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An Overview of Physicochemical Composition and Methods used for Chickpeas Processing

Husnain Raza [a,b*], Farah Zaaboul [a,b], Muhammad Shoaib [a,b] and Lianfu Zhang [a,b,c,d*]
[a] State Key Laboratory of Food Science and Technology, Jiangnan University, Wuxi, Jiangsu, China.
[b] School of Food Science and Technology, Jiangnan University, Wuxi, Jiangsu, China.
[c] Beijing Advanced Innovation Center for Food Nutrition and Human Health, Beijing Technology and Business University, Beijing, China.
[d] Collaborative Innovation Center of Food Safety and Quality Control in Jiangsu Province, Jiangnan University, Wuxi, China.
*Corresponding author email id: husnain_ju@hotmail.com ; lianfu@jiangnan.edu.cn

***Abstract* – Chickpeas are a very important part of the human diet due to its nutritional and bioactive composition. They contain an ample amount of protein, carbohydrates, lipids, and fibers. Furthermore, many bioactive components, important vitamins, and minerals are also present in chickpe--as. Besides having nutritional benefits, the consumption of chickpeas always requires some processing as it has many anti-nutritive factors like trypsin and chymotrypsin inhibitors to inhibit protein digestion; α-amylase inhibitor to inhibit starch digestion; and also the phytates and oxalates to inhibit mineral absorption. Therefore, the pretreatment of chickpeas is important before consumption. The pretreatme--nts not only improve the digestibility of the chickpeas but also the bioactive and physicochemical profile. The processing treatments physical (husking, soaking, grinding or ball milling), biochemical (fermentation or germination), or a heat treatment (Roasting, extrusion, and IVDV) are discussed in this review as well as the chemical composition of chickpeas.**

***Keywords* – Chickpeas, Chemical Composition, Extrusion, IVDV, Processing Methods.**

I. INTRODUCTION

Legumes (peas, lentils, beans, soybeans, and chickpeas) are one of the most important crops due not only to their nutritional quality but also to their various agro-environmental benefits. Legume seeds and powders are important sources of protein, carbohydrates, vitamins, minerals and dietary fiber [6, 11, 38]. Food legumes suffer from an unfavorable image. And they are called "poor's meat". Changing lifestyles in favor of fast-cooking foods have made these seeds less attractive. The revival of their production through the use of Mediterranean biodiversity is of major importance. Nutritionists strongly recommend the introduction of legumes in the human diet in view of their nutritional benefits.

For health, there are many benefits associated with the consumption of legumes: Lower glycemic index for people with diabetes [55], increased satiety [26] and Prevention of Cancer [22]. Celiac disease is an autoimmune enteropathy induced by ingestion of gluten in genetically predisposed subjects [48]. This disease is currently considered as one of the most common gastrointestinal diseases. It is widespread in European countries with a prevalence of between 0.1 and 3.3‰; It also appears to be high in North Africa with 1.4% [17].

Chickpea (Cicer arietinum L.) is the 2nd largest legume in the world on the basis of total production after soybean and bean, which is mainly grown in warm climates of India, Pakistan, Iran, Ethiopia, Mexico, and Mediterranean region [7]. It is a rich legume in protein (19-29 g/100 g) [8], complex carbohydrates (60-65 g/100 g) and a source of B-complex vitamins and minerals [49]. However, even though its high protein digestibility, chickpea also contains anti-nutritional factors such as protease inhibitors, tannins, phytic acid, and saponins [57].

Taking into account its nutritional properties, chickpea powder was proposed to be used as a functional ingredient in some gluten-free bakery products such as bread, cakes, and snacks [1, 21, 31]. However, complete substitution (100%) Wheat flour by chickpea powder is difficult to reach in bakery products without affecting their quality, especially bread, where gluten is responsible for its texture. Despite the treatments applied to improve the nutritional properties of chickpea, rare information exists on the production capacity of baked goods from the resulting powders.

In the present review, we have discussed t description, physicochemical composition and industrial treatments of chickpeas.

II. DESCRIPTION

It is the second most consumed legume and the third most cultivated in the world [18]. From a nutritional standpoint, it is an excellent source of protein (18-29%), carbohydrates (59-65%), fibre (3-17%), lipids (4.5-6.6%), and Ash (2.48-3.50%) besides a very high protein digestibility where it went from 53 to 89% [8]. On the medicinal level, chickpea seed is used for its anthelmintics properties as well as for the treatment of bronchitis, leprosy, skin diseases, and liver infections. It is considered to be the most cholesterol-lowering g food compared to other legumes [59].

A. *Taxonomy and Botanical Characteristics*

Chickpea is related, in taxonomic terms, to the Papilionaceous family, genus Cicer and species Cicer arietinum L. On the botanical level, it is described as an annual, erect or creeping herb, covered with dwarf hairs. Its germination is of the hypoge type (cotyledons remain underground). The plant has a very deep root system, suitable for arid and dry areas. Its height varies between 20 and 100 cm. Its leaves are composed of 7 to 17 oval and toothed leaflets. Flowers may be white, blue or violet; solitary and stalked. The size of the pods varies from 8 to 41 mm in length and from 6 to 15 mm in width. Usually,

each pod contains one to two seeds. The weight of 100 seeds varies from less than 8g to more than 70g [15].

From the agronomic point of view, the root system of chickpea is colonized by nodules capable of fixing atmospheric nitrogen. They are due to the symbiosis of the root system with Rhizobium ciceri-type bacteria; generally present in calcareous Mediterranean soils. This symbiosis allows to bring and fix, up to 90 kg of nitrogen/ha. Therefore, there is no need for nitrogen (except in exceptional cases of nodule problem). Chickpea is a plant secreting malic acid, which induces, on the one hand, a repulsion towards insects and promotes, on the other hand, a "natural resistance" of the plant, limiting the applications of phytosanitary products.

B. *Varieties of Chickpea*

There are two types or varieties of chickpea marketed worldwide: Desi chickpea and Kabuli chickpea. The Desi variety (meaning the local variety) is characterized by small seeds, covered with a dark, thick, striated seed coat. It is grown mainly in India, Ethiopia, Mexico, and Iran. For the Kabuli variety (meaning "Kabul" variety) is distinguished by larger, clear cream-colored seeds with a fine, smooth coat. It is grown in the Mediterranean, South America, and Southeast Asia. These two varieties differ by the appearance of the seeds, but also by their chemical composition (**Table 1**), which depends on the conditions and the areas of cultivation [38].

Table 1. Chemical Composition (in %mass) of the two varieties of chickpea [30, 45].

Components	*Chickpea varieties*	
	Kabuli	*Desi*
Proteins	24.63%	22.76%
Starch	39.12%	38.48%
Lipids	6.8%	6.7%
Soluble sugar	8.43%	7.53%
Fibres	6.49%	9.94%
Tannins	0.09%	0.12%

III. Chemical Composition

A. *Protein*

Legume seeds are relatively high in protein; their content ranges from 18.5 ± 1.74/21.3 ± 0.73 depending on the species [14]. Legume proteins can be subdivided into two distinct groups: reserve proteins, and metabolic proteins (enzymatic and structural proteins). Reserve proteins are the main protein component of the mature legume seed [16]. The amino acid content is a very important indicator of the nutritional value of foods. Of all the amino acids, nine are essential and must be present in the diet [38]. Unlike animal proteins, plant proteins do not contain these essential amino acids in the required proportions [37]. The essential and non-essential amino acid content (table V) is significantly higher in chickpea powder (38.89% and 58.64% of protein, respectively) than in wheat flour (32.20 and 56.55% of protein, respectively) [4]. Chickpea proteins are rich in lysine but deficient in sulfur amino acids (methionine and cysteine), whereas cereal proteins are deficient in lysine but contain adequate levels of sulfur amino acids [38]. This complementarity provides a balance in the amino acid content that could improve the nutritional value of proteins, hence the interest of the cereal-legume association [27].

B. *Carbohydrates*

Generally, legumes contain carbohydrate content (60 to 65%), slightly lower than cereals (70-80%). Carbohydrates of legumes are mainly composed of monosaccharide, Disaccharide, Oligosaccharide, and Polysaccharide [37], which are enzymatically digested in the small intestine and (ii) unavailable (oligosaccharides, resistant starch, non-cellulosic polysaccharides, pectins, hemicelluloses and cellulose), which are not digested in the small intestine. The total carbohydrate content in chickpea is higher than pulses than other pulses. Chickpea has: (i) monosaccharides-ribose, glucose, galactose and fructose (ii) disaccharides-sucrose, maltose and (iii) oligosaccha--rides-stachyose, ciceritol, raffinose and verbascose. The amount of these fractions varies though not significantly, between desi and kabuli genotypes.

C. *Starch*

Starch (carbohydrate reserve form in plants) is the major fraction of carbohydrates in almost all legumes: ranging from 75 to 80% according to [54]. The starch molecule is composed of two polymers: amyloidosis (linear structure) and amylopectin (branched structure). The starch content of chickpea seeds is 53% MS; 35% of this content is considered to be resistant starch, and 65% of the starch available [2]. Wheat is richer in starch than a chickpea, but the latter contains a higher amyloidosis content ranging from 30 to 40% versus 25% in wheat [20]. The in vitro digestibility of starch in chickpea seeds varied between 37 and 60%, and was higher than those of other legumes such as lentils, red bean. However, this digestibility remains low compared to that of cereals (Due to the high amyloidosis content) and gives legumes a lower glycemic index [28].

D. *Fibers*

The fibers, an indigestible part of the plants in the human small intestine, they are classified as soluble and insoluble fibers. The soluble fibers (SF) are slowly digested in the colon; in contrast, insoluble fibers (IF), metabolically inert are subjected to fermentation in the colon inducing intestinal bacteria growth [53]. The total fiber content varies from 18 to 20% in [37]. Divided into 4 to 8% FS and 10 to 18% FI [12, 42].

E. *Soluble Sugars*

Chickpea seeds are characterized by high levels of monosaccharides (ribose, fructose, and glucose), disaccharides (sucrose and maltose), and Oligosaccharides (Raffinose, Ciceritol, Stachyose, and Verbascose) [3].

F. *Lipids*

The lipid content of chickpea seeds ranges from 4.5 to 6 g/100 g of Sample. This content is high compared to other protein and cereal grains: lentils (1.06%), red bean (1.06%), mung bean (1.15%), pigeon pea (1.64%), wheat (1.70%) and rice (0.60%) [8; 23]. Lipids of chickpea seeds are characterized by their high content of essential unsaturated fatty acids: linoleic acid (54,7-56,2% mg), oleic acid (21.6-22.2% mg) and linolenic acid (0.5-2.35%

mg), as well as saturated fatty acids such as Palmitic acid (18.9-20.4% mg) and stearic acid (1.3-1.7% mg) [38].

G. *Minerals and Vitamins*

Potassium (K), phosphorus (P), copper (Cu), iron (Fe), calcium (Ca) and magnesium (MG) are the main minerals contained in legume seeds [5]. Chickpea is a significant source of Ca, Mg, Fe, and K, the Mn, Zn, and P levels were higher in it compared with other legumes [56]. A ration of 100 g of chickpea, can provide the recommended daily intake of Fe (1.05 mg for homes and 1.46 mg for women), and zinc (4.2 mg and 3 mg), while consumption of 200 g chickpeas will provide the recommended daily intake (260 mg and 220 mg) in Mg [23]. Legumes are also a good source of vitamins, especially group B, including Thiamine (B1), riboflavin (B2), niacin (B3), pantothenic acid (B5), pyridoxine (B6) and folic acid (B9). Chickpea is significantly richer in folic acid and vitamin E compared to other legumes [37].

H. *Polyphenols*

Polyphenols are a class of chemical compounds that are characterized by the presence of a hydroxyl group (OH) directly linked to an aromatic group (Wang et al., 2010). They are mainly located in the outer envelope of the legume seed [54]. The dominant phenolic compounds in legumes are phenolic acids, tannins, and flavonoids [10]. The total phenol content in the chickpea seed ranged from 0.72 to 1.81 mg/g, and anthocyanin content was 14.9 mg/kg. These values vary according to the extraction and dosing methods used [38]. Chickpea is characterized by its low level of polyphenols and anthocyanins compared to other legumes such as bean and lentil, which is reflected by its low capacity to trap free radicals, thus by a low antioxidant capacity [50].

I. *The Anti-nutritional Factors*

Anti-nutritional factors are the compounds that reduce the nutritional value of foods. For example, they may reduce the bioavailability of certain compounds or inhibit enzymes necessary for digestion. In legumes, there are several anti-nutritional factors such as anti-tryptic, alpha-galactosides and Phytate [44]. These anti-nutritional factors can be subdivided into protein and non-protein factors. Nonprotein factors include tannins, saponins, phytic acid, and oligosaccharides, while the protein factors are principally lictines, trypsin inhibitors and chymotrypsin inhibitors.

IV. Processing Treatments

Chickpeas are seldom consumed raw. They are subject to various treatments, according to traditional practices and taste preferences. Several authors have reported the interest of treatments (Physical, biochemical and thermal) in the reduction and elimination of the ant-nutritional factors, and in the improvement of their digestibility [25].

V. Physical Treatment

A. *Husking*

The legume seed coat is important for the protection of the seed against physical damage, pests, infections and early germination. It is mainly composed of cellulose, lignin, polyphenols, and minerals [51]. The husking of the seed decreases the fiber content; therefore, proportionately, the content of other nutrients increases, and thus improves the nutritional value compared to the whole seed. The majority of tannins (79 to 86%) are located at the seed coat, and by shelling, 75 to 93% of the tannin content is eliminated [40]. However, this process does not eliminate the anti-nutritional factors thermo labile (protease inhibitors, α-galactosides, and lectins).

B. *Grinding*

Grinding is a mechanical treatment that reduces food to finer-sized particles. This process induces a deterioration of starch granules, which become more susceptible to enzymatic hydrolysis. Also, the mineral content (calcium, iron, and zinc) decreases significantly in the resulting powders. The grinding improves the digestibility of the starch and nevertheless decreases that of the proteins [52].

C. *Soaking*

Soaking is often done before or conjugated with other treatments such as germination, fermentation, baking, and canning. It allows the seeds to soak in water inside its cells, and to inflate as a result of hydration. This phenomenon induces leaching of soluble molecules such as monosaccharides, disaccharides, oligosaccharides, soluble polyphenols, and phytic acid. The soaking (overnight) seed of chickpea, decreases 53% of tannins [40]. According to [47], this treatment improves the digestibility of starch, and reduces the content of proteins, phenols and protease inhibitors.

D. *Ball Milling*

Size reduction has achieved a great interest in food and pharmaceutical industry due to various benefits provided by the reduced sized particles. After sieving, the materials could be divided into the mixture of particles ranging from a very fine to large particles based on particle size distribution. The properties of a food material can be changed due to its particle size distribution. According to researchers, the properties of powder are mainly dependent on its chemical composition.

Due to greater effect of milling on food properties, the improvements in the equipment for grinding are made, and ball-milling has got great importance in making very fine powders without damaging the physicochemical characteristics of the food material compared with traditional milling or grinding. In the planetary ball milling, various types and size of balls are used, and the speed and time of milling can be controlled, based on the type of food material.

Despite the benefits of ball milling, very few literatures is available to discuss the importance of ball milling in foods. The changes in the composition due to particle size distribution are being widely considered for food industries [39, 43].

VI. Biochemical Treatments

A. *Fermentation*

The fermentation process is a traditional practice in India and in some African countries. This treatment has

many advantages such as reducing the risk of development of pathogenic microorganisms by acidification of the environment, degradation of certain anti-nutritional factors (phytate and α-galactosides), development of the organoleptic quality by synthesis of organic acids and aromas in the fermented product [36]. The fermentation gives an optimum pH to the phytases present in the seeds, inducing their activation and a decrease of the phytate contents. This process increases the levels of vitamins (thiamin, riboflavin, niacin, ascorbic acid), protein and amino acids, and improves protein digestibility [46].

B. *Germination*

Germination is the cause of many biochemical changes in legume seeds. It improves their nutritional quality by increasing the content of vitamins (ascorbic acid, riboflavin, niacin, tocopherols, thiamine, and pantothenic acid), and by reducing the anti-nutrients content (tannins, phytic acid and α-galactosides). This process also improves protein and starch digestibility [29, 54]. The study was conducted to understand the usefulness of germination under mineral stress for a specific period to not only increase the content of isoflavones and minerals but also the functional properties of chickpeas. The profound increase in the content of isoflavones was found after sprouting the chickpea seeds for 5-7 days under minerals stress [41].

VII. Heat Treatments

A. *Roasting*

Roasting is an essential operation and one of the most frequent processing processes for seeds [9, 32]. It is intended to increase the palatability of the product and it significantly promotes the development of color, flavor, texture, and appearance of seeds [58]. The resulting product is refined and highly appreciated by the consumer in comparison to raw seeds. Roasting also destroys unwanted microorganisms and inactivates the enzymes that promote deterioration of the product during storage [9]. This treatment allows the preservation of nutrients, as it is a dry treatment compared to the wet cooking that causes leaching. Roasting reduces the levels of oligosacch--arides. However it reduces the in vitro digestibility of proteins and starch (formation of resistant starch), and decreases the content of riboflavin, thiamine, and niacin [19, 24].

B. *Extrusion*

Extrusion is an efficient thermal processing technique used for the foods with higher starch content or in the processing of protein-fortified food [13]. In extrusion processing, the food material in a viscous form is forced through a die where it expands to a porous structure. The process of extrusion provides unique textural properties to a material due to high temperature and shear. During the process of extrusion, many biochemical transformations take place, like protein denaturation, starch gelatinization, browning, and destruction of anti-nutritional components.

C. *Intensification of Vaporization by decompression to the Vacuum (IVDV)*

Recently, a newly emerged process, known as IVDV (i--ntensification of vaporization by decompression to the vacuum) is being used as a texturizing pre-treatment. This technique allows rapid compression for thermo sensitive food material under high pressure for a few seconds. IVDV technique provides the excellent opportunity as potential pre-treatment method to bring the modification of structural features of raw chickpeas to prepare them for further unit operations or treatments [33, 34].

In the processing through IVDV, the rehydrated and homogenized chickpeas are placed in the processing chamber; where the initial vacuum is established by a subject of pressure drop from atmospheric to vacuum pressure. The purpose of an initial vacuum is better to steam diffusion and improved heat transfer in the chickpeas. After this, the chickpeas were treated with high pressure (up to 15 bar) steam for a short time of around 1-200 s. This process is important for the sample to attain the required rheological and thermal equilibrium for expansion. The final stage of the process includes the instant pressure release towards the vacuum that could be 1mbar. This instant pressure release is responsible for auto-vaporization of the internal water content in the chickpeas, and instant cooling which protects the product from thermal degradation while providing the porous structure. Finally, the chickpeas were rehydrated in an oven at 50 °C for 24 h followed by roasting at 200 °C for 6 minutes using electric seed roasting machine.

The use of extrusion has recently increased to produce foods and food products like breakfast cereals, poultry, and meat, ready to eat snacks, baby foods and some modified starches. Intense mechanical shear used during the extrusion makes it a unique heat treatment as it moistens the food having an abundant quantity of starch and proteins making them viscous and elastic, and the food is cooked before being forced through the die [35].

VIII. Conclusion

The composition of chickpeas provides the importance of this legume for the food industry. Besides providing an ample amount of protein and starch, it is also a good source of many bioactive components like isoflavones. The processing treatments are essential for chickpeas and can destroy the anti-nutritional factors. Besides, there are many new technologies available, which are further decreasing the processing time for chickpeas. This review provides an insight into the different processing used for chickpea. Further research is needed to use these processing parameters to know their effect on different functional, compositional and physicochemical properties.

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REFERENCES

[1] Aguilar, N., Albanell, E., Minarro, B. and Capellas, M. 2015. Chickpea and tiger nut flours as alternatives to emulsifier and shortening in gluten-free bread. *Lwt - Food Science and Technology*, 62 (1), 225-232.

[2] Aguilera, Y., Martín-Cabrejas, M.A., Benítez, V., Mollá, E., López-Andréu, F.J. and Esteban, R.M. 2009 Changes in carbohydrate fraction during dehydration process of common legumes. *Journal of Food Composition and Analysis*, 22 (7-8), 678-683.

[3] Alajaji, S.A. and Eladawy, 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 (8), 806-812.

[4] Arab, E.A., Helmy, I. and Bareh, G. 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.

[5] Aykroyd, W.R., Doughty, J. and Walker, A.F. 1982. *Legumes in human nutrition*. Food & Agriculture Org.

[6] Baljeet, S.Y., Ritika, B.Y. and Reena, K. 2014. Effect of incorporation of carrot pomace powder and germinated chickpea flour on the quality characteristics of biscuits. *International food research journal*, 21 (1), 217-222.

[7] Bar-El Dadon, S., Pascual, C.Y. and Reifen, R. 2014. Food allergy and cross-reactivity-chickpea as a test case. *Food chemistry*. *165*, 483-488.

[8] Boye, J.I., Zare, F. and Pletch, A. 2010. Pulse proteins: Processing, characterization, functional properties and applications in food and feed. *Food Research International*, 43 (2), 414-431.

[9] Buckholz JR, L.L., Daun, H., Stier, E. and Trout, R. 1980. Influence of roasting time on sensory attributes of fresh roasted peanuts. *Journal of Food Science*, 45 (3), 547-554.

[10] Campos-Vega, R., Loarca-Piña, G. and Oomah, B.D. 2010. Minor components of pulses and their potential impact on human health. *Food research international*, 43 (2), 461-482.

[11] Costa, G.E.D.A., Queirozmonici, K.D.S., Reis, S.M.P.M. and De Oliveira, A.C. 2006. Chemical composition, dietary fibre and resistant starch contents of raw. and cooked pea, common bean, chickpea and lentil legumes. *Food Chemistry*, 94 (3), 327-330.

[12] Dalgetty, D.D. and Baik, B. 2003. Isolation and Characterization of Cotyledon Fibers from Peas, Lentils, and Chickpeas. *Cereal Chemistry*, 80 (3), 310-315.

[13] Day, L., and Swanson, B.G. 2013. Functionality of protein-fortified extrudates. *Comprehensive Reviews in Food Science and Food Safety*. *12*(5), 546-564.

[14] de Almeida Costa, G.E., da Silva Queiroz-Monici, K., Pissini Machado Reis, S.M. and de Oliveira, A.C. 2006. Chemical composition, dietary fibre and resistant starch contents of raw and cooked pea, common bean, chickpea and lentil legumes. *Food Chemistry*, 94 (3), 327-330.

[15] De Falco, E., Imperato, R., Landi, G., Nicolais, V., Piccinelli, A.L. and Rastrelli, L. 2010. Nutritional characterization of Cicer arietinum L. cultivars with respect to morphological and agronomic parameters. *Emirates Journal of Food and Agriculture*, 22 (5), 377-387.

[16] De Shpande, S. and Nielsen, S. 1987 In vitro enzymatic hydrolysis of phaseolin, the major storage protein of Phaseolus vulgaris L. *Journal of Food Science*, 52 (5), 1326-1329.

[17] Denery-Papini, S., Popineau, Y. and Guéguen, J. 2008. Implication des protéines de céréales dans la maladie cœliaque.

[18] Dodok, L., Ali, M.A., Hozova, B., Halasova, G. and Polacek, I. 1993. Importance and utilization of chickpea in cereal technology. *Acta Alimentaria*, 22 (2), 119-129.

[19] Geervani, P. and Theophilus, F. 1980. Effect of home processing on the nutrient composition of certain high yielding legume varieties. *Indian Journal of Nutrition and Dietetics*, 17 (12), 443-446.

[20] Guillon, F. and Champ, M.-J. 2002 Carbohydrate fractions of legumes: uses in human nutrition and potential for health. *British Journal of Nutrition*, 88 (S3), 293-306.

[21] Han, J., Janz, J.A.M. and Gerlat, M. 2010. Development of gluten-free cracker snacks using pulse flours and fractions. *Food Research International*, 43 (2), 627-633.

[22] Hangen, L. and Bennink, M.R. 2002. Consumption of Black Beans and Navy Beans (Phaseolus vulgaris) Reduced Azoxymethane-Induced Colon Cancer in Rats. *Nutrition and Cancer*, 44 (1), 60-65.

[23] Jukanti, A.K., Gaur, P.M., Gowda, C. and Chibbar, R.N. 2012. Nutritional quality and health benefits of chickpea (Cicer arietinum L.): a review. *British Journal of Nutrition*, 108 (S1), S11-S26.

[24] Kelkar, M., Shastri, P. and Rao, B. 1996. Effect of processing on in vitro carbohydrate digestibility of cereals and legumes. *Journal of food science and technology. Mysore*, 33 (6), 493-497.

[25] Khattak, A.B., Zeb, A. and Bibi, N. 2008. Impact of germination time and type of illumination on carotenoidcontent, protein solubility and in vitro protein digestibility of chickpea (Cicer arietinum L.) sprouts. *Food chemistry*, 109 (4), 797-801.

[26] Leathwood, P.D. and Pollet, P. 1988. Effects of slow release carbohydrates in the form of bean flakes on the evolution of hunger and satiety in man. *Appetite*, 10 (1), 1-11.

[27] Livingstone, A.S., Feng, J.J. And Malleshi, N.G. 1993 Development and nutritional quality evaluation of weaning foods based on malted, popped and roller dried wheat and chickpea. *International journal of food science & technology*, 28 (1), 35-43.

[28] Madhusudhan, B. and Tharanathan, R.N. 1996. Structural studies of linear and branched fractions of chickpea and finger millet starches. *Carbohydrate Research*, 284 (1), 101-109.

[29] Mahadevamma, S. and Tharanathan, R. 2004. Processing of legumes: resistant starch and dietary fiber contents. *Journal of Food Quality*, 27 (4), 289-303.

[30] Maheri-Sis, N., Chamani, M., Ali-Asghar, S., 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 (16).

[31] Minarro, B., Albanell, E., Aguilar, N., Guamis, B. and Capellas, M. 2012. Effect of legume flours on baking characteristics of gluten-free bread. *Journal of Cereal Science*, 56 (2), 476-481.

[32] Moss, J. and Otten, L. 1989. A relationship between colour development and moisture content during roasting of peanuts. *Canadian Institute of food science and technology journal*, 22 (1), 34-39.

[33] Mrad, R., Debs, E., Saliba, R., Maroun, R.G. and Louka, N. 2014a. Multiple optimization of chemical and textural properties of roasted expanded purple maize using response surface methodology. *Journal of Cereal Science*. *60*(2), 397-405.

[34] Mrad, R., Rouphael, M., Maroun, R.G. and Louka, N. 2014b. Effect of expansion by "Intensification of Vaporization by Decompression to the Vacuum"(IVDV) on polyphenol content, expansion ratio, texture and color changes of Australian chickpea. *LWT-Food Science and Technology*. *59*(2), 874-882.

[35] Nikmaram, N., Leong, S.Y., Koubaa, M., Zhu, Z., Barba, F.J., Greiner, R. and Roohinejad, S. 2017. Effect of extrusion on the anti-nutritional factors of food products: An overview. *Food Control*. *79*, 62-73.

[36] Nout, M. and Sarkar, P. 1999. Lactic acid food fermentation in tropical climates. In *Lactic Acid Bacteria: Genetics, Metabolism and Applications*, Springer, pp. 395-401.

[37] Oomah, B.D., Patras, A., Rawson, A., Singh, N. and Compos-Vega, R. 2011 Chemistry of pulses. *Pulse foods: processing, quality and nutraceutical applications*, 9-55.

[38] Rachwarosiak, D., Nebesny, E. and Budryn, G. 2015 Chickpeas Composition, Nutritional Value, Health Benefits, Application to Bread and Snacks: A Review. *Critical Reviews in Food Science and Nutrition*, 55 (8), 1137-1145.

[39] Ramadhan, K., and Foster, T.J. 2018. Effects of ball milling on the structural, thermal, and rheological properties of oat bran protein flour. *Journal of Food Engineering*. *229*, 50-56.

[40] Rao, P.U. and Deosthale, Y.G. 1982. Tannin content of pulses: Varietal differences and effects of germination and cooking. *Journal of the Science of Food and Agriculture*, 33 (10), 1013-1016.]

[41] Raza, H., H. R. Sharif, F. Zaaboul, M. Shoaib, W. Aboshora, B. Ali and L. Zhang. 2019. Effect of chickpeas (cicer arietinum) germination under minerals stress on the content of isoflavones

and functional properties. *Pakistan Journla of Agricultural Sci*ences. 56(x),xxx,xxx; 2019. doi: 10.21162/pakjas/19.7844

[42] Rincon, F., Martinez, B. and Ibanez, M.V. 1998. Proximate composition and antinutritive substances in chickpea (cicer arietinum L) as affected by the biotype factor. *Journal of the Science of Food and Agriculture*, 78 (3), 382-388.

[43] Roa, D.F., Santagapita, P.R., Buera, M.P. andTolaba, M.P. 2014. Ball milling of Amaranth starch-enriched fraction. changes on particle Size, starch crystallinity, and functionality as a function of milling energy. *Food and bioprocess technology*. *7*(9), 2723-2731.

[44] 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 (2), 432-442.

[45] Sanjeewa, W.G.T., Wanasundara, J.P.D., Pietrasik, Z. and Shand, P.J. 2010. Characterization of chickpea (Cicer arietinum L.) flours and application in low-fat pork bologna as a model system. *Food Research International*, 43 (2), 617-626.

[46] Sanni, A.I., Onilude, A.A. and Ibidapo, O.T. 1999. Biochemical composition of infant weaning food fabricated from fermented blends of cereal and soybean. *Food chemistry*, 65 (1), 35-39.

[47] Saxena, A.K., Chadha, M. and Sharma, S. 2003. Nutrients and antinutrients in chickpea (Cicer arietinum L.) cultivars after soaking and pressure cooking. *Journal of Food Science and Technology-mysore*, 40 (5), 493-497.

[48] Schmitz, J. and Garnier-Lengliné, H. 2008. Diagnostic de la maladie cœliaque en 2008. *Archives de pédiatrie*, 15 (4), 456-461.

[49] Seena, S., Sridhar, K. and Jung, K. 2005. Nutritional and antinutritional evaluation of raw and processed seeds of a wild legume, Canavalia cathartica of coastal sand dunes of India. *Food Chemistry*, 92 (3), 465-472.

[50] 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.

[51] Singh, U. 1984. Dietary fiber and its constituents in Desi and Kabuli chickpea (Cicer arietinum L.) cultivars. *Nutrition reports international*, 29 (2), 419-426.

[52] Tan, Y. and Phillips, R.D. 1991. Effect of the hard-to-cook defect and processing on protein and starch digestibility of cowpeas. *Cereal Chemistry*, 68 (4), 413-418.

[53] Tosh, S.M. and Yada, S. 2010. Dietary fibres in pulse seeds and fractions: Characterization, functional attributes, and applications. *Food Research International*, 43 (2), 450-460.

[54] Uebersax, M. and Occena, L. 2003. LEGUMES| Legumes in the Diet.

[55] Viswanathan, M., Indira, P., Sherry, J., Snehalatha, C., Mohan, V. and Kymal, P.K. 1989 Responses to legumes in NIDDM subjects: lower plasma glucose and higher insulin levels. *Nutrition reports international*, 40 (4), 803-812.

[56] Wang, N., Hatcher, D., Tyler, R., Toews, R. and Gawalko, E. 2010. Effect of cooking on the composition of beans (Phaseolus vulgaris L.) and chickpeas (Cicer arietinum L.). *Food Research International*, 43 (2), 589-594.

[57] Xu, Y., Cartier, A., Obielodan, M., Jordan, K., Hairston, T., Shannon, A. 2016. Nutritional and anti-nutritional composition, and in vitro protein digestibility of Kabuli chickpea (Cicer arietinum L.) as affected by differential processing methods. *Journal of Food Measurement and Characterization*, 10 (3), 625-633.

[58] Zaaboul, F.H. Raza, C., Cao and L. Yuanfa. 2019. The impact of roasting, high pressure homogenization and sterilization on peanut milk and its oil bodies. *Food Chemistry*. 280:270-277.

[59] Ziaulhaq, 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 (4), 1357-1363.

AUTHORS PROFILE'

First A. Author
The first author is currently a PhD Scholar in Food Science & Technology at Jiangnan Unviersity, Wuxi, China. The author has several publications in SCI indexed journals with expertise in food processing and functional food. The researchgate score of the author is 19.21 with over 10000 reads of full articles and 90 citat--ions.

The second author is currently a research fellow at Jiangnan University, Wuxi, China. Author has a good profile for publication in the field of food science specifically on lipids science and technology.

The third author is also a PhD scholar at School of Food Science and Technology, Jiangnan University. The author has a good profile in research field with 100 plus citations and several publications in the field of food science.

The 4th author is a professor at School of Food Science and Technology, Jiangnan University, Wuxi, Jiangsu, China and has several other linkages for research projects with Collaborative Innovation Center of Food Safety and Quality Control in Jiangsu Province, Jiangnan University, Wuxi, China and Beijing Advanced Innovation Center for Food Nutrition and Human Health, Beijing Technology and Business University, Beijing, China.