International Journal of Food, Agriculture and Veterinary Sciences ISSN: 2277-209X (Online)
An Open Access, Online International Journal Available at http://www.cibtech.org/jfav.htm
2017 Vol.7 (3) September-December, pp.31-38/Sofi et al.
Research Article

CHARACTERISTICS OF PULSES AND THEIR APPLICATION IN FOODS: A REVIEW

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ABSTRACT
Pulses are leguminous crops, including pinto beans, mung, beans, peas, lentils and chickpeas Due to advancement in technologies, bioactive components and health effects of pulses, the application of pulses in food products have increased. Pulses contain high contents proximate compositions such as protein (ranging from 17-30%), dietary fiber (DF) (ranging from 15-30%), starches, vitamins, minerals, and other important nutrients including carotenoids and Isoflavones. Pulses are the richest sources of plant proteins and provide approximately 10% of the total dietary requirements of the proteins world over. Pulses are also high in dietary fibers and complex carbohydrates leading to low GI (glycemic index) foods. Pulses help to lower cholesterol and triglycerides as leguminous fibers are hypoglycosuria because of consisting more amylose than amylopectin. Pulses provide tremendous opportunities to be utilized in the processed foods such as bakery products, bread, pasta, snack foods, soups, cereal bar filing, tortillas, meat, etc. These show excellent opportunities in frozen dough foods either as added flour or as fillings. Pulses in view of their nutrient profile, seem to be ideal for inclusion in designing snack foods, baby, and sports foods.

***Keywords**: Bioactive, Glycemic index, Dietary fiber, Leguminous*

INTRODUCTION

Legumes include pulses, grazing crops, forage crops, green food crops (green beans, green peas, etc.), oil seeds (soybeans and groundnuts) and crops whose seeds are solely used for sowing purposes, such as alfalfa and clover. However the term ‘pulses’, is limited to legume crops harvested for dry grains only. Pulses include dry beans, dry peas, vetches, lupins, dry broad beans, lathyrus, lentil, black gram, mung bean, chickpea, pigeon pea, and cowpea (Rahman, 2007). Pulses occupy an important place in human nutrition as major protein source, contributing about 5% of the energy supply per capita globally (FAO, 2012). These are cultivated over an area of 70 million hectares with annual production of 61 million metric tonnes in the world (FAO, 2012). These are ranked fifth in terms of annual grain production after wheat, rice, corn and barley. India is the largest producer and consumer of pulses accounting for about 25% of world production, 27% of global consumption and about 33% of the world's area under pulse cultivation (Srivastava et al., 2010). India produced 17.2 million metric tonnes during 2011 – 2012 on 20 million hectares land. Next top producers of pulses are Canada, China, Myanmar and Brazil (FAO, 2012)**.** Due to advancement in technologies and beneficial physiological health effects of pulses, the application of pulses in food products have increased, (Boye *et al*., 2010). Pulses contain high contents proximate compositions such as protein (ranging from 17-30%), dietary fiber (DF) (ranging from 15-30%), starches, vitamins, minerals, and other important nutrients including carotenoids and isoflavones (Boye *et al*., 2010). Pulses usage in diet is associated with lowering the risk of cardiovascular disease, cancer, aging and type II diabetes (Veenstra et al., 2010). Also, according to the American Diabetes Association, consumption of pulses can be positive effect for weight control, which is highly recommended and prescribed for obese individuals who are at risk of developing diabetes (Papanikolaou & Fulgoni, 2008). Following are the characteristics of pulses, as well as their application in foods are:

Characteristics of Pulse Starches

Starch is one of the main constituents present in pulses. However, the starch content of pulses is lower than cereal grains and in pulses 35 to 60% of starch present in pulses. Particularly, the total starch contents of chickpea varieties range from 29.1% to 46.0%, respectively, mung bean starch 30.1 to 36%, lentil ranges from 46.0% to 52.1% (Dalgetty & Baik, 2003; Hoover, Hughes, Chung, & Liu, 2010). Granule size of pulse starches in range of 0.4 to 103 µm with oval, spherical, round, elliptical, disks or irregular shapes (L. Kaur, Singh, & Sodhi, 2002; J. Singh & Singh, 2001; N. Singh, 2011). Pulse starch granules on the basis of X-ray diffraction pattern shows type C pattern structure. The type C pattern arrangement in pulse starch is due to amylopectin double helices (Sandhu & Lim, 2008; N. Singh et al., 2008). However among different pulse starches, content of long chain amylopectin are associated with the variation in nature of crystallinity. Pulse starches contain high amount of amylose and the range of amylose content depends on environment conditions, soil type and variety of pulses (N. Singh et al., 2008). During gelatinization there is disruption of crystalline structure and Hydrogen bonding due to which starch granules tend to swell and increase solubility (N. Singh, Sandhu, & Kaur, 2004). Pulse starches due to orderly arrangement of polymer chains restricted swelling and low solubility, which shows that maximum interaction due to hydrogen bonding within the starch granules. The swelling and solubility of pulse starches restricted initially due to their high amylose content, since after the amylose leaching from starch granules, increasing in swelling power and solubility of starches occurs (N. Singh, 2011).

Pulse Dietary Fiber

Pulses are rich resource of dietary fiber which has beneficial effects on human health (Piwinska *et al*., 2015). Dietary fiber was first used in 1953 by Eben Hipsley to describe the unavailable carbohydrate content in foods, which lowered the rates of pregnancy toxaemia (Hipsley, 1953). Previously the analytical term ‘crude fiber’ was used for components that escaped acid and alkali extractions (Trowell, 1976). Trowell *et al*.,(1985) defined dietary fiber as sum of polysaccharides and lignin not digested by human gastrointestinal tract. Dietary fiber resist digestion in the small intestine but fermentable by microflora locating in the large intestine (Phillips & Cui, 2011). Dietary fiber has tmajor beneficial properties such as decreases transit time within the intestine; reduces LDL cholesterol levels and lowers postprandial blood glucose or insulin levels. Soluble and insoluble dietary fiber are the two main composed of total dietary fiber. Cellulose, hemicellulose, and lignin are the Insoluble dietary fiber (Chawla & Patil, 2010). Cellulose is defined as homopolymer with linkage of β-(1→4)-D-Glc with extensive hydrogen bonding, whereas hemicellulose is composed of heteropolymers of pentoses (i.e. xylose and arabinose), hexoses (i.e. glucose, galactose, mannose) and sugar acids (i.e. acetic acid). Lignin is a heteropolymer bound with cellulose that is extremely resistant to digestion (Lunn & Buttriss, 2007). Insoluble dietary fiber is not digested in the stomach and the intestines, but helps in removals organic toxins and waste as due to absorption in water and bind capacity (Tosh & Yada, 2010). Insoluble dietary fiber helps in constipation and digestive health due to gut transit time (Weickert & Pfeiffer, 2008). Soluble dietary fiber (SDF) is composed of some hemicelluloses, pectins, gums, mucilages and storage polysaccharides (Cappa, Lucisano, & Mariotti, 2013; Chawla & Patil, 2010; Lunn & Buttriss, 2007). Reported research had shown that consuming SDF helps regulate postprandial glucose responses and decreases blood cholesterol levels, thus leading to prolonged gastric emptying and reducing the risk of colorectal cancer and cardiovascular disease (Piwinska et al., 2015; Weickert & Pfeiffer, 2008). Pulse hulls as good source of dietary fiber and is major source of insoluble dietary fiber. Among pulse dietary fiber from hulls such as 75% in chickpeas hulls and 87% in lentil hulls from dry mass (DM) (Dalgetty & Baik, 2003). In pulse such as lentils contain no cholesterol, With regards to monosaccharide composition, glucose and arabinose/rhamnose mainly contained in the hull and insoluble fiber fractions of pulses while as xylose galactose and cellobiose in SDF fraction in major pulses (Dalgetty & Baik, 2003). The high complex carbohydrates and dietary fiber diet obtained from pulses permit slow digestions and provide a feeling of satiety, increases stool volume and colon transit time. There is evidence to suggest that consuming pulse could improve bowel function and satiety (FAO, 2016). The DF also acts to bind toxins and cholesterol in the gut, thus allowing the removal of these substances from the body, which could reduce the risk of associated heart diseases and blood cholesterol level. Also, high iron level possessed within pulses helps transport oxygen throughout the body, which boosts energy production and metabolism. Pulses nutrients and non-nutrient substances are associated with reducing the risk of cancer and cardiovascular diseases (CVD) and diabetes (Dahl et al., 2012). Furthermore, high dietary fiber-containing (including high resistant starch content) foods such as pulses, including chickpeas and lentils, usually have GI values lower than 55. Therefore, consuming pulses regularly will be beneficial for people with diabetes, because it could reduce blood lipid levels and slow down the glucose released into the blood, with balanced insulin response. Also, RS contained in pulses aids in increasing glucose tolerance and insulin sensitivity, which is particularly beneficial for type II diabetes patients (Jenkins et al., 2002). Pulses with high dietary fiber have great potential to be applied as natural health ingredients for functional food products.

Protein Characteristics in Pulses

Pulses also contain an excessive amount of protein, ranging from 17% to 30% (Boye et al., 2010). The storage protein such as globulins and albumins are the two major protein groups within pulses. Globulins are usually multi-subunit molecules with high molecular weight among them, legumin (11S) and vicilin (7S) are two major globulin components in pulses (Dziuba et al., 2014). Opposite to globulins, albumins are low or medium molecular weight molecules which are soluble in water with hydrophilic surfaces. Also, albumins also rich source of enzymatic proteins, enzyme inhibitors, and lectins. The prolamins and glutelins are minor protein groups that exist in pulses (Boye, Zare, & Pletch, 2010). Prolamin contains proline and glutamine which are soluble in alcohol and mainly. Glutelins are storage proteins that are acid or alkali soluble and contain more methionine and cysteine than globulins, but this is yet a minuscule percentage of total protein content in pulses. The protein contents of major pulses range from 20.8 to 37.5% (Dalgetty & Baik, 2003). Specifically, the total protein content of pulses such as lentil includes 16.8 % albumins, 44.8% legumins, 4.2% vicilin, 11.2% glutelins and 3.5% prolamins (Boye, Zare, &Pletch, 2010). Also, 2.8% carbohydrate in all the protein fractions due to process of glycosylation (Boye et al.,2010). The protein content of chickpeas varies from 20 to 28.9 (Jukanti et al., 2012). Desi chickpea varities has high protein content than Kabuli chickpea type. Chickpea protein shows higher nutritional value than peas and lentils and major pulse grown in world especially in india. The chick pea contains total protein content includes 16.18% albumins, 41.79% legumins, 9.99% glutelins and 0.48 % prolamins (da Silva, Neves, & Lourenço, 2001). In general, chickpea flour has a higher amount of fat and DF, as well as a relatively lower protein content compared to other pulses (Asif et al., 2013; Jukanti et al., 2012). There are 20 amino acids (AA) and non-essential amino acid (NEAA) commonly occurring in food proteins. The essential amino acids (EAA) are the amino acids that human body cannot synthesize by itself, including lysine, methionine, threonine, valine, isoleucine, leucine, phenylalanine, histidine, and tryptophan. The non-essential amino acids are the ones that can naturally occur in the human body, including alanine, arginine, asparagine, aspartic acid, glutamic acid, cysteine, glutamine, glycine, proline, serine, and tyrosine. In general, commonly consumed pulse proteins have limited sulphur containing amino acids (cysteine and methionine) and tryptophan, but considerable amounts of lysine, leucine, aspartic acid, glutamic acid and arginine (Boye et al., 2010; Jukanti et al., 2012). The deficiencies of sulfur containing amino acids in pulses could be minimized by combining processed foods that contain excessive cysteine, methionine, and tryptophan such as in corporation of pulses flour or protein in cereal products which will offer balanced essential amino acid profile (Boye et al., 2010; Carvalho et al., 2013; Jukanti *et al*., 2012). Several food products, such as bread, chapatties, noodles, pasta, biscuits, protein enriched or supplemented fruit powders or fruit bars etc have successfully used pulses as an functional ingredient for improving their nutritional values (Asif et al., 2013).

Micronutrients and Antioxidants in Pulses

Pulses are also regarded as good source of micronutrients, including a high level of selenium, thiamin, niacin, folate, riboflavin, saponins and pyridoxine (Tiwari., *et al*., 2011). Among all the pulses chickpeas contain the right amount of thiamin, niacin, calcium, phosphorus, iron, magnesium and potassium, lentils contain a good quantity of iron, phosphorous, thiamine, vitamins B, and C, folic acid and antioxidants (Asif *et al*., 2013). Phenolic compounds with have been positively correlated with antioxidant activities, such as inhibition of lipid peroxidation by scavenging free radicals and avoiding free radical damage (Rafiq *et al*., 2016). Polyphenol antioxidants produced from some food components can donate electrons to free radical molecules, thereby preventing oxidative damage and cell apoptosis. Thus, natural antioxidants may avoid the chance of getting chronic diseases, such as cancer, cardiovascular diseases, obesity, and cataracts (Gujral *et al*, 2011; Kan *et al*., 2016). Pulses in addition to their unique dietary fiber and protein contains phenolic compounds, which provide valuable sources of antioxidants in the human diet and contributes to well being of humans (Mudryj *et al*., 2014; Padhi *et al*., 2016). Among four major pulses: peas (green and yellow), lentils, chickpeas and beans (black and red kidney), lentils contain highest phenolics/flavonoids, followed by beans (Xu and Chang, 2007). Total phenolic content (TPC) of 6.56 and 1.81 mgGAEg^{-1} and total flavonoid content of 1.30 and 0.18 mg catechin equivalents g^{-1} has been reported in lentils and chickpeas respectively and it has been pointed out that green lentils contained the highest TPC of 7.45 mg GAE/g for Laird and 7.30 mg GAE/g. A number of factors such as varieties, geological locations, and method of determination can affect the antioxidant activity of the pulses. Colour of pulse seeds can be a good indicator of their phenolic content and antioxidant activities. Scientific evidences have proven that pulses having dark color coating are positively correlated with TPC and their antioxidant activities (Rocha-Guzmán *et al*., 2007; Xu & Chang, 2007). Hulled pulses contained higher TPC than dehulled pulses, which indicates that most of the phenolic compounds are present in the hull of pulses. Giusti *et al*., 2017 reported that TPC of nine lentil varieties ranged from 0.84 to 4.52 mg of GAE/g with black lentil having the highest and dehulled red lentils reported the lowest value of TPC. Their corresponding antioxidant activity ranged from 39.2 to 92.5% with black lentils having the most and dehulled lentils having the weakest inhibition activity. In case of chickpea varieties black chickpeas reported highest TPC and Desi chickpea reported lowest ranging from 0.72 to 1.2 mg GAE/g, while the contributed DPPH inhibition activity ranged from 25.5 to 64.9% according to their TPC content (Giusti *et al*., 2017).

Minor Components in Pulses

Minor components in pulses consist of fat, vitamins, and minerals, such as iron, zinc, and copper (Mudryj *et al*., 2014; S. Wang *et al*., 2011). Pulses contain a fair amount of vitamins such as pyridoxaine, pyridoxal, pyrodoxine. Research indicated lentil and chickpea contains 63.3 and 26.9 µg/100 g DM of pyridoxaine, 94.2 and 74.8 µg/100 g DM of pyridoxal and 44.2 and 23.5 µg/100 g DM of pyrodoxine, respectively. Pulses have a good amount of zinc, copper and calcium; lentil usually has slightly higher content (2-10 µg/100 g DM) of these minerals than chickpea. Zinc is positively correlated with reducing oxidative stress in cell and increasing immune cell function (Ibs & Rink, 2003; Mudryj *et al*., 2014). In addition, the fat content of pulse ranging from 2-21% are composed of exogenic unsaturated fatty acids (linoleic and linolenic) (Oomah *et al*., 2011) and chickpeas have reported higher fat content (3-5%) than some pulses including pea and lentil (Asif *et al*., 2013). Many evidences have proven that regular consumption of pulses could lower the risk of cardiovascular disease by influencing the blood pressure, platelet activity, lipid profiles, and inflammation. The mono- and polyunsaturated fat and plant sterols present in pulses aid in enhancing high-density lipoprotein (HDL) cholesterol, meanwhile reducing low-density lipoprotein (LDL) and total cholesterol (Mudryj *et al*., 2014), as well as lower heart disease associated inflammatory biomarkers (Esmaillzadeh & Azadbakht, 2012).

Application of Pulse Ingredients in Food

There is increasing trend in incorporating pulses products into food products due to various benefits and balanced nature of amino acids in pulses with other ingredient such as cereals, to enrich their quality and nutrients, including applying pulses to make breads, biscuits, meatadded with pulses, in dairy products etc. Pulse flours have been used successfully as ingredients in the formulation of meat products (e.g., burgers, sausages, nuggets, etc.) use of Bengal gram flour, black gram flour, green gram flour, and soy flour in buffalo hamburger formulations and all products were acceptable when stored for up to four months (Modi et al.,2003). Serdaroglu et al., (2005) formulated meatballs using pulse ingredients such as black-eyed bean flour (BBF), chickpea flour (CF), and lentil flour (LF) at a 10% supplementation level slightly increased the toughness and the protein content of the formulation. Abdel-Aal., (1987) used flours, concentrates, powders and protein micellar mass (PMM) concentrates (prepared using a salting-in procedure) from chickpea and faba bean as sausage meat extenders at substitution levels ranging from

20% to 40%. Products containing faba bean and chickpea PMM were found to be more acceptable at all levels of substitution than the powder-substituted products. Dzudie et al. (2002) found that meatballs extended with pulse flours had higher water holding capacity than did those extended with rusk probably due to the high protein contents of the pulses. Addition of 5-30% green and yellow peas, lentil and chickpea flours into semolina increased cooking loss, firmness, pulse flavor, and colour intensity of spaghetti (Zhao et al., 2005). The consumers preferred spaghetti with 15 % lentil or green pea and 20 % chickpea substitution addition of pulse flours. The effects of incorporating 10% of four types of legume (mung bean, soya bean, red lentil, and chickpea) flour into semolina spaghetti were produced with improved nutrition values, including dietary fiber and protein (Chillo *et al*., 2010). Gluten-free noodles, mainly relating the approach of incorporation of pulse starch or flour into rice flour that could lead to improved quality, mouthfeel and acceptability (Rathod & Annapure, 2017). For instance, the addition of Mung bean starches up to 8% positively affected rice noodle quality including improved cooking (lower cooking time, cooking loss and break rate) and texture properties (increased firmness, elasticity, slipperiness and chewiness) (F. Wu et al., 2015). However, based on the comprehensive analysis of cost and quality of fortified rice noodles, 5% Mung bean starch substitution is the most efficient way to improve rice noodle quality. Novel starch noodles showed less colour intensity, better firmness and superior textures compared with commercial mung bean starch noodles. The influences of blending lentil from 0 to 100% with rice on the qualities of noodles with increased fiber and protein content (Rathod & Annapure, 2017). Spink et al., (1984) formulated a cake doughnut using high protein flours from black bean and navy beans were used as substitute for all purpose flour by up to 30%. up to 15% chickpea flour (24.83% protein), lupin flour (26.30% protein) and soybean flour (56.36% protein) were used to replace wheat flour in a cookie formulation (Faheid & Hegazi, 1991). Replacing wheat flour with chickpea or soy bean flour increased protein, ash, fibre and moisture contents and the amino acid scores. Fortification of bread with pulse ingredients also been studied (Dalgetty & Baik, 2006). The use of whole pulses for the preparation of baby foods but very little on the use of pulse extracts (e.g., pulse protein isolates or concentrates). Singh and Singh (1992) used boiled mung bean with rice soup as a protein supplement for baby foods, and demonstrated that a porridge-type weaning food could be prepared from boiled, mashed and sieved mung bean with the addition of selected cereals and sugar. Marero et al.,(1991) showed that germination decreased the level of anti-nutritional factors and increased protein digestibility in an infant feeding trial of gruel (weaning food) made from germinated mung beans and cowpeas. Swanson (1990, and references therein) reported on the use of pea and lentil protein isolates for the preparation of imitation milks.

CONCLUSION

Protein malnutrition continues to be a major problem in many places developing countries. Pulses contain high contents such as protein, dietary fiber, starches, vitamins, minerals, and other important nutrients including carotenoids and isoflavones. Pulses usage in diet is associated with lowering the risk of cardiovascular disease, cancer, aging and diabetes. At the same time there is growing social consciousness about the impact of climate change and agricultural practices. Food manufacturers, as well as consumers, are increasingly searching for food alternatives that offer variety and which provide functional as well as nutritional benefits and which have reduced carbon footprints. This growing trend offers an opportunity to the pulse industry to identify novel food uses for whole pulses as well as to develop ingredients and products that can be used in complement with other grains and cereals in the development of convenient alternative food and industrial products.

ACKWNOWLEDGMENT

The first author is very much thankful UGC for providing fellowship during his research tenure.

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