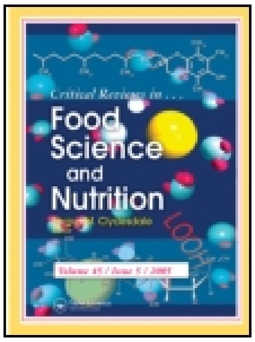

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Chickpeas—Composition, Nutritional Value, Health Benefits, Application to Bread and Snacks: A Review

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Chickpea is grain legumes grown mainly in areas with temperate and semiarid 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 antinutritional compounds that 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 an antinutritional substance present in foods, such as bread, snacks, and chips. Chickpea flour and protein may be new way to a reduce the content of acrylamide in products of this type. The addition of chickpea flour affects the sensory and textural properties.

Keywords Chickpea, nutritional composition, antinutritional factors, acrylamide

INTRODUCTION

Chickpea *(Cicer arietinum* L.) is an annual plant derived from the Fabaceae family (Nwokolo and Smartt, 1996). It is mainly grown in temperate and semiarid 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 contribute only to a small extent to total production of chickpea in the world (respectively, 1.6% and less than 1%) (Smith and Jimmerson, 2005; Menale et al., 2009). Chickpeas are reproduced from grains. Like all legumes, it enriches the soil with nitrogen and leaves it in good shape (Biggs et al., 2007). Chickpea occurs mainly in two varieties *Kabuli* and *Desi*. *Desi* chickpea grains are small, dark, and have a ridged surface. The *Desi* variety is grown mainly in semiarid land. The 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 the growing region and the conditions, which affect the length of the plant 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 327 kcal/100 g, while for *Kabuli* variety it equals 365 kcal/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 once cooked may be applied in the case of displacements of bones and dislocations, while the extract gives 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 antidandruff products. Immature grains can be eaten raw and the ripe ones 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 by sugar or spices. Chickpea grains flour is also used as an addition to pasta, soups, and bread (Sękara, 2005).

CHEMICAL COMPOSITION OF CHICKPEAS

Comparison of the Chemical Composition of 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

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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
Nonfibrous carbohydrate	49.13	46.81
Starch	39.12	38.48
Soluble sugars	8.43	7.53

Source: Maheri-Sis et al. (2008)

of protein, fat, ash, and fiber (Hulse, 1991; Khan et al., 1995). 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.

Characteristics of Chickpea Proteins and Their Biological Properties

The major proteins found in legumes belong to 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 and Dhillon 1993; Saharan and Khetarpaul, 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 of leguminous plants should be linked to obtaining in them more content of gluteins (Singh and Jambunathan, 1982).

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)..

In assessing the six varieties of chickpea Dhawan et al. (1991) showed that the protein content of these varieties ranges from 20.9 to 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%, and 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 and 89.01%, depending on the source of research results (Chitra et al., 1995; Chitra et al., 1996; Clemente et al., 1998; Prakash and Prakash, 1999; Monsoor and Yusuf, 2002; Han et al., 2007). 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 is synthetic enzyme fungus *Rhizopus sp.* which is the method used in the 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 that has not undergone this treatment (Angulo-Bejarano et al., 2008). Singh and Jambunathan (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, plant growing season, and method of analysis used by the authors (Table 3) (Maheri-Sis et al., 2008; Alajaji and El-Adawy, 2006; Zia-Ul-Haq et al., 2007).

Amino Acids Composition of Chickpea

The content of amino acids is a very important indicator of the nutritional value of foods. The content of essential amino acids (39.89 g/100 g protein) and endogenous amino acids (58.64 g/100 g protein) is significantly higher in chickpea flour than in wheat flour (32.20 and 56.55 g/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

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
Nonessential 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 and El-Adawy (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
Nonessential 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).

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 are characterized by high content of monosaccharides, disaccharides, and oligosaccharides. Major monosaccharides forming part of chickpea are: ribose, fructose, and glucose. 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 and El-Adawy, 2006).

Lipids Composition of Chickpea

The total lipid content of chickpeas ranges from 4.5 to 6.0 g oil/100 g 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 is 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

Table 5 Carbohydrate content of chickpea (g/100 g 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 and El-Adawy (2006).

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

	Minerals (mg/100g dm)						
Type	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).

to its metabolism in the tissues of the body where a production of prostaglandins takes place, which reduces blood pressure and regulates 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 and El-Adawy, 2006). Chickpea has a higher content of such manganese, zinc, and phosphorous than other legumes (Wang et al., 2010).

Antinutritional Compounds and Effect of Processing Techniques to Reduction Thereof Chickpea

Antinutritional compounds are molecules that disrupt the digestion process. The accumulation of antinutritional 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 antinutritional compounds found in pulse crops are classified into two categories: protein antinutritional components and nonprotein antinutritional components, and range in effect from relatively inoffensive polyphenols to the relatively harmful protease inhibitors. Antinutritional protein compounds are: alkaloids, phytic acid, oligosaccharides, phenolic compounds, such as tannins and saponins. Protein antinutritional compounds commonly found in legumes include lectins or agglutinins, trypsin inhibitors, chymotrypsin inhibitors, or antifungal peptide (Roy et al., 2010). Antinutritional compounds of chickpea are reduced in varying degrees when chickpea is subjected to heating processes (Table 7).

Lectins (agglutinins) are carbohydrate-binding proteins. It has been identified that there are several hundred different types of lectins present in plants. The four main groups of lectins that can be distinguished are: 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 are reported when sufficient quantities of raw grains or flour are consumed (Peumans and Van Damme, 1996). The agglutination activity of chickpea seeds as compared to the lentils and peas is much lower (400 units/g) and may vary depending on variety, growing area, and the method of collection (Singh, 1988). Scientific data have 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 (6.7–14.6 units/mg) and chymotrypsin (5.7–94 units/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 from 0 to

Table 7 The effect of processing on antinutritional of chickpea grain summarized from several sources

Antinutritional 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 and El-Adawy (2006)
Trypsin inhibitor activity TIA (mg/g dm)	8.29	0.75	—	—	—	Wang et al. (2010)
Phytic acid (mg/g)	1.21	0.86	0.71	0.75	—	Alajaji and El-Adawy (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 and El-Adawy (2006)
Tannins (mg/g)	4.85	2.52	2.42	2.50	—	Alajaji and El-Adawy (2006)
Total carbohydrates (g/100g dm)	56.21	—	—	—	42.51	Frias et al. (2000)

15 units/g (Singh, 1988). The use of, among others, ultrafiltration of chickpea flour reduces the trypsin inhibitor content. Using this 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 an extrusion procedure in kidney bean reduces the content of protease inhibitors and amylase inhibitor, and completely eliminates the activity of agglutination. In addition, the aforementioned method reduces the amount of condensed tannins and polyphenols (Marzo et al., 2002).

Another antinutritious substance present in legume beans is phytic acid, which forms weakly soluble 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, it was found that chickpea had lower phytic acid concentrations (4.9–6.1 mg/g) than kidney bean (11–17 mg/g), fava bean (10.1–13.7 mg/g), and soybean (10–14.7 mg/g) (Thavarajah et al., 2009). Other authors reported that phytic acid content is lower in chickpea and ranges from 1.38 to 1.71 mg/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., 2009). For example, subjecting the chickpea cooking under pressure reduces phytic acid content by 20% (Xu and Chang, 2009).

Antinutritive 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 to hot extrusion at 160°C can result in decrease of oligosaccharides. Also, the traditional way of cooking and microwave cooking lead to the reduction of 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. 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 1.81 mg/g of bean and the content of anthocyanin amounts to 14.9 mg/kg of bean, depending on the reagents used in extraction, extraction time, and the method of analysis used by the authors (Xu et al., 2007; Segev et al., 2010; 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 having 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, and chlorogenic. Phenolic acids are characterized by strong antioxidant properties, the 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).

The 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 (1.34 mg/g), than protein concentrates produced from defatted flour (1.48 mg/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 grain chickpeas is possible when used under traditional, autoclaving, and microwave cooking methods. The highest reduction (50.1%) of condensed tannins was obtained using microwave heating. Cooking treatments decreased the concentrations of saponins to 51.65%. All three processes caused significant decreases in trypsin inhibitor activity of 80.5–83.87% (Alajaji and El-Adawy, 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, the 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. A 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 form 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 210 mm), 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. This 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.

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 net protein utilization (NPU) 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 is carbohydrate. Isolation of protein from chickpea flour leads to a reduction in carbohydrate content from 57.88% to 10.33%, which may help in deciding on the beneficial use of the 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°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., 2008; Mottram et al., 2002). The formation of acrylamide also occurs during decarboxylation and deamination of aspartic acid (Granvogl and Schieberle, 2006). In addition, acrylamide formation was observed as a result of thermal degradation of triacylglycerols released from fats during heating of food products (Gertz and Klostermann, 2002; Mestdagh et al., 2008). The largest amounts of acrylamide are found in fried potato crisps type products (330–2,300 μg/kg), chips (300–1,100 μg/kg), fried potatoes (43–688 μg/kg), bread and baguettes (30–430 μg/kg), crisp bread (30–1,900 μg/kg), breakfast cereals (30–1,400 μg/kg), cookies and crackers (30–3,200 μg/kg), rusk (800–1,200 μg/kg), gingerbread (90–1,660 μg/kg), or biscuits and wafers (30–640 μg/kg) (Friedman and Levin, 2008).

The 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, and the addition of substances with antioxidant properties and selected amino acids.

Research conducted by Vattem and Kalidas (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 shown 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 the beneficial effect of chickpea flour may be related to the protective effect of thermally stable chickpea 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 and Kalidas, 2003).

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

Shortcrust cookies baked at 180°C for 10 min, using flour caused the generation of acrylamide in an amount of 41.9 mg/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 5.7 mg/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 and Taylor (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 and Levin, 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 the content of carbohydrates and fat and increases 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 antinutritional compounds using heat treatments that improve the nutritional value of chickpeas.

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