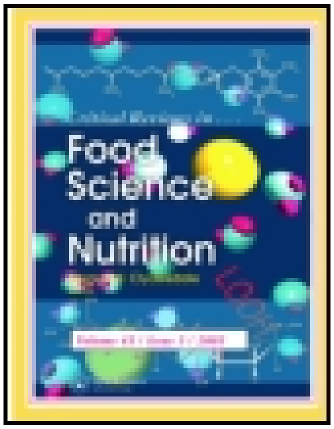

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Chickpeas - composition, nutritional value, health benefits, application to bread and snacks: A review

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Abstract

Chickpea is grain legumes grown mainly in areas with temperate and semi-arid climate. It is characterized by a high content of protein, fat, vitamins, fiber and a lower content of carbohydrates than flour of wheat. Chickpeas may contain anti-nutritional compounds which can impair utilization of the nutrients by people. Heat treatment is an effective method to increase the amount of protein available for intestinal digestibility. Adding chickpeas to a foodstuff can increase their nutritional value and reduce the acrylamide content. Acrylamide is a substance anti-nutritional present in foods such as bread, snacks and chips. Chickpea flour and protein may be new way to a reduce content of acrylamide in products of this type. The addition of chickpea flour affects the sensory and textural properties.

Key words: chickpea, nutritional composition, anti-nutritional factors, acrylamide

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Introduction

Chickpea *(Cicer arietinum* L.) is an annual plant derived from the Fabaceae family (Nwokolo et al., 1996). Is mainly grown in temperate and semi-arid regions, i.e. Asia, Europe, Australia and North America. A leading manufacturer of chickpeas is India, which provides approximately 66% of global production, second country in order is Turkey (7.6%), followed by Pakistan and Iran (7% and 3.5%), Canada and the United States, which give only a small extent contribute to total production of chickpea in the world (respectively 1.6% and less than 1%) (Smith, et al., 2005; Menale, et al., 2009). Chickpeas is reproduced from grains. Like all legumes it enriches the soil with nitrogen and leaves it in good shape (Biggs et al., 2007). Chickpeas occurs mainly in two varieties *Kabuli* and *Desi*. *Desi* chickpea grains are small, dark and have a ridged surface. *Desi* variety is grown mainly in semi-arid land. Kabuli variety is slightly larger than *Desi*, has a thin, bright cover grain and is cultivated in temperate climates (Agriculture, 2006). The differences in appearance and chemical composition of chickpea varieties (Table 1) are dependent on growing region and the conditions, which affect the length of the plants growing season or resistance to various diseases. Comparing the chemical composition of chickpea cultivars *Desi* and *Kabuli* it can be seen that they differ primarily in content of protein, fiber, polyphenols, and carbohydrates. The energy value of *Desi* variety grains is 327kcal/100g, while for *Kabuli* variety it equals 365kcal/100g (Maheri-Sis et al., 2008).

Chickpea is a plant known for a long time in Asia, mainly due to the wide possibilities of its application. Chickpea leaves have astringent properties and cooked may be applied in the case of displacements of bones and dislocations, while extract operates a treatment for diarrhea or indigestion. In Egypt, chickpea grains have been used to increase body weight, cure head and throat aches and cough. Powdered grains are used for preparation of facial masks and added to anti-dandruff products. Immature grains can be eaten raw and ripe can be dried and ground into flour and used as animal feed or as a substitute for coffee. Cooked grains are a great addition to salads especially popular in Western Europe and the USA, while in the Middle East they are consumed surrounded sugar or spices. Chickpea grains flour is also used as an addition to pasta, soups and bread (Sękara, 2005).

Chemical composition of chickpeas

Comparison the chemical composition flour of chickpea with wheat flour

By comparing the chemical composition of wheat flour and chickpeas flours (Table 2), chickpea flour has a higher content of protein, fat, ash and fiber (Khan et al., 1995; Hulse, 1991). In addition, chickpea flour is richer in minerals, both in the case of macronutrients, namely: potassium, calcium, sodium and magnesium, and micronutrients such as copper, iron, and zinc (Esmat et al., 2010). Some reports indicate that chickpea is also distinguished by a low glycemic index (GI) (Foster-Powell et al., 2002; Johnson et al., 2005). Chickpea flour is characterized by a lower availability of carbohydrates contained in it, and after a meal containing chickpea flour glucose concentration is lower than in the case of wheat flour products. A study conducted on a group of adults, however, did not find much difference in reducing GI or insulin index, when a portion of wheat flour was replaced with chickpea flour. However, the bread with addition of chickpea flour was characterized by a lower GI than bread from wheat flour.

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Characteristics of chickpea proteins and their biological properties

The major proteins found in legumes belong albumins and globulins. The major globulin proteins found in legumes include legumin (11S), vicilin (7S) and convicilin (15S) (Schwenke, 2001). Other proteins, present in small amounts, incorporated in legumes, and thus in chickpeas are gluteins and prolamines (Gupta et al., 1993; Saharan et al., 1994). Prolamines are soluble in alcohol and have a high content of proline and glutamine. Gluteins are soluble in dilute solutions of acids and bases, detergents and chaotropic and reducing salts. Gluteins contain higher concentrations of methionine and cystine than globulins, and thus are a more important nutrient. In connection with that some of researchers suggest that the cultivation leguminous plants should be linked to obtaining in them more content of gluteins (Singh et al., 1982).

In assessing the six varieties of chickpea Dahawan et al. (1991) showed that the protein content of these varieties ranges from 20.9-25.27%, of which the amount of albumin, globulin, glutein and prolamine were, respectively: 8.39-12.31%, 53.44-60.29%, 3.12-6.89%, 19.38-24.40%. In another study by da Silva et al. (2001), globulins in the chickpea protein accounted for 41.79%, albumin 16.18%, gluteins 9.99% and prolamines 0.48%.

Chickpea protein digestibility varies between 48–89.01%, depending on the source of research results. (Monsoor et al., 2002; Chitra et al., 1996; Chitra et al.,1995; Clemente et al., 1998; Han et al., 2007; Prakash et al., 1999). Increasing the digestibility of chickpea flour from 72.2-83.2% to 83.7-88.8% can be achieved via fermentation of flour. The application for this purpose synthetic enzyme fungus *Rhizopus sp.* is method used in case of soya. At the same time the product obtained from flour processed this way is characterized by better textural properties, aroma and taste. In addition, chickpea flour subjected to fermentation has in its composition a higher level of essential amino acids including methionine, cysteine, phenylalanine, tyrosine and threonine than chickpea flour untreated with this treatment (Angulo-Bejarano et al., 2008). Singh et al. (1981), found that *in vitro* digestibility of Kabuli chickpeas varieties (Dhal type, 72.7-79.1% and 52.4-69 % for whole beans) are higher than for the Desi variety (63.7-76% and 52.4-69% for whole beans).

Proteins, which are characterized by high levels of branched chain amino acid content (isoleucine, leucine, and valine), and low aromatic amino acid content, are beneficial to health (Oomah, 2001). The proteins contained in legumes are rich in lysine, leucine, aspartic acid, glutamic acid and arginine amino acids (Swanson, 1990). Differences in the composition and amount of protein found in chickpeas and other legumes may be due to the variety, environmental conditions, as well as geographic location, plants growing season and method of analysis used by the authors (Table 3) (Maheri-Sis et al., 1997; Alajaji et al., 2006; Zia-Ul-Haq et al., 2007).

Amino acids composition of chickpea

Content of amino acids is a very important indicator of the nutritional value of foods. The content of essential amino acids (39.89g/100g protein) and endogenous amino acids (58.64g/100g protein) are significantly higher in chickpea flour than in wheat flour (32.20 and 56.55g/100 g protein respectively). Wheat flour has a low content of essential amino acids: lysine, methionine, cysteine, and leucine. However, in the case of chickpea flour the limiting amino acids are methionine and cysteine (Table 4) (FAO/WHO 1985).

On the other hand, in other studies it was reported that limiting amino acids present in the chickpea flour are also aspartic acid and arginine (Boye et al., 2010). Supplementation of sorghum flour with chickpea flour showed that chickpea flour content increases essential amino acids content, namely lysine, methionine, cysteine and tyrosine, while subjecting the mixture of flours to heating caused a slight decrease in the content of these amino acids (Omima et al., 2010). It was also found that proteins isolated from chickpea flour have a looser structure, which means they are more accessible to our body. This is confirmed by, research carried out by Sánchez-Vioque et al. (1999), which showed that protein digestibility is hindered by its globular structure and the presence of inhibitors of trypsin and chymotrypsin. While isolating the protein from chickpea flour, which is the removal of albumin, in which protease inhibitors are found, increases the digestibility of 76.2% in the case of chickpea flour to 95-96% for the isolation of the protein.

Carbohydrate of chickpea

Chickpeas grains and flour characterized high content of monosaccharides, disaccharides and oligosaccharides. Major monosaccharides from part of chickpea are: ribose, fructose and glucose. In its composition also includes sucrose and maltose. The main oligosaccharides included in the chickpeas are: raffinose, ciceritol, stachyose and a small amount verbascose (Table 5). (Sánchez-Mata et al., 1998; Alajaji et al., 2006).

Lipids composition of chickpea

The total lipid content of chickpeas ranges from 4.5 to 6.0g oil/100g of bean (Boye et al., 2010). Triglycerides are the major components of neutral lipids, whereas lecithin is the major component of polar lipids. Fat in chickpea grains are characterized by high levels of essential unsaturated fatty acids, primarily, linoleic acid (54.7-56.2% in oil), oleic acid (21.6-22.2% in oil) and linolenic acid (0.5-0.9% in oil) and to a lesser extent palmitic acid (18.9-20.4% in oil) and stearic acid (1.3-1.7% in oil). The nutritional value of linoleic acid is very important due to its metabolism in the tissues of the body where a production of prostaglandins takes place, which reduce blood pressure and regulate smooth muscle contraction (Zia-Ul-Haq et al., 2007). Other compounds included in the chickpeas fat are waxes, fatty alcohols and sterols, whose content is reduced by chemical treatment such as the flour protein isolation (Sánchez-Vioque et al.,1998).

Mineral contents of chickpea

Chickpeas are also a good source of minerals, such as Ca, P, Mg, Fe and K (Table 6). The contents of these compounds decreases the treatment of chickpea grain thermal processes (Wang et al., 2010; Alajaji et al., 2006). Chickpea has a higher content of such manganese, zinc and phosphorous than other legumes (Wang et al., 2010).

Anti-nutritional compounds and effect of processing techniques to reduction there of chickpea

Anti-nutritional compounds are molecules that disrupt the digestion process. The accumulation of anti-nutritional compounds in the grains of leguminous plants is thought to have evolved as a protective mechanism during unfavorable environmental conditions and the presence of parasites, fungi, insects and herbivores. The anti-nutritional compounds found in pulse crops are classified into two categories: protein anti-nutritional components and non-protein anti-nutritional components, and range in effect from relatively inoffensive polyphenols to the relatively harmful protease inhibitors. Anti-nutritional protein compounds are: alkaloids, phytic acid, oligosaccharides, phenolic compounds such as tannins and saponins. Protein anti-nutritional compounds commonly found in legumes include lectins or agglutinins, trypsin inhibitors, chymotrypsin inhibitors or antifungal peptide (Roy et al., 2010). Anti-nutritional compounds of chickpea are reduce in varying degrees when chickpea is subjected to heating processes (Table 7).

Lectins (agglutinins) are carbohydrate-binding proteins. Identified several hundred different types of lectins present in plants. The four main groups of lectins distinguish: legume lectins, chitin-binding lectins, monocot mannose-binding lectins and the ribosome inactivating proteins type 2. Legumes in its composition contain many legume lectins. In humans and animals, diarrhea, bloating, vomiting and red blood cell agglutination, when sufficient quantities of raw grains or flour are consumed have been reported (Peumans et al., 1996). Agglutination activity of chickpea seeds is compared to the lentils and peas are much lower (400units/g) and may vary depending on variety, growing area and the method of collection (Singh, 1988). Scientific data has demonstrated that the lectins of legumes, are poorly understood, but can be used as a therapeutic agent for preventing or controlling obesity and reduce the risk of certain cancers (Sames et al., 2001).

In dry beans chickpea inhibitors of trypsin (6.7-14.6units/mg) and chymotrypsin (5.7-94units/mg) are found, which inhibit the action of protein digesting enzymes and contribute to the deterioration of the use of proteins in the human body. The inhibitor of amylase content of chickpea ranges 0-15units/g (Sing, 1988). The use of, among others ultrafiltration of chickpea flour reduces the trypsin inhibitor content. Using the above procedure along with the degreasing of flour leads to increased availability of protein from 22.3 to 88.0%dm for Desi chickpea varieties and from 18.9 to 85.7%dm in Kabuli variety (Mondor et al., 2009). The use of extrusion procedure kidney bean reduces the content of protease inhibitors and amylase inhibitor, and completely eliminates the activity of agglutination. In addition, the above method reduces the amount of condensed tannins and polyphenols (Marzo et al., 2002).

Another anti-nutritious substances present in legume beans is phytic acid, which forms weakly soluble in water complexes with Ca, Zn and Fe, which inhibit the absorption of these elements into the body. In comparison to the phytic acid concentration found in seeds of other major grain legumes found that chickpea had lower phytic acid concentrations (4.9-6.1mg/g) than kidney bean (11-17mg/g), fava bean (10.1-13.7mg/g), and soybean (10-14.7mg/g) (Thavarajah et al., 2009). Other authors reported that phytic acid content is lower in chickpea and ranges 1.38-1.71mg/g (Zia-Ul-Haq et al., 2007).

Research by Shahzadi et al. (2007) confirms that mixing 10% chickpea flour with wheat flour reduces phytic acid content from 0.81% to 0.54%. Additionally, the heating process and degreasing of flour leads to a reduction in phytic acid content in chickpea flour (Mondor et al., 2007). For example, subjecting the chickpea cooking under pressure reduces phytic acid content of 20% (Xu et al., 2009).

Anti-nutritive substances occurring in chickpea include oligosaccharides stachyose, raffinose and verbascose. These sugars cause flatulence. During their decomposition by bacteria present in the large intestine large quantities of gases are created. Subjecting of chickpea flour treatment of hot extrusion at 160°C can get results in decrease of oligosaccharides. Also, traditional of cooking and microwave of cooking leads to the reduction stachyose, respectively by 40% and 42% (Berrios et al., 2010).

Chickpea beans are a rich source of polyphenols and flavonoids, which have high antioxidant properties. The most of their content, 95%, is in the pile of the bean. The darker the chickpea bean color the greater the content of polyphenols, flavonoids and higher antioxidant properties (Segev et al., 2010). The total content of polyphenolic compounds present in the bean of chickpeas ranges from 0.72 to 1.81mg/g of bean and content of anthocyanin in quantities 14,9mg/kg of bean, depending on the reagents used in extraction, extraction time and method of analysis used by the authors (Segev et al., 2010; Xu et al., 2007; Silva-Cristobel et al., 2010). Chickpea is characterized by a lower content of polyphenols and anthocyanins than black beans or lentils, which is also reflected in its weaker ability to scavenge DPPH free radical, and thus lower antioxidant properties (Segev et al., 2010). Despite this, chickpea beans in contrast to pea are a rich source of phenolic acids such as: cinnamic, salicylic, hydroxycinnamic, p-coumaric, gallic, caffeic, vanillic, ferulic, anise, tannic, isoferulic, piperonyl, chlorogenic. Phenolic acids are characterized by strong antioxidant properties, ability to chelate metal ions and they play an important role in reducing oxidative stress in the organism (Tiwari et al., 2009). Bioactive compounds found in the chickpea beans include isoflavones, which have great importance because of their diverse and broad biological activities including antioxidant, oestrogenic, antifungal, and antibacterial activities (Zhao et al., 2009).

Isolation of protein from chickpea flour leads to a reduction in the content of polyphenolic compounds by 20%. Production of concentrates from full fat flours by isoelectric precipitation resulted in lower content of polyphenolic compounds (1.34mg/g), than protein concentrates produced from defatted flour (1.48mg/g). Processed by ultrafiltration method flour chickpea also allows the removal of polyphenolic compounds, but to a lesser extent than protein precipitation at the isoelectric point (Mondor et al., 2009).

Reduction of saponins and condensed tannins present in the grains chickpeas are possible when used traditional, autoclaving and microwave cooking methods. The highest reduction (50.1%) of condensed tannins were obtained using microwave heating. Cooking treatments decreased the concentrations of saponins of 51.65%. All three processes caused significant decreases trypsin inhibitor activity of 80.5-83.87% (Alajaji et al., 2006).

Properties of confectionery products obtained with the addition of chickpea

As mentioned earlier chickpea flour has a different chemical composition than wheat flour, which has a large impact on the appearance, taste and behavior of dough during and after baking. In a study by Gomez et al. (2008) in case of replacement of wheat flour with chickpea flour sponge cake was characterized by a lower volume. Reduction of the volume of the dough was the greater the larger the addition of chickpea flour was used. Strong influence on the properties of the dough may come from the fact that chickpea flour compared to wheat flour has a lower viscosity, which may reduce the ability to development of the dough.

Dough made from coarse fraction chickpea flour was characterized by significantly lower volume than the dough from the white chickpea flour (particle size lower than 210mm), which may be associated with a higher content of fiber affecting the behavior of gelatinized starch. (Gomez et al., 2008). Similar results were obtained by Hollingsworth (2007), who in his research replaced the corn flour with chickpea flour for baking muffins, which led to worse textural results than the muffins derived from corn flour only. Dough with chickpea flour was characterized by higher hardness and lower volume. Additionally Dodok et al. (1993), found that dough made from chickpea flour at the end of heating drops in a little, which means that there is a reduction of gas production and retention in the final stage of baking. However, comparing the behavior of sponge cake dough from chickpea flour to the dough from wheat flour, the dough dropped only slightly. Which means that chickpea flour can be used for this kind of dough. It was also found that the type and amount of added chickpea flour affects the color of products. Cake with chickpea flour was characterized by a darker color compared to the cake obtained from wheat flour. As it is known, the color of cake crust is produced in the process of baking as a result of the *Maillard* reaction between monosaccharides and amino acids, and in the process of caramelization of sugars. However, the color of the crumb coming from the interior of the cake was also darker when using chickpea flour. Darker color of dough obtained from chickpea flour is dependent on the composition of flour and the interaction between the components contained therein. Similar results were obtained by Dodok et al. (1993), who noticed the changes in the color of crumb of bread after addition of chickpea flour.

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Hemeda et al. (2010) found that the dough made with the addition of chickpea flour has a higher content of minerals (K, Zn and Fe) and a higher content of protein, carbohydrates and fiber, and at the same time a lower moisture and fat content than dough obtained from wheat flour. Additionally, the product with the addition of chickpea flour has a higher content of essential amino acids (isoleucine, lysine, aromatic amino acids and tryptophan) than the dough obtained only from wheat flour.

The addition of chickpea flour to wheat flour bread increases the nutritional value of the resulting bread. The value of NPU (net protein utilization) when 40% of chickpea flour is added to wheat bread increases from 37 to 65. This increase proves that the biological value of bread went up close to the level of casein protein (NPU=70). Thus, the essential amino acid content and protein quality in bread supplemented with chickpea flour was higher than in wheat bread (Hallab et al., 1974). Of great importance is also the lowered amount of carbohydrates present in chickpea flour compared to wheat flour (Table 3). Dough with 10% chickpea flour addition is characterized by 2.7% lower carbohydrate content than dough obtained only from wheat flour (Hemeda et al., 2010). It can have a huge impact on the amount of formed acrylamide, one of the precursors of which are carbohydrates. Isolation of protein from chickpea flour leads to a reduction in carbohydrate content from 57.88% to 10.33%, which may decide on the beneficial use of isolated protein as an additive in bread (Ionescu et al., 2009). This is due to the fact, that the lower availability and amount of carbohydrates present in the raw materials for confectionery may lead to a lessening of the *Maillard* reaction, and thus prevent the intermediate reactions leading to the formation of acrylamide.

Acrylamide and possibility of reducing this content using flour with chickpeas

The most widespread flour used for baking bread and pastries is wheat flour, which contains precursors of acrylamide. Acrylamide (2-propenamide) is a colorless and odorless substance that is melting at a temperature of 84-86 ˚C. When exposed to UV light or heating it undergoes polymerization. It is well soluble in water and other polar solvents (methanol, acetone and ethanol) (Rice, 2005). Acrylamide formation takes place by the action of temperatures above 120^{o}C during frying, deep frying and baking of food rich in carbohydrates. Food products, in which the acrylamide content is the highest are cereal and potato products (Amrein et al., 2004). Acrylamide is formed mainly as a result of complex reactions between the amino acid asparagine and monosaccharides as a result of the *Maillard* reaction (Claus et al., 2003; Mottram et al., 2002). The formation of acrylamide also occurs during decarboxylation and deamination of aspartic acid (Granvogl et al., 2006). In addition, acrylamide formation was observed as a result of thermal degradation of triacylglycerols released from fats during heating of food products (Gertz et al., 2002; Mestdagh et al., 2008). The largest amounts of acrylamide are found in fried potato crisps type products (330-2300µg/kg), chips (300-1100µg/kg), fried potatoes (43-688µg/kg), bread and baguettes (30-430µg/kg), crisp bread (30-1900µg/kg), breakfast cereals (30-1400µg/kg), cookies and crackers (30-3200µg/kg), rusk (800-1200µg/kg), gingerbread (90-1660µg/kg), or biscuits and wafers (30-640µg/kg) (Friedman et al., 2008).

International Agency for Research on Cancer (IARC) considers acrylamide as a substance "probably carcinogenic to humans" (IARC, 1994). In the Official Journal of the European Union were adopted new recommendations of the European Commission (EC) of 2

June 2010 associated with monitoring the level of acrylamide in treated foods rich in carbohydrates (2010/307/UE). Therefore, it is very important to conduct further research in order to lower the content of acrylamide in carbohydrate products. The main methods for lowering acrylamide content in cereal and potato products include: lowering the temperature and lengthening the time of heating of products, modifying recipes, using the enzyme asparaginase, the addition of substances with antioxidant properties and selected amino acids.

Research conducted by Vattem et al. (2003) suggest that chickpea protein exhibits thermal stability and can act as a so-called advanced thermal barrier. Swedish committee of experts suggests that acrylamide formation is a typical surface phenomenon (Tareke et al., 2002). Therefore, covering of potato slices with chickpea flour allowed to limit the formation of acrylamide by 50%. It was also showed that the potato slices coated with chickpea flour were characterized by low content of substances with antioxidant properties, and low ability to reduce DPPH, so beneficial effect of chickpea flour may be related to the protective effect of thermally stable chickpeas proteins. Chickpea proteins may also be involved in the creation of complexes with starch in high temperatures. Thanks to that sugars derived from starch are not available in the *Maillard* reaction, do not undergo thermal degradation and do not participate in the formation of acrylamide. Chickpea protein activity may also come from their participation in the relocation of electrons in monosaccharides such as glucose and fructose, protecting them from breaking of the carbon chain, thus creating tricarbon compounds undergoing condensation reactions, leading to the formation of acrylamide (Vattem et al., 2003).

Studies related to the characteristics of thermal DSC flour, protein and starch of chickpea protein confirms high temperature resistance. Temperature denaturation of the protein depending on moisture concentration in the sample ranges from 144-182°C (Tabaeh et al., 2007).

Shortcrust cookies baked at 180°C for 10 minutes, using flour caused the generation of acrylamide in an amount of 41.9mg/kg. But using a mixture of wheat flour with chickpea flour (1:1) to bake cookies, in the same conditions of heating, reduced acrylamide content of 5.7mg/kg, a reduction of 86.4%. Blend flour: wheat and chickpea (1:1) was characterized by high amounts of aspartic acid and asparagine and low in sugars, glucose, fructose and sucrose. Consequently, baked cookies were marked by a slight decrease of sugars: glucose and sucrose. The high level of total aspartic acid and asparagine, and sugars in baked cookies proves that the precursors of acrylamide formation did not participate in the *Maillard* reaction and thus the level of acrylamide is lower (Miśkiewicz et al., 2012).

Cook et al. (2005) showed that covering hydrated potato flakes with soy protein hydrolysates leads to a lowering of acrylamide content. This suggests that the beneficial effect of soy protein hydrolysates probably results from the reaction of NH_2 group of the protein peptide with an acrylamide molecule, transforming it into a derivative of $-NH-CH_2CH_2CONH_2$ peptide (Friedman, et al., 2008).

Conclusions

Chickpea is a more and more appreciated and more widely analyzed plant. The chemical composition of chickpea flour is different significantly from the composition of wheat flour.

Chickpea flour has increased health properties, with little impact on the texture of food products manufactured from it. A small addition of this flour can significantly lower content of carbohydrates and fat and increase the amount of protein, fiber and mineral substances in food products. Chickpea and its protein may limit the formation of acrylamide in cookies and other foodstuff based on flour wheat. Adding of chickpeas to food can be used after removal of anti-nutritional compounds using heat treatments which improves the nutritional value of chickpeas.

References:

Agriculture and Agri-Food Canada. (2006). Chickpeas: Situation and outlook. *Bi-weekly Bulletin.* **19**: 1–14.

Alajaji, S. A., and El-Adawy, T. A. (2006). Nutritional composition of chickpea (*Cicer arietinum L.*) as affected by microwave cooking and other traditional cooking methods. *Journal of Food Composition and Analysis.* **19**: 806–812.

Alsohaimy S.A. , Sitohy M. Z., and El-Masry R. A. (2007). Isolation and partial characterization of chickpea, lupine and lentil and lentil seed proteins. *World Journal of Agricultural Sciences.* **3(1)**: 123–129.

Amrein, T. M., Schonbachler, B., Escher, F., and Amado, R. (2004). Acrylamide gingerbread: critical factors for formation and possible ways for reduction. *Journal of Agricultural and Food Chemistry*. **52**: 4282–4288.

Angulo-Bejarano, P. J., Verdugo-Montoya, N. M., Cuevas-Rodrıguez, E. O. , Milan-Carrillo, J., Mora-Escobedo, R., Lopez-Valenzuela, J. A., Garzon-Tiznado, J. A. and Reyes-Moreno, C. (2008). Tempeh flour from chickpea (*Cicer arietinum L.*) nutritional and physicochemical properties. *Food Chemistry*. **106**: 106–112.

Attia, R.S., El-Tabey Shehata, A. M., Aman, M. E., and Hamza, M.A. (1994). Effect of cooking and decortication on the physical properties, the chemical composition and the nutritive value of chickpea (*Cicer arietinum* L.). *Food Chemistry*. **50**: 125–131.

Berrios, J. D. J, Morales, P., Cámara, M., and Sánchez-Mata, M. C. (2010). *Food Research International*. **43**: 531–536.

Biggs, M., McVicar, J., and Flowerdew, B. (2007). *Wielka Księga warzyw, ziół i owoców.* Bellona. Poland. 72–73.

Boye, J., Zare, F., and Pletch, A. (2010). Pulse proteins: Processing, characterization, functional properties and applications in food and feed. *Food Research International.* **43**: 414–431.

Candela, M., Astiasaran, I., and Bello, J. (1997). Cooking and warm-holding: Effect on general composition and amino acids of kidney beans (*Phaseolus vulgaris*), chickpeas (*Cicer arietimum*), and lentils (*Lens culinaris*). *Journal of Agricultural and Food Chemistry.* **45**: 4763–4767.

Chitra, U., Singh, U., and Rao, V. R. (1996). Phytic acid, in vitro protein digestibility, dietary fiber, and minerals of pulses as influenced by processing methods. *Plant Foods for Human Nutrition.* **49**: 307–316.

Chitra, U., Vimala, V., Singh, U., and Geervani, P. (1995). Variability in phytic acid content and protein digestibility of grain legumes. *Plant Foods for Human Nutrition.* **47**: 163–172.

Claus, A., Carle, R., and Schieber, A. (2008). Acrylamide in cereal products: A review. *Journal Cereal Science.* **47**: 118–133.

Clemente, A., Shanchez-Vioque, R., Vioque, J., Bautistab, J., and Millin, F. (1998). Effect of cooking on protein quality of chickpea (*Cicer arietinrum*) seeds. *Food Chemistry*. **62**: 14.

Cook, D. J., and Taylor, A. J. (2005). On-line MS/MS monitoring of acrylamide generation in potato- and cereal-based systems. *Journal of Agricultural Food Chemistry*. **53**: 8926–8933.

da Silva, M. A., Neves, V. A., and Lourenço, E. J. (2001). Protein fractions and major globulin from chickpea (*Cicer arietinum L.*). *Alimentose Nutrição.* **12**: 131–149.

Dhawan, K., Malhotra, S., Dahiya, B. S., and Singh, D. (1991). Seed protein fractions and amino acid composition in gram (*Cicer arietinum*). *Plant Foods for Human Nutrition.* **41**: 225–232.

Dodok, L., Ali, M. A., Hozova, B., Halasova, G., and Polacek, I. (1993). Importance and utilization of chickpea in cereal technology. *Acta Alimentaria.* **22**: 119–129.

Esmat, A. A. A., Helmy, I. M. F., and Bareh G. F. (2010). Nutritional evaluation and functional properties of chickpea (*Cicer arietinum L.*) flour and the improvement of spaghetti produced from its. *Journal of American Science.* **6(10)**: 1055–1072.

Foster-Powell, K., Holt, S.H.A., and Brand-Miller, J.C. (2002). International table of glycemic index and glycemic load values. *The American Journal of Clinical Nutrition.* **76**: 5–56.

Frias, J., Vidal-Valverde C., Sotomayor C., Diaz-Pollan C., and Urbano G. (2000). Influence of processing on available carbohydrate content and antinutritional factors of chickpeas. *European Food Research and Technology.* **210**: 340–345.

Friedman, M., and Levin, C. E. (2008). Review of methods for the reduction of dietary content and toxicity of acrylamide. *Journal of Agricultural Food Chemistry.* **56**: 6113–6140.

Gertz, Ch., and Klostermann, S. (2002). Analysis of acrylamide and mechanism of its formation in deep-fried products. *European Journal Lipid Science Technology.* **104**: 762–771.

Gomez, M., Oliete, B., Rosell, M. C, Pando, V., and Encarnacion F. (2008). Studies on cake quality made of wheate-chickpea flour blends. *LWT - Food Science and Technology.* **41**: 1701–1709.

Granvogl, M., and Schieberle, P. (2006). Thermally Generated 3-Aminopropionamide as a transient intermediate in the formation of acrylamide. *Journal of Agricultural and Food Chemistry.* **54**: 5933–5938.

Gupta, R., and Dhillon, S. (1993). Characterization of seed storage proteins of Lentil (*Lens culinaris M.*). *Annals of Biology*. **9**: 71–78.

Hallab, A. H, Khatchadourian, H. A., and Jabr, I. (1974). The nutritive value and organoleptic properties of white Arabic bread supplemented with soybean and chickpea. *American of Cereal Chemists*. **51**: 106–112.

Han, I. H., Swanson, B. G., and Baik, B. K. (2007). Protein digestibility of selected legumes treated with ultrasound and high hydrostatic pressure during soaking. *Cereal Chemistry*. **84**: 518–521.

Hemeda, H. M., and Eman, F. M. (2010). Functional attribute of chickpea and defatted soybean flour blends on quality characteristic of shortening cake. *European Journal of Applied Sciences*. **2(2)**, 44–50.

Hollingsworth, B. A. (2007). Effects of ground chickpea as wheat flour replacer in corn muffins. *Individual project Written Raport. F&N*. **453**: 1–11.

Hulse, J.H. (1991). Nature, composition and utilization of grain legumes. In: Uses of Tropical Legumes, pp. 11–27. ICRISAT Center. ICRISAT, India.

International Agency for Research on Cancer (IARC). (1994). Summaries & Evaluations, ACRYLAMIDE (Group 2A). **60**: 389.

Ionescu, A., Aprodu, I., Daraba, A., Gurau, G., Baciu, C., and Nichita, A. (2009). Chemical amd functional characterization of chickpea protein derivates. *Food Technology*. **33**: 16–27.

Johnson, S. K., Thomas, S. J., and Hall, R. S. (2005). Palatability and glucose, insulin and satiety responses of chickpea flour and extruded chickpea flour bread eaten as part of a breakfast. *European Journal of Clinical Nutrition*. **59**: 169 –176.

Jood, S., Chauhan, B. M., and Kapoor, A. C. (1989). Protein digestibility (*in vitro*) of chickpea and blackgram seeds as affected by domestic processing and cooking. *Plant Foods for Human Nutrition.* **39**: 149–154.

Khan, M. A., Akhtar, I. U., and Jaffery, S. (1995). Nutritional evaluation of desi and kabuli chickpeas and their products commonly consumed in Pakistan. *International Journal of Food Sciences* & *Nutrition.* **46**: 215–223.

Maheri-Sis, N., Chamani, M., Sadeghi, A-A., Mirza- Aghazadeh, A., and Aghajanzadeh-Golshani, A. (2008). Nutritional evaluation of kabuli and desi type chickpeas (*Cicer arietinum* L.) for ruminants using *in vitro* gas production technique. *African Journal of Biotechnology*. **7**: 2946–2951.

Marzo, F., Alonso, R., Urdaneta, E., Arricibita, F.J., and Ibánez, F. (2002). Nutritional quality of extruded kidney bean (Phaseolus vulgaris L. var Pinto) and its effects on growth and skeletal muscle nitrogen fractions in rats. *Journal of Animal Science.* **80**: 875–879.

Menale, K., Bekele, S., Solomon, A., Tsedeke, A., Geoffrey, M., Setotaw, F., Million, E., and Kebebew, A. (2009). Current Situation and Future Outlooks of the Chickpea Sub-sector in Ethiopia ICRISAT and EIAR 1–35.

Mestdagh, F., Castelein, P., Peteghem, C., & Meulenaer, B. (2008). Importance of Oil Degradation Components in the Formation of Acrylamide in Fried Foodstuffs. *Journal of Agricultural and Food Chemistry*. **56**: 6141–6144.

Miśkiewicz, K., Nebesny, E., and Oracz, J. (2012). Formation of acrylamide during baking of shortcrust cookies derived from various flours. *Czech Journal of Food Science*. **30**: 53–66.

Mondor, M., Aksay, S., Drolet, H., Roufik, S., Farnworth, E., and Boye, J. I. (2009). Influence of processing on composition and antinutritional factors of chickpea protein concentrates produced by isoelectric precipitation and ultrafiltration. *Innovative Food Science and Emerging Technologies*. **10**: 342–347.

Monsoor, M. A., and Yusuf, H. K. M. (2002). In vitro protein digestibility of lathyrus pea (*Lathyrus sativus*), lentil (*Lens culinaris*) and chickpea (*Cicer arietinu*m). *International Journal of Food Science and Technology*. **37**: 97–99.

Mottram, D. S., Wedzicha, B., and Dodson, A. T. (2002). Acrylamide is formed in the Maillard reaction. *Nature*. **419**: 448–449.

Nwokolo, E., and Smartt, J. (1996). Food and feed from legumes and oilseeds. In: Chapman and Hall E-publishing. pp. 4–5.

Omima, E. F., Abdullahi, H. E., and Babiker, E. E. (2010). Effect of Fermentation on Biochemical Characteristics of Sorghum Flour Supplemented with Chickpea Flour. *Journal of Applied Sciences Research*. **6(7)**: 860–865.

Oomah, B. D. (2001). Flaxseed as a functional food source. *Journal of Food Science*. **81**: 889–894.

Peumans, W. J., and Van Damme, E. J. M. (1996). Prevalence, biological activity and genetic manipulation of lectins in foods. *Trends in Food Science & Technology*. **7**: 132–138.

Prakash, V. H. P., and Prakash, J. (1999). In vitro protein digestibility of legumes cooked with spices. *Nahrung/Food*. **43**: 19–21.

Recommendation Commission of 2 June 2010 on the monitoring of acrylamide levels in food (Text with EEA relevance) (2010/307/UE) EUROPEAN COMMISSION having regard to the Treaty on the Functioning of the European Union in particular 292.

Ref. Pattern FAO/WHO 1985

Rice, J. M.: The carcinogenicity of acrylamide. (2005). *Mutation Research*. **580**: 3–20.

Roy, F., Boye, J.I., and Simpson, B.K. (2010). Bioactive proteins and peptides in pulse crops: pea, chickpea and lentil. *Food Research International*. **43**: 432–442.

Saharan, K., and Khetarpaul, N. (1994). Protein quality traits of vegetable and field peas: Varietal differences. *Plant Foods for Human Nutrition*. **45**: 11–22.

Sames, K., Shumacher, U., Halata, Z., Van Damme, E. J., Peumans, W. J., Asmus, B., et al. (2001). Lectins as bioactive plant proteins: A potential in cancer treatment. *Critical Reviews in Food Science and Nutrition*. **45**: 425–445.

Sánchez-Mata, M. C, Penuela-Teruel, M. J., Camara-Hurtado, M., Diez-Marques, C., and Torija-Isasa, M. E. (1998). Determination of mono-, di-, and oligosaccharides in legumes by high-performance liquid chromatography using an amino-bonded silica column. *Journal of Agricultural and Food Chemistry*. **46**: 3648–3652.

Sánchez-Vioque, R., Clemente, A. , Vioque, J., Bautista, J., and Millan., F. (1999). Protein isolates from chickpea (*Cicer arietinum L.*): chemical composition, functional properties and protein characterization. *Food Chemistry*. **64**: 237–243.

Sánchez-Vioque, R., Clemente, A., Vioque, J., Bautista, J., and Millan, F. (1998). Neutral lipids of chickpea flour and protein isolates. *Journal of the American Oil Chemists' Society (JAOCS)*. **75**: 851–855.

Sasaki, T., Yasui, T., and Matsuki, J. (2000). Influence of non-starch polysaccharides isolated from wheat flour on the gelatinization and gelation of wheat starches. *Food Hydrocolloids*. **14**: 295–303.

Schwenke, K. D. (2001). Reflections about the functional potential of legume proteins. *Nahrung/Food*. **45**: 377–381.

Segev, A., Badani, H., Kapulnik, Y., Shomer, I., Oren-Shamir, M., and Galili, S. (2010). Determination of polyphenols, flavonoids, and antioxidant capacity in colored chickpea (*Cicer arietinum* L.). *Journal of Food Science*. **75(2)**: 115–119.

Sękara, A. (2005). Chickpea milkvetch. *Działkowiec*. **12**.

Shahzadi, F., Butt, M. S., Rehman, S., and Sharif, K. (2007). Chemical Characteristics of Various Composite Flours. *International Journal of Agriculture & Biology*. **7**: 105–108.

Silva-Cristobala L., Osorio-Díaza P., J. Tovarb J., and Bello-Péreza L. A. (2010). Chemical composition, carbohydrate digestibility, and antioxidant capacity of cooked black bean, chickpea, and lentil Mexican varieties. *CyTA - Journal of Food*. **8**: 1, 7–14.

Singh, U. (1988). Antinutritional factors of chickpea and pigeonpea and their removal by processing. *Plant Foods Human Nutrition*. **38**: 251–261.

Singh, U., and Jambunathan, R. (1981). Studies on desi and kabuli chickpea (*Cicer arietinum L.*) cultivars: Levels of protease inhibitors, levels of polyphenolic compounds and in vitro protein digestibility. *Journal of Food Science*. **46**: 1364–1367.

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

Smith, V., and Jimmerson, J. (2005). Chickpeas (Garbanzo beans). *Agricultural Marketing Policy Center (AMPC)*. 55.

Swanson, B. G. (1990). Pea and lentil protein extraction and functionality. *Journal of the American Oil Chemists Society*. **67**: 276–280.

Tabaeh, E., and Seyed, S. (2007). Hydrocyclone fractionation of chickpea flour and measurement of physical and functional properties of flour and starch and protein fractions. In: Agricultural and Bioresource Engineering, pp. 134–147. University of Saskatchewan, Saskatoon Canada.

Tareke, E., Rydberg, P., Karlsson, P., Eriksson, S., and Tornqvist, M. (2002). Analysis of acrylamide a carcinogen formed in heated foodstuffs. *Journal of Agricultural Food Chemistry*. **50**: 4998–5006.

Thavarajah, P., Thavarajah, D., & Vandenberg, A. (2009). Low phytic acid lentils (*Lens culinaris* L.): a potential solution for increased micronutrient bioavailability. *Journal of Agricultural and Food Chemistry*. **57**: 9044–9049.

Tiwari, P., Singh, A., Singh, U., Maurya, S., and Singh, M. (2009). Chromatographical analysis of Phenolic acids in different preparations of pea (*Pisum sativum*) and chickpea (*Cicer arietinum*). *The Internet Journal of Alternative Medicine.* **8(1)**. Retrieved from: www.ispub.com/

Vattem, D. A., and Kalidas, S. (2003). Acrylamide in food: a model for mechanism of formation and its reduction. *Innovative Food Science and Emerging Technologies.* **4**: 331–338.

Wang, N., Hatcher, D.W., Tyler, R.T., Toews, R., and E.J. Gawalko. (2010). Effect of cooking on the composition of beans (Phaseolus vulgaris L.) and chickpeas (Cicer arietinum L.). *Food Research International.* **43**: 589–594.

Xu, B. J., and Chang, S. K. A. (2007). Comparative study on phenolic profiles and antioxidant activities of legumes as affected by extraction solvents. *Journal of food Science.* **2(72)**: 159 – 166.

Xu, B., and Chang, S. C. K. (2009). Phytochemical Profiles and Health-Promoting Effects of Cool-Season Food Legumes As Influenced by Thermal Processing. *Journal of Agricultural and Food Chemistry*. **57**: 10718–10731.

Yaylayayan, V.A., Wnorowski, A., and Perez, L. C. (2003). Why asparagine needs carbohydrates to generate acrylamide. *Journal of Agricultural and Food Chemistry*. **51**: 1753–1757.

Zhao, S., Zhang, L., Gao, P., and Shao, Z. (2009). Isolation and characterisation of the isoflavones from sprouted chickpea seeds. *Food Chemistry.* **114**: 869–873.

Zia-Ul-Haq, M., Iqbal, S., Ahmad, S., Imran, M., Niaz, A., and Bhanger, M. I. (2007). Nutritional and compositional study of Desi chickpea (*Cicer arietinum L.*) cultivars grown in Punjab, Pakistan. *Food Chemistry*. **105**: 1357–1363.

Table 1 Chemical composition of *Kabuli* and *Desi* types of chickpea on dry matter basis (%)

Component	Varieties of chickpea (%)	
	Kabuli	Desi
Dry matter	92.08	91.17
Crude protein	24.63	22.76
Crude fibre	6.49	9.94
Total tannin	0.09	0.12
Total phenolic compounds	0.27	0.26
Non fibrous carbohydrate	49.13	46.81
Starch	39.12	38.48
Soluble sugars	8.43	7.53

Source: Maheri-Sis et al., 2008

Table 2 Chemical composition of wheat and chickpea flour (%)

Component	Wheat flour	Chickpea flour
Protein	9.3-14.3	24.4-25.4
Carbohydrates	64.6-69.04	47.4-55.8
Fat	1.25-2.93	3.7-5.1
Fiber	0.9-1.8	3.9-11.2
Ash	1.48-3.3	3.2-2.8

Source: Khan et al., 1995.

Table 3 Comparison of amino acid composition of chickpea grains

Type of amino acid	Amino acid content		
	g/100g sample[a]	g/16g N[b]	g/100g protein[c]
Essential amino acids			
Isoleucine	0.36	4.1	4.5-4.8
Leucine	0.48	7.0	8.1-8.5
Lysine	0.91	7.7	6.7-7.0
Methionine	0.12	1.6	0.8-1.1
Phenylalanine	0.42	5.9	5.0-5.3
Threonine	0.06	3.6	2.7-3.0
Tryptophan	-	1.1	0.8-0.9
Valine	0.38	3.6	4.1-4.6
Cystine	-	1.3	0.4-0.6
Tyrosine	0.19	3.7	2.6-2.8
Non-essential amino acids			
Alanine	0.26	4.4	47-5.2
Arginine	0.48	10.3	8.0-8.5
Aspartic acid	0.58	11.4	10.9-11.5

Glutamic acid	1.67	17.3	17.3-17.8
Glycine	0.26	4.1	3.4-3.6
Histidine	0.24	3.4	2.9-3.2
Proline	0.24	4.6	3.8-4.1
Serine	0.12	4.9	3.3-3.7

Source: [a]Candela et al.,1997, [b]Alajaji et al., 2006, [c]Zia-Ul-Haq et al., 2007

Table 4 Comparison of amino acid composition of chickpea flour and wheat flour

Type of amino acid	Wheat flour[a]	Chickpea flour[a]	FAO[b]
Essential amino acids			
Leucine	6.96	7.59	7.14
Isoleucine	4.25	4.76	4.42
Lysine	2.14	6.00	5.50
Methionine	2.00	1.54	3.50
Cysteine	1.33	1.36	
Phenylalanine	4.48	5.57	6.80
Tyrosine	3.50	3.58	
Threonine	2.60	3.86	4.0
Valine	4.94	5.60	5.0
The total content of essential amino acids	32.20	39.89	36.36
Non-essential amino acids			

Alanine	3.94	4.88	-
Arginine	3.61	7.82	-
Aspartic acid	4.64	11.18	-
Glutamic acid	26.59	18.05	-
Glycine	3.36	4.30	-
Histidine	2.45	2.96	-
Proline	8.11	4,68	-
Serine	3.85	4.77	-
The total content of non-essential amino acids	56.55	58.64	-
The total amino acids	**88.75**	**98.53**	-

Source: [a]*Contents: g/100g proteins* (Esmat et al., 2010), [b]Pattern FAO/WHO 1985

Table 5 Carbohydrate content of chickpea (g/100g dm)

Compounds	Chickpea grains
Monosaccharides	0.32-0.97
ribose	0.03-0.19
fructose	0.23-0.28
glucose	0-0.065
Disaccharides:	
sucrose	1.09-2.28
maltose	0.16-0.68
Oligosaccharides:	3.87-6.98
raffinose	0.62-1.45
ciceritol	2.51-2.78
stachyose	0.74-2.56
verbascose	0-0.19

Source: Sánchez-Mata et al., 1998; Alajaji et al., 2006

Table 6 Mineral content of chickpea type *Desi* and *Kabuli*

Type	Minerals (mg/100g dm)						
	Ca	K	Mg	Fe	P	Zn	Mn
Desi chickpea	165.0	994.5	169.0	4.59	451.5	4.07	3.81
Kabuli chickpea	81.7	1060.0	147.0	5.50	394.0	3.40	3.28

Source: Wang et al., 2010.

Table 7 The effect of processing on anti-nutritional of chickpea grain summarized from several sources

Anti-nutritional compounds	Chickpea processing					Reference
	Raw	Boiled/ Cooked	Autoclaved	Microwave cooked	Dry heating	
Trypsin inhibitor activity (mg protein/dm)	11.90	2.11	1.92	2.32	-	Alajaji et al., 2006
Trypsin inhibitor	8.29	0.75	-	-	-	Wang et al,

activity TIA (mg/g dm)						2010
Phytic acid (mg/g)	1.21	0.86	0.71	0.75	-	Alajaji et al., 2006
Phytic acid (g/kg)	10.6	11.2	-	-	-	Wang et al, 2010
Polyphenols	3.39	1.35	-	-	-	Attia et al. (1994)
Saponin (mg/g)	0.91	0.44	0.51	0.48	-	Alajaji et al., 2006
Tannins (mg/g)	4.85	2.52	2.42	2.50	-	Alajaji et al., 2006
Total carbohydrates (g/100g dm)	56.21	-	-	-	42.51	Frias et al., 2000