce obesity and related metabolic disorders as it can be used in calorie-reduced foods. However, for its full acceptance in developed countries, the concentration of antinutritional factors needs to be reduced to overcome stomach disorders associated with consumption of chickpea based foods. ■

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