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EDITORIAL

Pulses: an overview

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Pulses are an important source of nutrition for billions of people around the world. The terms "legumes" and "pulses" are interchangeable because all pulses are considered legumes but not all legumes are considered pulses. Pulses belong to leguminoseae family and include those species that are consumed by human beings and domestic animals, commonly in the form of dry grains and does not include groundnut (*Arachis hypogaea*) and soybean (*Glycine max*) which are grown mainly for edible oil. The Food and Agriculture Organization of the United Nations has declared 2016 as the International Year of Pulses with aims to enhance public awareness of the nutritional benefits of pulses as part of sustainable food production. This was intended towards global food security and nutrition. The Year of 2016 was expected to generate a distinct opportunity to encourage associations all over the food chain for better utilization of pulse-based proteins, increase global production of pulses, crop rotations and address the challenges in the trade of pulses. Pulse grains are an excellent source of protein, carbohydrates, dietary fibre, vitamins, minerals and phytochemicals. Large number of people in the world consumes pulses as staple food in combination with cereals and depends on them for meeting their protein requirement. The high lysine and folate content makes pulses perfect for making the composite flours with cereals. Pulses and cereal grains have similar total carbohydrate, fat, niacin, riboflavin, thiamine and vitamin B_6 contents. However, pulses has higher protein, folate, iron, magnesium, potassium and zinc content that cereals. Traditional sources of proteins including animal were considered superior both nutritionally and functionally; however, utilizing animals as source of proteins raised many ethical issues. Moreover, it cannot be continued to be used as a sole source of protein to meet the growing need for proteins due to increasing population. Therefore, interest in pulses due to their high protein content compared to cereal grains is growing. These are second most consumed food crop after cereals in world. They are important food source for poor people especially those living in developing and under developed nations.

Pulses contain approximately 21–25% protein; however have limiting amount of essential amino acids such as methionine, tryptophan and cystine (Tiwari and Singh 2012). The protein content and amino acid composition vary with the variety, germination, environment and application of fertilizers. The protein content in pulses is almost double than that found in cereals. Pulse proteins were classified into two major fractions viz albumin and globulin. Globulins are the major storage proteins in pulse seeds constituting 35–72% of total protein and the remaining protein fraction mainly consists of albumins. Globulin proteins have higher amount of glutamine aspartic acid, arginine and lysine (Dahl et al. 2012). Albumins usually have physiological role present in low amount than globulins constituting only up to 15–25% of total seed protein (Casey et al. 1998; Machuca 2000). The albumins have higher amount of cystine, methionine and lysine contents as compared to globulin fractions in beans (Marquez and Lajolo 1981). Globulins have highly packed rigid structure due to the presence of disulfide bonds and hydrophobic interactions (Utsumi 1992). Among the four major classes of protein in pulses, albumins are unique due to their solubility in water (Bean and Lookhart 2001). Because of solubility, albumins were capable of interacting

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and competing with starch for water. Pulse protein has poor digestibility that is the major nutritional constraint in their utilization in weaning food formulations. Digestibility is measured to determine the susceptibility of proteins to proteolysis and is an indicator of protein availability. Highly digestible proteins are more desirable since these provide more amino acids for absorption on proteolysis, therefore, has better nutritional value than those of low digestible proteins. Functional properties, such as foaming properties, water and oil absorption capacities, emulsification and solubility determine the suitability of proteins to be used as hydrocolloids in food formulations (Kinsella and Phillips 1989). Globulins from lentils and horsegram were shown to have better digestibility as compared to albumins due to presence of lower cystine content and hence less number of disulphide bonds as compared to albumins. The digestibility of proteins varies with characteristics of starch. An increase in protein digestibility of albumins and globulins was observed in the presence of starch that was related to the opening of compact protein structure on binding to the surface of starch granules and forming new bonds that resulted into easier access to the proteolytic enzymes (Ghumman et al. 2016).

Carbohydrate content in pulses is 60–65% and starch constitutes the major fraction of the carbohydrates. Pulse starch is consisted of amylose and amylopectin, and wide variation in amylose content in pulse starches has been reported (Tiwari and Singh 2012). Starches from various pulses have different physicochemical, pasting and technological properties (Singh et al. 2008). Pastes formed from pulse starches were found to have high retrogradation tendency and are hard to swell and rupture during cooking as compared to cereal starches (Singh et al. 2008; Singh 2010). Their high stability towards mechanical shearing and heat makes them useful in number of food application and were considered to be a good alternate to replace cross-linked starches (Singh 2010). The tendency to retrogradation in pulse starches dependent on the amylose content. Higher retrogradation tendency of pulse starches make them resistant towards the action of digestive enzymes resulting in the reduction of glycemic index (Singh 2010). Hence, pulse starch is useful ingredient for developing products for diabetic patients. Pulse grains hulls are rich source of water-insoluble fibres and polyphenols (having high antioxidant activities), while cotyledons contain higher soluble fibres, slowly digestible and resistant starch as well as oligosaccharides (Singh et al. 2017). The presence of oligosaccharides (raffinose, stachyose, verbascose and ciceritol) in pulses also limits their utilization. These oligosaccharides were known as flatus-producing carbohydrates due to the presence of α-galactosidic bonds. The human body lacks the α-galactosidase that are required to break these bonds and hence these carbohydrates remained undigested in the human intestine. The anaerobic fermentation of undigested carbohydrates led to the production of H_2, CO_2 and traces of CH_4. These gases caused abdominal discomfort and excessive consumption of these carbohydrates may lead to diarrhea (Sefa-Dedeh and Stanley 1979).

Pulses are rich source of many vitamins and minerals (iron, zinc, calcium, magnesium). The deficiency of various minerals in different parts of the world led to cardiovascular disease and imbalance in majority of the biological pathways. Pulses can provide adequate minerals required to fulfill nutritional requirement. Phenolic compounds are grouped into phenolic acids, tannins and flavonoids. Phenolic compounds and antioxidant activity also varied among different varieties of pulses. Dark colored and pigmented pulses tend to have more phenolic content as compared to light colored varieties. The presence of phenolics and flavonoids in the grain especially in the hull also vary with the color of grain. Interaction of these phenolics with different grain components (starch and protein) imparts different properties to grain and its products. Polyphenols and flavonoids have anti-tumoral, anti-platelet, anti-inflammatory and anti-allergic properties. They are highly useful for prevention of lipid peroxidation and scavenging free oxygen radicals due to their high antioxidant activities thus improving the stability of foods and protecting living systems against oxidative damage (Vazquez et al. 2008). Many studies have suggested that antioxidant capacity was positively correlated with phenolic content of pulses, which was higher in lentil, black beans and red kidney beans (Xu and Chang 2008). The ferulic acid was the most abundant phenolic compound followed by *p*-coumaric acid and sinapic acid in common beans (Luthria and Pastor-Corrales 2006). Pulses are consumed as whole seeds and split-dehusked *dhals*. The phenolics compounds are concentrated in hull portion of the pulses. Milling of pulses to produce the *dhals* led to the reduction in phenolic compounds. Pulses consumption are especially recommended for reducing the risks of chronic diseases such as obesity, coronary heart diseases, type-2-diabetes, etc. The utilisation of pulses in the form of flours has been reported to satisfy the nutritional requirements of a large portion of population in developing countries.

Besides having lots of healths benefits, pulses are also have antinutritional factors such as phytate, enzyme inhibitors (trypsin inhibitors, chymotrypsin inhibitors, and α-amylase inhibitors), polyphenolics (including tannins), lectins, and saponins. These antinutrients impart hindrance in many biochemical pathways. Pulses were reported to have low digestibility owing to the presence of anti-nutrients which inhibit enzymes involved in digestion and reduces bioavailability of nutrients. Among anti-nutritional factors, phenolic compounds interfere with the digestibility of the proteins in human body. They are considered to be highly reactive and bind reversibly as well as irreversibly with proteins, leading to lower digestibility and bioavailability of amino acids. Tannins are mainly concerned with the defence mechanism in plants and have the capability to chelate with metal ions (Carbonaro et al. 1996) and forming hydrogen bonds with proteins (Beebe et al. 2000). Hence, reduces mineral absorption and digestibility of proteins (Reddy and Butler 1989). Tannins also contribute towards the reduction in nutritional value of pulses by complex formation with starch or its digestive enzymes and reduced palatability because of undesirable astringency (Chung et al. 1998). Antinutritional factors in pulses also include phytic acid which is a potent chelator of metal ions and forms irreversible complexes with proteins and minerals (Cheryan and Rackis 1980).

Pulses are less acceptable due to the presence of typical flavor, which is sometimes considered as off flavor by many consumers, that is inherent/produced during harvesting, processing and storage (Roland et al. 2017). Generally, volatile off-flavor compounds in pulses belong to the categories of aldehydes, alcohols, ketones, acids, pyrazines and sulfur compounds. The off-taste also has been associated to the presence of saponins, phenolic compounds and alkaloids. No systematic studies have been performed on the identification of the off-flavor compounds present in pulses in relation to their contribution to the overall perception of the pulses and their products. The major factor that limits the use of pulses as ingredient in food products is presence of off-flavor imparting chemicals. Many pulses impart flavor that are obstacle to the consumption and utilization of pulses and pulse based products in different food formulations. For example, the objectionable flavor of pea proteins hinders the wide application in food products. The inherent off-flavor imparting chemicals in pulses are modified or eliminated during processing. The development of off-flavor can be diminished by implying appropriate processing to the pulses. The oxidation of unsaturated fatty acids also lead to the development of off-flavor in pulses. The thermal degradation of phenolic acids and thiamine and formation Maillard products during heating of amino acids and sugars also led to the formation of off-flavors (MacLeod et al. 1988). Oxidation together with thermal degradation of cartenoids also contributes to the off-flavor development in pulses. Lipoxygenase catalyzed degradation of polyunsaturated fatty acids attributed to the off-flavor formation. The off-flavor development in pulses varies with storage conditions, cultivar and growing locations. The saponin content was related to the bitterness of peas (Heng et al. 2006). While, phenolics such as caffeic acid, vanillic acid, *p*-coumaric acid and ferulic acid were reported to be responsible to the astringent character in pulses whereas ethyl esters of these phenolics were related to bitterness (Hufnagel and Hofmann 2008). The variation in these off-flavor contributing compounds in different varieties of pulses grown in different agro-climatic conditions and soils has not been studied in depth. Since, the pulses vary in protein, starch and fat composition, therefore, the retention and adsorption in these may differ significantly. Various pulses are processed by different methods and their effects on the retention and degradation of off-flavors cannot be ruled out. The detailed studies in this context are also required.

The utilization of pulses is obstructed by the presence of harder-to-cook (HTC) grains. The development of this defect was associated mainly with the prolonged storage in high temperature and humidity (Liu and Bourne 1995; Reyes-Moreno et al. 2000). HTC defect in grains led to the loss of their ability to soften during soaking and made the cell separation as well as starch gelatinization difficult during cooking (Liu and Bourne 1995). Various factors contribute to this defect including seed size, ripening degree, genetic factor and environmental factors while the most important is the storage of the grains in adverse conditions after harvesting (Prihayati et al. 2011). Different hypothesis have been given for the development of HTC defect in pulses which include (1) phytate-cation-pectin model, (2) β-eliminative degradation of pectin and lignifications of cell wall (Liu and Bourne 1995). Interaction between phytate, mineral cations and pectin was the most acceptable hypothesis. This defect adversely affects the nutritional quality along with high energy requirements and longer cooking duration that results in their constrained acceptability by the consumer (Tuan and Phillips 1991; Ruiz-Ruiz et al. 2012). Prolonged storage of black beans in adverse conditions revealed its negative relationship with protein digestibility and solubility (Molina et al. 1976; Antunes et al. 1979). Both enzymatic as well as non-enzymatic reactions that contribute towards this defect, simultaneously leads to the toughness in grains (Reyes-Moreno and Paredes-Lopez 1993). Reports have also been found which includes the protein denaturation and pectin insolubilization leading to the inability of grains to soften during cooking. Limited inter as well as intra-cellular water availability was also attributed of this defect (Hincks and Stanley 1987). β-eliminative degradation of pectin is also one of the most important factor which results in the HTC defect. Being sensitive towards the increase in temperature, pectin undergoes degradation via breakdown of glycosidic bonds in the affinity of carboxyl group causing the formation of low molecular weight products. To avoid the development of this defect it is very important to store the pulses in proper environment conditions. Protein concentrates, starch fractions and fiber rich fractions from HTC grains can be produced using wet fractionation methods (Chel-Guerrero et al. 2002). These concentrates were reported to have low trypsin inhibitor activity and also meets FAO recommendations for essential amino acid content for adults (Morales de leon et al. 2007). Moreover, the proteins from HTC grains had higher amount of β-sheets structures which resulted in higher stability of paste formed (Parmar et al. 2017).

Pulses are also being used by the processors worldwide for developing canned products as they are ready to use and the demand is expected to increase as they are having high shelf life (Warsame and Kimani 2014). Varieties with ease of preparation, processing efficiency and high yield of raw product were mostly preferred by the processors for thermal processing (Wassimi et al. 1990; Hosfield et al. 2000). Pulse varieties with uniform size and rapid expansion during soaking, high water holding capacity during processing and less splitting are required to be developed for canning. The effects of conventional processing methods (soaking, dehulling, boiling, pressure cooking, germination, fermentation etc.) on the levels of anti-nutritional factors (phytate, protein inhibitors, phenolics, tannins, lectins, saponins etc.) have been extensively evaluated, however, novel methods to eliminate these needs to be developed (Patterson et al. 2017). Canning of pulses also reported to decrease phenolic content (Parmar et al. 2016). Though the pulses are used in number of indigenous products but their functional attributes and potential health benefits have not been fully explored.

References

Antunes PL, Sgarbieri VC, Garruti RS (1979) Nutrification of dry bean (*Phaseolus vulgaris*, L.) by methionine infusion. J Food Sci 44:302–1306

Bean SR, Lookhart GL (2001) Recent developments in high-performance capillary electrophoresis of cereal proteins. Electrophoresis 22:1503–1509

Beebe S, Gonzalez AV, Rengifo J (2000) Research on trace minerals in the common bean. Food Nutr Bull 21:387–391

Carbonaro M, Virgili F, Carnovale E (1996) Evidence for protein–tannin interaction in legumes: implications in the antioxidant properties of Faba bean tannins. LWT Food Sci Technol 29:743–750

Casey RC, Domoney C, Forster C, Hedley C, Hitchin E, Wang T (1998) The effect of modifying carbohydrate metabolism on seed protein gene expression in peas. J Plant Physiol 152:636–640

Chel-Guerrero L, Perez-Flores V, Betancur-Ancona D, Davila-Ortiz G (2002) Functional properties of flours and protein isolates from *Phaseolus lunatus* and *Canavalia ensiformis* seeds. J Agric Food Chem 50:584–591

Cheryan M, Rackis JJ (1980) Phytic acid interactions in food systems. Crit Rev Food Sci Nutr 13:297–335

Chung KT, Wong TY, Wei CI, Huang YW, Lin Y (1998) Tannins and human health: a review. Crit Rev Food Sci Nutr 38(6):421–464

Dahl WJ, Foster LM, Tyler RT (2012) Review of the health benefits of peas (*Pisum sativum* L.). Br J Nutr 108:3–10

Ghumman A, Kaur A, Singh N (2016) Functionality and digestibility of albumins and globulins from lentil and horse gram and their effect on starch rheology. Food Hydrocoll 61:843–850

Heng L, Vincken JP, van Koningsveld GA, Legger L, Roozen JP, Gruppen H, van Boekel MAJS, Voragen AGJ (2006) Bitterness of saponins and their contents in peas. J Sci Food Agric 86:1225–1231

Hincks MJ, Stanley DW (1987) Lignification: evidence for a role in hard-to-cook beans. J Food Biochem 11:41

Hosfield GL, Uebersax MA, Occena LG (2000) Technological and genetic improvements in dry bean quality and utilization. In: Proceedings of the Idaho Bean Workshop, University of Idaho, Moscow, 135–152

Hufnagel JC, Hofmann T (2008) Quantitative reconstruction of the nonvolatile sensometabolome of a red wine. J Agric Food Chem 56:9190–9199

Kinsella JE, Phillips LG (1989) Structure: functional relationship in food proteins, film and foaming behaviour. In: Kinsella JE, Soucie WG (eds) Food proteins. Amer Oil Chem Soc, Urbana

Liu K, Bourne MC (1995) Cellular, biological, and physicochemical basis for the hard-to-cook defect in legume seeds. Crit Rev Food Sci Nutr 35(4):263–298

Luthria DL, Pastor-Corrales MA (2006) Phenolic acids content of fifteen dry edible bean (*Phaseolus vulgaris* L.) varieties. J Food Compos Anal 19:205–211

Machuca J (2000) Characterization of the seed proteins of Velvet Bean (*Mucuna pruriens*) from Nigeria. Food Chem 68:421–427

MacLeod G, Ames J, Betz NL (1988) Soy flavor and its improvement. Crit Rev Food Sci Nutr 27(219):400

Marquez UML, Lajolo FM (1981) Composition and digestibility of albumin, globulins, and glutelins from *Phaseolus vulgaris*. J Agric Food Chem 29:1068–1074

Molina MR, Fuente GDL, Bressani R (1976) Interrelationships between storage, soaking time, cooking time, nutritive value and other characteristics of the black bean (*Phaseolus vulgaris*). J Food Sci 40:587–589

Morales-de Leon JC, Vazquez-Mata N, Torres N, Gil-Zenteno L, Bressani R (2007) Preparation and characterization of protein isolate from fresh and hardened beans (*Phaseolus vulgaris* L.). J Food Sci 72:C96–C102

Parmar N, Singh N, Kaur A, Virdi AS, Thakur S (2016) Effect of canning on color, protein and phenolic profile of grains from kidney bean, field pea and chickpea. Food Res Int 89:526–532

Parmar N, Singh N, Kaur A, Virdi AS, Shevkani K (2017) Protein and microstructure evaluation of harder-to-cook and easy-to-cook grains from different kidney bean accessions. LWT Food Sci Technol. doi:10.1016/j.lwt.2017.01.027

Patterson CA, Curran J, Der T (2017) Effect of processing on antinutrient compounds in pulses. Cereal Chem 94:2–10

Prihayati M, Soltanizadeh N, Kadivar M (2011) Chemical and microstructural evaluation of 'hard-to-cook' phenomenon in legumes (pinto bean and small-type lentil). In J Food Science Technol 46:1884–1890

Reddy V, Butler LG (1989) Incorporation of 14C from [14C] phenylalanine into condensed tannin of sorghum grain. J Agric Food Chem 37:383–384

Reyes-Moreno C, Paredes-Lopez O (1993) Hard-to-cook phenomenon in common beans. A review. Crit Rev Food Sci Nutri 33:227–286

Reyes-Moreno C, Okamura-Esparza J, Armienta-Rodelo E, Gomez-Garza RM, Milan-Carrillo J (2000) Hard-to-cook phenomenon in chickpeas (*Cicer arietinum* L): effect of accelerated storage on quality. Plant Food Hum Nutri 55:229–241

Roland WSU, Pouvreau L, Curran J, van de Velde F, de Kok PMT. (2017) Flavor aspects of pulse ingredients. Cereal Chem 94:58–65

Ruiz-Ruiz JC, Davila-Ortiz G, Chel-Guerrero LA, Betancur-Ancona DA (2012) Wet fractionation of hard-to-cook bean (*Phaseolus vulgaris* L.) seeds and characterization of protein, starch and fibre fractions. Food Bioprocess Technol 5:1531–1540

Sefa-Dedeh S, Stanley DW (1979) The relationship of microstructure of cowpeas to water absorption and dehulling properties. Cereal Chem 56:379–386

Singh N (2010) Physico-chemical and functional properties of pulse starch. In: Tiwari B, Gowen A, McKenna B (eds) Pulse foods: quality, technology, and nutraceutical application. Elsevier, Amsterdam

Singh N, Nakaura Y, Inouchi N, Nishinari K (2008) Structure and viscoelastic properties of starches separated from different legumes. Starch/Starke 60:349–357

Singh B, Singh JP, Shevkani K, Singh N, Kaur A (2017) Bioactive constituents in pulses and their health benefits. J Food Sci Technol. doi:10.1007/s13197-016-2391-9

Tiwari BK, Singh N (2012) Pulse chemistry and technology. Royal Society of Chemistry, Cambridge

Tuan Y, Phillips RD (1991) Effect of the hard-to-cook defect and processing on protein and starch digestibility of cowpeas. Cereal Chem 68:413–418

Utsumi S (1992) Plant food protein engineering. Adv Food Nutri Res 36:189–208

Vazquez G, Fontenla E, Santos J, Freire MS, Gonzalez-Alvarez J, Antorrena G (2008) Antioxidant activity and phenolic content of chestnut (*Castanea sativa*) shell and eucalyptus (*Eucalyptus globulus*) bark extracts. Ind Crops Prod 28:279–285

Warsame AO, Kimani PM (2014) Canning quality of new drought-tolerant dry bean (*Phaseolus vulgaris L*) lines. Am J Food Tech 9(6):311–317

Wassimi NN, Hosfield GL, Uebersax MA (1990) Inheritance of physico-chemical seed characters related to culinary quality in dry bean. J Am Soc Hortic Sci 115:492–499

Xu B, Chang SKC (2008) Effect of soaking, boiling, and steaming on total phenolic content and antioxidant activities of cool season food legumes. Food Chem 110:1–13