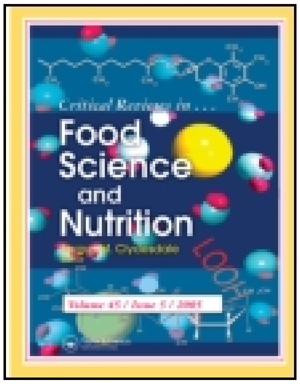

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Application and Opportunities of Pulses in Food System: A Review

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Application and Opportunities of Pulses in Food System: A Review

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Pulses are highly nutritious seeds of pod-bearing leguminous plants, specifically dry peas, lentils, and chickpeas. US farmers harvest about 2.6 million pounds of pulses every year but 75% of this is being exported internationally because of its increased consumption in the developing countries. In the current scenario, increasing costs of production, bad economy, and fluctuating food commodity prices have made a strong case for US producers to seek opportunities to increase domestic consumption of pulses through value-added products. 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 Chickpea, green gram, kidney bean, black gram, pigeon peas, lentils

INTRODUCTION

Word “pulse” is derived from a Latin word “puls pultis” means thick slurry. Generally, the pulses are dried seeds from leguminous crops (excluding the crops used for oil extraction like soybean) and are next to cereals as a source of food, especially in developing countries. Pulses belong to the family *Leguminosae*, which has been used for centuries for food. Every pulse is a legume and the definition of legume is “any dry fruit or pod” that contains seeds or dry grains that fix nitrogen into the soil. Every dry bean is a pulse-like pinto, black, navy, red, and lima beans are an example of pulses because they are dried naturally in the sun and not used for oil extraction. All legumes are not pulses like soybeans and peanuts or green beans and fresh peas while pulses include, dry peas, lentils, chickpeas, dry beans, etc. All pulses are not beans as dry peas, lentils, and chickpeas are not considered beans because of their growing conditions, growth structure, and maturation (USADPLC, 2010).

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Pulses are categorized as the most important dietary predictor of survival in older citizens of various ethnicities and may be the key factor in increasing the life span of populations (Darmadi-Blackberry et al., 2004). The world production of pulses is 57 million tons (Anonymous, 2007) but in 2004, only in Asia the total pulse production was 33 million tons. India, one of the world’s largest producers of pulses, could increase output by 30% of total production, reflecting a normal monsoon season and a rise in government support prices to stimulate the growth of pulses (FAO stat, 2008).

The consumption of pulses is increasing globally in view of their high nutritional value, being low in calories, and glycemic index (GI). Pulses are the richest source of dietary fibers and complex carbohydrates leading to low-GI foods. Pulses help to lower cholesterol and triglycerides as leguminous fibers are hypoglycosuria because of consisting of more amylose than amylopectin. The proteins from pulses are easily available as shown by in vitro digestibility (Mansoor and Yusuf, 2002). Research indicates that pulses and legume consumption lower total serum cholesterol by an average of 5%, and also lower LDL (low-density lipoprotein) cholesterol by an average of 9% while serum HDL (high-density lipoprotein) cholesterol, VLDL (very

Table 1 Chemical composition of some pulses

Name	Crude protein (%)	Lipid (%)	Carbohydrate (%)	Crude fiber (%)	Minerals (%)
Black gram	26.9	1.6	66.9	1.0	3.6
Broad beans	26.7	2.3	64.0	7.2	3.6
Chickpeas	22.7	5.0	66.3	3.0	3.0
Garden beans	24.1	1.8	65.2	4.5	4.4
Green gram	27.2	1.3	66.6	0.9	3.8
Lentils	28.6	0.8	67.3	0.8	2.4
Dry Peas	25.7	1.6	68.6	1.6	3.0

low-density lipoprotein) cholesterol, and serum triglyceride were all unaffected by pulses and legume consumption (Duane, 1997).

Pulses have double the amount of proteins than cereals, moreover, proteins from the cereals and that from the pulses complement each other in daily diet. The pulses proteins particularly from the lentil are deficient in methionine and cysteine (sulfur containing amino acids) while rich in lysine. Cereal proteins in contrast are short of lysine and provide the ample quantity of metionine and cysteine. The chemical composition (Table 1) of pulses elaborating that generally these are rich in proteins and carbohydrates but low in fat (Belitz and Grosch, 1996). The pulses also contain a variety of antinutrient factors (ANFs) such as the lectins, proteinase inhibitors, nonprotein amino acids, gums, tannins, cynogens, saponins, alkaloids, phytates, etc., which are mostly destroyed in soaking, washing, cooking, and other processes (Ali and Muzquiz, 1998). In spite of the fact that pulses are the most economical source of good quality proteins, with potentials to be used as healing foods, the utilization of pulses is presently very limited. Daily per capita consumption of pulses products in Asia is about 110 g as compared to US where only 9 g is taken in diet with the result that Asian population show lower risk of coronary heart diseases (CHD; Kahlon et al., 2005).

Mass production of pulses is localized in underdeveloped world, where technologies involved for value addition are not approachable. Pulses provide tremendous opportunities and challenges to be utilized in processed foods such as bakery products, bread, pasta, soaked and dried food, snack foods, soups, cereal bar filing, tortillas, meat, etc. Pulses 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. Some of the pulses proteins with high oil- and water-binding capacities are suitable as additives in sausages, sauces, soups, confectionary, chocolates, and frozen desserts (Barbut, 1999).

Chickpea (*Cicer arietinum* L.): (Bengal gram, garbanzo bean, Indian pea, ceci beans, homes, poi chiche, boot, chana, chhole, desi chana, kabuli chana)

Chickpeas are a common component of traditional diets of Asian, Mediterranean, Arab, and South American communities (Phillips, 1993; Geil and Anderson, 1994). The chickpea originated from Turkey in 5450 B.C. (Maesen and Vander, 1972), and has expanded with time in both areas as well as in production and now more than 100 varieties of chickpeas have already been introduced and is fifth in world production (Chavan and Salunkhe, 1986). Chickpea is largely classified in two different varieties as black chickpea also called desi chana and white chickpea (garbanzo bean). White type is grown in temperate regions while the black chickpea is grown in the semiarid tropics (Malhotra et al., 1987; Muehlbauer and Singh, 1987). Chickpea seeds are eaten fresh as green vegetables, parched, fried, roasted, and boiled; as snack food, sweets, and condiments; seeds are ground and the flour can be used as soup, dhal, and to make bread; prepared with pepper, salt, and lemon; and is served as a side dish (Saxena, 1990). Chickpea is also used for making hummus and is typically eaten with pita or other flat bread. Hummus is a Middle Eastern food composed of chickpeas, and tahini, a paste similar in texture to peanut butter that is made from sesame seeds.

Chickpeas contain moderately high protein (17–22%), low fat (6.48%), high available carbohydrate (50%), and crude fiber contents of 3.82% (Saleh and Tarek, 2006). The nutritional value of chickpea protein is superior to those of soybean, cowpeas, mung beans, peas, dry bean, lentils, faba bean, pigeonpea, and black gram (B. gram) (Pak and Barja, 1974; Chandrasekharappa, 1979; Khan et al., 1979). Chickpeas also supply thiamin, niacin calcium, phosphorus, iron, magnesium, and potassium (Milan-Carrillo et al., 2000). The chemical composition of the chickpea shows high fat and fiber contents while protein quantity remains about 22%. The protein quality of chickpea hydrolysates and isolates has been explored in order to improve nutritional and functional properties of chickpea proteins (Clemente, et al., 1999). In contrast to most other pulses and cereals, chickpeas have a relatively high fat content (William and Singh, 1987; Messina, 1999), however, the fat is composed mostly of polyunsaturated fatty acids, with less than 1% saturated fatty acids. Proteinase inhibitors including trypsin and chymotrypsin are reported to be present in chickpeas (Smirnoff et al., 1976; Giri et al., 1998).

It was demonstrated that chickpeas and wheat co-extruded products have chemopreventive capacity against dimethylhydrazine-induced colon cancer in rats (Mcintosh et al., 1998). Use of chickpeas in food may be implemented through extrusion to produce either a functional protein food ingredient or a snack-type product. The high starch content of chickpea (Chavan and Salunkhe, 1986) favors extrusion to produce expanded snack products. The advantage of such a product over the traditional corn snack would be its higher protein content and superior protein nutritional quality (Batistuti et al., 1991). According to Milan-Carrillo et al., (2000), extruded chickpeas may be considered for the fortification of widely consumed cereal-based food products. Shirani and Ganesharanee (2009) investigated the effect of fenugreek flour and debittered fenugreek polysaccharide inclusion on physical and sensory quality characteristics and GI of chickpea-rice-based extruded products.

The starch and proteins present in the chickpea display excellent pasting, foaming, and emulsifying properties to make it suitable for deep-frying. Chickpea flour suspensions are widely used in the preparation of oriental traditional sweet and savory snacks as products of deep-frying. The droplets of chickpea flour slurry, become twice in size after incorporation of air bubbles at high temperature during frying. Sweets preparations like sweet meats or baked products are also prepared by using chickpea flour with attractive porous crust and surface color (Keshava and Bhattacharya, 2001). The chickpea flour has promising characteristics for identical preparation of products as tortilla chips and it is also used in extruded products with the combination of corn and rice flour by using the fried extruder. Chickpea flour is very popular in Pakistan, India, Bengal, Middle East, and in other East Asian countries and is used in smooth semiliquid form while mixed with water or a beaten egg to give a coat on different kinds of fries, ranging from chicken, potato egg, fish, and some vegetables, and hence producing various kinds of fried food like pakora, peyaji, chop, namkkens, chickpea spicy noodles, and sweet meats. As it consists of carbohydrates, so it is not recommended for low-carbohydrate diets, but it goes very well with gluten-free diets.

Gomez et al. (2008) mentioned that it is possible to use chickpea flour to totally or partially substitute wheat flour in the elaboration of different kinds of cakes. But they found that as the substitution percentage of wheat flour by chickpea flour increased, the cake volume was decreased and texture became firmer, gummier, and less cohesive. Cardoso-Santiago and Areas (2001) prepared a snack by extruding a blend of chickpea and bovine lung and these snacks were more acceptable than comparable commercial brands. The chickpea flour shows high potential to be used in extrusion and the acceptable nutritional attributes. The extruded products were developed with excellent bioavailability of iron, proteins, and vitamins.

The flow behavior of chickpea flour is suitable for production of imitation milk and product formulations. Reducing apparent viscosity to enhance rheological properties by incorporating additives such as salt, oil, or the carboxy methyl cellulose has brought the flour from household products to industrial levels (Ravi and Bhattacharya, 2004). A linear programming model was developed by Valencia et al. (1988) in order to formulate mixtures based on rice, chickpea, commercially defatted soybean meal, and methionine at the lowest possible cost and in such a way as to fulfill the amino acid profile established by Food and Agriculture Organization (FAO). Researchers found that chemical analysis and biological evaluation of the linear programming model formulated products confirmed their highly nutritive value in agreement with infant food specifications outlined by FAO/WHO (1976).

Kaur and Singh (2007) prepared protein isolates by alkaline solubilization followed by isoelectric precipitation and freeze drying from desi (black) and kabuli (white) chickpea cultivars. They were evaluated for functional (water and oil absorption capacities, least gelation concentration, foaming capacity, and stability) and thermal properties and found a significant difference in properties of kabuli and desi chickpea protein isolates. The solubility-pH profile of different protein isolates showed minimum solubility in the pH between 4.0 and 5.0 and two regions of maximum solubility at pH 2.5 and 7.0. Foaming capacity of all protein isolates increased with the increase in concentration. Miao et al. (2009) characterized the starches of kabuli- and desi-type chickpea. They investigated this by monitoring amylose content, swelling power, solubility, syneresis, water-binding capacity, and turbidity properties. They found that total amylose and apparent amylsoe content were 31.80% and 29.93% for kabuli and 35.24% and 31.11% for desi, respectively. The shape of starch granules varied from round to oval or elliptic. The transition temperatures (To, Tp, and Tc) were (62.237, 67.000, and 72.007°C) and (59.396, 68.833, and 77.833°C) for kabuli and desi starches, respectively.

Green gram (*Vigna radiate* (L) R. Wilczek): (green bean, mung bean, golden gram, moog, moong dal, mongo, mash bean, oregon pea, chickasano pea, chiroko)

Green gram (*G. gram*) is commonly known as *mung* bean in the Indian subcontinent and is widely grown in all Asian countries. The 100 g of G. gram gives 30 calories and consist approximately 3 g proteins, 6 g carbohydrates, and 2 g dietary fibers. It provides about 15% and 45% of the RDA of calcium and iron, respectively. The G. gram is almost nil in raffinose or other oligosaccharides and is free of flatulence-causing agent, making it suitable for convalescent, baby, or senior citizen foods. It is deficient in sulfur containing amino acids and contains trypsin inhibitors considerably which are heat labile and are completely inactivated during cooking making it easily digestible. Chinese believe it is remedy for edema, fever, headache, anxiety, and it is found to be diuretic. It also has a high-binding capacity for arsenic and is good for removing mineral toxicity.

G. gram has been used to lower the GI of other foods in combinations as it has its own GI quite low and is recommended in the diet of diabetic, obese, and consumers who desire to lose weight (Mani et al., 1993). Recently, the health-linked-functionality of G. gram was enhanced through solid-state bioconversion to enrich the bean substrate with phenolic antioxidants and levo-dihydroxy phenylalanine (L-DOPA). The two compounds are chemopreventive agents used for diabetic management and control of peptic ulcer, which work through by separate strategies. Increased phenolic contents in mung beans were responsible for α amylase inhibition and thus in lowering GI of the diet while the increased antioxidant activity is co-linked with inhibition of *Helicobactor pylori* responsible for peptic ulcer. It seems that increased α amylase inhibition accompanied by increased L-DOPA content have a synergetic effect and propose attractive strategy in designing foods to manage carbohydrate metabolism which will control carbohydrate-related metabolic diseases as in diabetes (Randhir and Shetty, 2007).

The molecular architecture of G. gram starch has been studied after fractionation by enzymic methods and size exclusion chromatography. G. gram starch has a high content of sparsely branched amylose of a relatively high-molecular weight, highly branched amylopectin, and moderately branched intermediate fraction (Madhusudhan and Tharanathan, 1996). This is the reason that G. grams are largely consumed in the hospital diets as it is regarded to be suitable for patients with weak digestive system. Research also indicates that mung bean is a good source of essential fatty acids, minerals, and tocopherol (Anwar et al., 2007).

Recently, the detailed chemical analysis of four cultivars of G. gram revealed that although oil comprises only 1.20–1.56%, however, is extremely rich in linoleic acid. The beans are the rich source of tocopherols, the other antioxidants present are phenolic which are capable of inhibiting lipid peroxidation by 49.8–89.2% and contributes to nutraceutical attributes related to mung bean. The protein content may vary from 20.97–31.32%, however mung beans are best suitable for complementing the cereal proteins because of its profile of amino acids with high lysine/low methionine and vice versa in cereals (Anwar et al., 2007).

The fried G. gram is a popular snack food prepared by soaking in water overnight and immediate deep-frying after removal of water. It is used in soup and its flour is added in a variety of the snack foods. In view of its unique taste and functional properties, the G. gram flour has a promising future in baked products by substituting it in wheat flour, as the rheological properties are not altered significantly, however, flavor enhancement and protein enrichment are greatly achieved. G. gram is consumed in different forms, for example, as a viand, boiled, or cooked with vegetables or meat, as well as a dessert or incorporated in bread or cake. It can be used to make sprouts for egg rolls and other vegetable dishes (Mendoza et al., 2001).

Products like crackers, cookies, bread, pizza, noodles, cakes, etc. have great potential for its incorporation and production of protein rich foods. G. gram balls are somewhere between savory and sweet, and make a pleasant afternoon snack together with a cup of coffee or tea. Pandan leaf (or pandan paste) adds flavor and enhances the green color of the beans as they cook. The beans are then mashed and formed into balls, which are rolled in a mixture of crushed pistachio nuts and toasted coconut.

G. gram milk, which was first drunk about 1,000 years ago, is the number one snack. It is actually remnant of mung bean when it is used to make starch. It looks gray–green and tastes sour and a little sweet. G. gram milk is rich in protein, vitamin C, and dietary fiber and has some effects like appetizing, relieving summer heat, detoxifying, and some other effects that account for its popularity among many people (Anonymous, 2004). G. gram starch is used to make transparent cellophane noodles also known as glass or thread noodles. These noodles become soft and slippery when these are soaked in hot water. In north China, G. gram jelly called liangfen is a very popular food during summer (Anonymous, 2010). Imanishi et al. (2009) patented a process for producing instant bean-starch vermicelli that is capable of suppressing not only dissolution during boiling but also elongation and swell after cooking, and that exhibits appropriate elasticity and gives firm palatability. This instant bean-starch vermicelli is produced from a mixed starch consisting of potato starch (30%) and mung (70%) bean starch as a raw material. The resultant mixed starch is kneaded with water, and extruded into hot water through a die to thereby obtain linear noodles. The linear noodles are boiled with hot water, washed with water, and cooled. These cooled linear noodles are frozen in a freezer, thereafter thawed, cut into given lengths, weighed, and dried by means of hot air. Mung bean starch produced by sour liquid processing had better quality than that from centrifugation, which is widely used to produce starch noodle (Liu and Shen, 2007). Biodegradable film was developed using starch from mung bean and its physical and mechanical properties evaluated. Results indicate that this starch had relatively good mechanical and physical properties as compared with gelatin and other low-density polyethylene films. Starch films had better O_2 barrier, and improved H_2O barrier properties than gelatin films (Bae et al., 2008; Bourtoom, 2008).

Lentil (*Lens culinaris*): (masoor, pardina, brown spanish, adas, mercimek, messer, heramame)

Lentils are said to be the first domesticated crops, an important part of diet in many parts of the world. Lentils are a major part of Indian cuisine, as the Indian continent has a large vegetarian population. Lentils are found in various colors, ranging from yellow and red-orange to green, black, and brown. The skin of red, white, and yellow lentils is usually removed. They are also available in various sizes. Some lentils are sold with the skin and some are sold without the skin, some lentils are sold whole, while others are sold split. The various types of lentils are Spanish Pardina, yellow lentils, Eston green lentils, brown skinned-red lentils, and big Mexican yellow lentils (Satalkar, 2009). Approximately 80% of the world's lentils are red cotyledon and 95% of the world's red lentils are eaten after the seed coat is removed, resulting in either splits or whole dehulled lentils that cook very quickly, about the same time that it takes to prepare milled rice (Vandenberg and Bruce, 2008).

Whole lentil seeds are cooked with spices and are a popular dish eaten with rice or bread. Lentil has been selected as one of the five healthiest foods and in Spain, lentil is the second most consumed legume after chickpeas (Varela et al., 1995). Lentils have a high mineral density and are rich in starch and proteins. Lectins, a mandatory component of legumes as pure protein and lectin-depleted albumin proteins, had shown no adverse impact on nutritional performance of the rats (Cuadrado et al., 2002). Heat treatment like autoclaving of lentils increases digestibility and availability of leucine and lysine amino acids but decreases digestive utilization of tyrosine and methionine amino acids (Porres et al., 2002). Lentils are cholesterol free, low in saturated fat, very low in sugar, and a rich source of dietary fiber. These are high in iron, phosphorous, thiamine, vitamins B and C, folic acid, and packed with antioxidants (Satalkar, 2009). Flour made from lentils is gluten-free and is a nutritious alternative to wheat-based products for people with celiac disease.

Lentils can be beneficial in the management of type-2 diabetes since they have a low-GI (<55) suggesting that their impact on blood glucose levels is lower than that of many other carbohydrate-containing foods (Araya et al., 2002). They have been shown to have low-glycemic potential even when mixed with other grains (Hardacre et al., 2006). Lentils also reduce blood lipids that may help some serious complications of diabetes. Lentil is very well suited to vegetarian diets as they are a good source of protein and iron, and complement the amino acid profile of cereals and nuts.

Researchers from the U.S. Agricultural Research Service have developed a process of using extrusion technology to make healthy and tasty snacks out of lentils. These snacks were low in sodium and fat, cholesterol-free, as well as being rich in protein and fiber, so these reduce the risk of a variety of health problems such as obesity, heart disease, cancer, and diabetes (Berrios, 2006). Lentils have been pin-milled and air-classified into starch and protein fractions for incorporation into food and feed products and for industrial utilization. Relatively pure protein and starch fractions can be obtained from lentil by mechanical separation (Bhatty, 1988).

The functional properties of lentil protein isolates have illustrated good foaming, emulsifying, and fat absorption properties (Suliman et al., 2006). The native and succinylated globulins have exhibited maximum foam stability at pH 3.2 and 2.5, respectively, and show prospective as food additives in juices or carbonated food fluids (Bora, 2002). In view of its multibenefits, lentil plantation was explored in the UK as well (Andrews et al., 2001). Lentil protein concentrates (LPC) produce a strong, elastic, cohesive mass in addition to water, which possess good moisture barrier properties with physical integrity. Gonzales and Perez (2002) conducted a study to evaluate the effects of microwave irradiation and extrusion cooking on some different characteristics of lentil starch. Both treatments caused a decrease in water absorption, solubility, and swelling power and an increase of absolute density. Both treatments also reduced the retrogradation tendency of lentil starch, which could be interesting because this is one of the reasons that has limited the commercial use of lentil starches. The extrusion cooking produced the most pronounced modifications in the lentil starch characteristics evaluated, except granular morphology, which was more affected by microwave irradiation. The LPC-based edible films are comparable to soya, pea, and whey but has superiority in terms of sensitivity to light as LPC film have red to brown color suitable for food packaging (Bamdad et al., 2006).

According to Yadav et al. (2007), Indians consume more lentils than any other country and the country produces more than 50 varieties of the crop. Despite the wide variety of different people who consume them, the most common methods of preparation are more or less the same in these countries and include dhals and thinner lentil soups, but local ecologies and food habits differ further afield toward the Middle East and Europe where they are often eaten as an accompaniment to or sauce for meats. Dhal is India's comfort food and usually accompanies every meal eaten along with either hot steaming rice or fresh chapati (leavened bread) straight off the griddle or dhaba (dry-frying pan). It is also dried with spices to produce spice capsules to add to foods. The simplest may be boiled with turmeric and ginger and then seasoned with sautéed onion and tomatoes. Roasted or fried cumin seeds add an extra dimension to dhals and aids in their digestion. Some of the more unusual preparations include lentil cakes made from raw, soaked, and crushed lentils known as Varhia. Mongorhis are a similar food but are deep fried in hot oil after making into cakes. Alternatively, the entire lentil component can be ground to a flour and water used with other ingredients to make into a batter and used to make individual lentil cake or used to coat other vegetables.

Cowpeas (*Vigna unguiculata*): (lobia, rajmah, raean, kidney beans, blackeye bean, French bean)

One of the common pulses used in Asia is *lobia* (*lobiya*), which is represented by various species in English such as (i) kidney beans, blackeye beans, southern peas, colossus peas, crowther peas, French bean, or garden beans, in Hindi it is referred to as bakla, frash bean, or rajmah (*Phaseolus vulgaris Linn*), (ii) cowpea (*Vigna unguiculata Linn*) or (*Vigna sinensis*) in Hindi is called as rianishi, rawan, or santa. Lobia or cowpea with reference to *V. unguiculata* is discussed here. This pulse is indigenous to Africa and is commonly consumed in Eastern Africa, Central America, and Asia. It is the second important source of protein, next to meat in Nigeria.

The protein present in Cowpeas is rich in essential amino acids, isoleucine, lysine, and phenylalanine. The cowpea is a promising source of many minerals such as calcium, potassium, phosphorus, zinc, and iron. The seeds when mixed in the diet are a good source of nutrients for children (Akinyele and Akinlosotu, 1987). The condensed tannins are found bound to proteins or the neutral detergent fibers (NDFs; Baloyi et al., 2001). Several heat treatments are employed for preparations before cowpeas can be consumed. These include boiling to an eating-soft condition (atmospheric boiling), pressure cooking, steaming, frying, and roasting. Fried cowpea ball or akara is commonly consumed in Nigeria and other African countries because of its crisp and crunchy texture. It is usually consumed together with akamu (fermented corn starch gruel) or with eko (moulded akamu) as part of a family breakfast. Testa-free cowpea cotyledons can also be ground into dry flours or wet paste using mortar and pestle, grinding stones, or village hammer mills (Uzogara and Ofuya, 1992). A cowpea powder with no beany flavor adequate for use in bakery products (Tables 2 and 3) had earlier been developed by Okaka and Potter (1977). Olopade et al. (2003) prepared akara by using cowpeas processed in different ways and found that akara from reconstituted foam mat-dried and ground dry paste flours were less acceptable.

Different types of porridge can be produced by extrusion of the cowpea with sorghum by using a twin screw extruder. An increased proportion of cowpeas resulted in an increase in protein content, nitrogen solubility index, yellow color, water absorption (WAI) and solubility indices, and a decrease in total starch, enzyme-susceptible starch, expansion ratio, and porridge firmness (Pelembe et al., 2002). Mcwatter et al. (2004) made bread with 15% extruded cowpea flour and found no significant difference from all wheat control in sensory quality and acceptability. More food uses of cowpea are given in Table 4. The vicilin, a globulin from cowpea and green pea seed, has shown excellent emulsifying properties for perspective use in food

Table 2 Composition of wheat flour, cowpea powders, and blends

	Powders and blends								
Composition (%)	A	B	C	D	E	F	G	H	I
Moisture	11.14	3.62	2.9	10.68	10.94	10.02	10.16	9.08	9.07
Protein	13.25	22.77	22.55	14.2	14.2	15.2	15.1	16.1	16.0
Crude fat	2.31	1.46	1.50	2.23	2.29	2.14	2.15	2.06	2.07
Total ash	1.35	3.11	3.19	1.6	1.65	1.73	1.8	1.93	1.95
Carbohydrates	71.95	69.03	69.086	71.3	70.9	70.9	70.8	70.8	70.9
Bulk density (g/cc)	0.63	0.53	—	0.62	—	0.61	—	0.60	—

Note: A = wheat flour, B = cowpea powder without methionine, C = cowpea powder with methionine, D = 90/10 wheat flour-cowpea powder* blend, E = 90/10 wheat flour-cowpea powder blend, F = 80/20 wheat flour-cowpea powder blend, G = 80/20 wheat flour-cowpea powder* blend, H = 70/30 wheat flour-cowpea powder blend, I = 70/30 wheat flour-cowpea powder blend.
*Cowpea powder supplemented with 0.4% DL-methionine.

industries (Rangel et al., 2003). The other functional properties of cowpea isoelectric-protein-isolates, such as aromatic hydrophobicity, heat coagulability, and fluorescence intensity has been reported earlier that have suggested its use for commercialization (Aluko and Yada, 1997). Recently, the nutritional quality has been improved by removing the ANFs from seed powder by treating it with 60% ethanol, and the product is suitable in infant feeding (Alain et al., 2007). As early as, about two decades ago, the cowpeas have been declared safe and infant food for Nigerian babies is already reported (Oyele et al., 1985). The powdered weaning foods of high nutritional value have been prepared using germinated cowpea, which generally has high nutrient density (Jirapa et al., 2001). Cowpeas have a great potential in upgrading traditional weaning foods based on cereal consumed in that area (Oyeleke et al., 1985). The beans are sometimes fed as the main food to infants in developing countries unless such infants show intolerance to the cowpea diet. Bressani (1985) stated that a food product for weaning small children made of 75 7% cereal grain and 25% cowpea would be about 13% good-quality protein. The leaves of the plant are also nutrient rich and show potentials for product development (Ahenkora et al., 1998). Three cultivar of cowpeas were blended with either rice, corn, or both rice and corn and banana puree. The blends were dry extruded and found that the average protein was 20% while trypsin inhibitor activity was reduced by 63–84% (Akinyele et al., 1988).

Cowpeas are a potential alternative substrate for making fermented products in countries where soybeans are not locally available (Prinyawiwatkul et al., 1997). Changes in composition and functional properties of cowpeas fermented with *Rhizopus oligosporus*, the mold used in the preparation of tempeh, have been described. A simplified solid-state fermentation for preparing flour from nondecorticated cowpeas results in elimination of sucrose, stachyose, and raffinose (Prinyawiwatkul et al., 1996a). Lactic acid bacterial fermentation of aqueous extracts of cowpeas has been investigated as a method to produce substitutes for fermented milk products such as yogurt, sour cream, and buttermilk. Flour made from cowpeas fermented with *R. oligosporus* possesses functional properties different from the flour of nonfermented cowpeas. Fermented flour has less packed density but greater unpacked density than control flour (Prinyawiwatkul et al., 1996b).

Table 3 Basic bread making formula by using cowpea flour

Ingredients	Parts by wt
Wheat flour cowpea powder blend	100
Sugar	5.5
Salt	1.5
Yeast compressed	3.0
Dough conditioner	0.5
Vegetable shortening	3.0
Monoglycerides	0.5
Water	Variable

Wheat flour and corn tortillas are a staple food in many countries and growing in popularity in the United States. The usual ingredients are flour, salt, shortening, and water with the flattened pieces of dough cooked in a pan or on a griddle. Modeling, optimization, and verification procedures were used to evaluate the performance of cowpeas, peanuts, and wheat in preparation of tortillas (Holt et al., 1992). Substitution of wheat flour with 0–24% cowpea flour, 0–46% peanut flour, and their combinations resulted in tortillas with quality characteristics similar to 100% wheat. These findings and the mixture design approach are useful in the development of baked goods using flours derived from indigenous sources in areas where wheat flour is not widely available.

Despite their excellent nutritional quality, cowpeas contain a number of ANFs that limit their consumption and utilization. Among these are the indigestible oligosaccharides, raffinose, stachyose, and verbascose. These sugars are not utilized by monogastric animals, including humans, who lack the specific α-galactosidase enzyme needed to digest them. One of the common ANFs present is a trypsin inhibitor, four protenaseous isoinhibitors of peculiar peptide chain with the absence of –SH group (cystiene) tryptophan and methionine have been isolated from cowpeas. Two of them consist 96 residues, while the other two have 80 amino acids present in the peptide chain (Sammour, 2006). It has been pointed out that the cowpea protein isolates may be improved for their functionality to be utilized for product development after enzymatic or chemical modifications (Horax et al., 2004). The fat extracted from cowpeas having less saponification/acid value and high profile of unsaturated fatty

Table 4 Food uses of cowpea

Cowpea food	Description	Uses
Akara	Fried cowpea ball	Breakfast foods and snacks
Moin-moin	Steamed cowpea paste	Lunch and dinner foods
Ewa-ibji	Boiled whole cowpea	Lunch and dinner foods
Danwake	Boiled dehulled cowpea	Lunch and dinner foods
Gbegiri	Cowpea soup	Appetizers
Adayi	Cowpea puree	Pure baby foods
Cowpea spread	Boiled mashed cowpeas with fat and seasoning	Spread on bread and yam
Roasted cowpea	Flavored roasted cowpea	Snack food
Cowpea bread	Local bread made with cereal flour and cowpea flour	Breakfast, lunch, and snack food
Cowpea cake	Cowpea used as ingredient in cakes and pies	Breakfast and snack food
Rice and beans jollof	Boiled rice and boiled cowpea seed	Food for adults
Akidi-na-oka	Dish of maize, cowpea	Food for adults
Cowpea sorghum dish	Boiled sorghum and cowpea	Food for adult
Cowpea plantain potage	Boiled cowpea and plantain	Food for adult
Cowpea yam potage	Boiled cowpea and yam	Food for adult
Cowpea weaning food	De-hulled, boiled cowpea supplemented to cereal-based infant foods	Infants, children food

acids is recommended as safe use for supplementation in human nutrition (Onwuliri, 2002).

B. gram (*Vigna mungo* (L) Hepper): (Common name: mungo bean, mung bean urd, urid, urad)

B. gram is an important grain legume widely grown in the tropical and subtropical regions of the Indian subcontinent and is locally known as Urad or Mash. B. gram is boiled and eaten whole or after splitting into dhal. It is extensively used in various culinary preparation like curries and papad. The green pods are eaten as vegetables and they are highly nutritious. B. gram is consumed mainly as dal in India and this dal is an important ingredient in the diet of Indian people. This is ground into flour or paste and used in culinary preparation like idle, dosa, and paped (Anonymous, 2006).

The B. gram is highly rich in protein with excellent amino acid profile. The protein content varies between 22 and 25% and the essential amino acid score is comparable to good animal proteins, however biological values as digestibility, Net Protein Utilization (NPU), and protein efficiency ratio (PER) are low (Vijayaraghavan and Srinivasan, 1983). Geervani and Theophilus (1981) mentioned that starches from B. gram and G. gram showed significant differences in PER when fed to rats on 10% casein diet. Only B. gram and G. gram starches supported growth similar to corn starch. They further mentioned that availability of lysine and methionine to rats fed B. gram and G. gram starch was more than the rats fed on red gram and Bengal gram starches. B. gram-like rice showed tolerance while growing in the soil with industrial effluents, however toxic substances were absorbed to a certain extent (Niroula, 2003).

The consumption of B. gram is found to be hypocholestrolemic because of its NDF as shown by feeding experiments on rats (Indira and Kurup, 1989). The nutritional facts are well studied. The bile acids, which form complexes with the dietary fibers are associated for lowering the risk for CHD by 22% (Bazzano et al., 2001). B. gram and chickpeas are also known to contain a substantial amount of saponins. Saponins have been shown to possess a plasma cholesterol-lowering effect in experimental animals. Saponins may have considerable physiological significance in reducing the risk of heart disease within people having pulse in their diet. Processing of B. gram and Chickpea has determinant effect on the quantity of Saponins present in these pulses (Tables 5 and 6) (Jood et al., 1986). However, two major lectins are characterized in B. gram, lectins are usually inactivate during various steps of processing and are normally present in all foods (Suseelan et al., 1997). Tannins are another type of antinutrient present in most of the beans and nutritional implications have been reviewed, which reflects no adverse effect in product developments (Reddy et al., 1985).

B. gram flour of germinated and roasted seeds consisting of suitable physicochemical characteristics, showed minimal adverse effect upon optimal (25%) substitution in soft wheat

Table 5 Gelatinization temperature ranges for the isolated and modified black gram starches

Treatment	Gelatinization temperature range (°C)		
	Initiation	Midpoint	Completion
Isolated starch	71.5	73.0	74.0
Low-moisture heat treatment[a]			
18% moisture	66.0	68.0	70.0
21% moisture	65.0	68.0	70.0
24% moisture	65.0	68.0	70.0
27% moisture	65.0	68.0	70.0
High-moisture heat treatment[b]			
60°C	72.0	76.0	78.0
70°C	72.0	76.0	78.0
80°C		Completely gelatinized	
95°C		Completely gelatinized	
Chemical modification			
Acetylation	63.0	66.0	68.0
Oxidation	63.0	66.0	68.0
Cross-linking	68.0	71.0	73.0
Added fatty acids			
Palmitic acid	70.0	74.0	77.0
Stearic acid	71.0	73.0	75.0
Linoleic acid	71.0	74.0	76.0

[a]16 hours at 100°C.

[b]Heated for 30 minutes in excess water (1:10 w/v starch-to-water ratio).

Table 6 L values, gelation, water, and oil absorption of modified black gram starches

Treatment	L value[a]	Least[b] gelation conc.% w/v	Water absorption[b] g/g	Oil absorption[b] g/g
Isolated starch	84.6	5	3.04	2.76
Low-moisture heat treatment[c]				
18% moisture	72.1	6	2.25	2.03
21% moisture	77.5	8	2.75	2.5
24% moisture	77.4	6	2.25	2.08
27% moisture	72.8	6	2.28	2.03
LSD[d]	1.28		0.094	0.332
High-moisture heat treatment[e]				
60°C	80.3	8	3.5	3.34
70°C	79.4	8	3.75	3.61
80°C	78.9	6	6.09	5.69
95°C	82.3	5	7.71	5.98
LSD	1.74		0.119	0.189
Chemical modification				
Acetylation	85.9	16	2.83	6.73
Oxidation	90.1	10	2.13	6.85
Cross-linking	83.5	14	3.13	1.19
LSD	1.29		0.280	0.384
Added fatty acids				
Palmitic acid	85.1	12	2.74	2.51
Stearic acid	84.8	8	2.96	2.55
Linoleic acid	86.0	14	2.74	2.57
LSD	1.76		0.208	0.231

[a]Mean of five determinations, standard white, $L = 94.9$.
[b]Mean of duplicate determinations on a dry weight basis.
[c]16 hours at 100°C.
[d]Least significant difference at $P = 0.05$. Difference of two means exceeding this value are significant.
[e]Heated for 30 minutes in excess water (1:10 w/v, starch-to-water ratio).

flour for biscuit/cookie production. In general, roasting improves dough development and baking performance (Patel and Rao, 1995). The beans have dark green coat which itself is nutrient dense and shows high potentials for commercial exploitation. The husk of B. gram has shown the ability to detoxify the water by eliminating cadmium after binding with its fibers (Saeed and Iqbal, 2003). On the other hand, the B. gram induces immunoglobulin E-mediated reactions significantly causing asthma and allergic rhinitis. Pentosans are generally quantified in wheat flour as an indicator of bran left as fiber and in B. gram the quantity of pentosans is 7.41% while in rice these are 0.16% (Pradkar et al., 2002).

The highest relative breakdown was noticed in the pasting profile of B. gram alone, probably because of the presence of mucilaginous principle. Highest relative breakdown values increased in batter to various extents, before and after fermentation, compared with physical combination of rice and B. gram (Kyung and Vasudeva 2009). Deshpande et al. (1982) mentioned that low-moisture, high-temperature treatments of B. gram starch caused a decrease of 4°C in the final gelatinization temperatures. The high-moisture, high-temperature (at 60 and 70°C) treatment increase the final gelatinization temperature by 4°C, as did the addition of free fatty acids (Table 5). Low-moisture, high-temperature treatment decreased whiteness while oxidation sharpened it (Table 6). They also found that starches treated at 80 and 95°C in excess water were more soluble compared to those isolated at these temperatures. Rich and Goddard (1992) mentioned adherent, popable, nonexpandable coating of cooked dough preferably comprises B. gram or urid (*Phaseolus mungo* L.; *V. mungo* L.) flour, but in addition to this flour also other types of flour, such as wheat flour, wholemeal wheat flour, or soybean flour can be used for preparing this coating.

Pigeon pea (*Cajanus cajan* L): (Common name: Red gram, tur, arhar, toovar, toor)

The 100 g of pigeon peas provide 301 kcal as the other beans caloric value of pulses varies from 302 to 347 kcal, lentil provide the least while chickpeas give the highest caloric value. The dietary fibers in chickpeas are quite low comprising (11.9) as compared to kidney beans giving 25.4 g/100 g (Amarteifio et al., 2002). A low quantity of fibers is related to high-energy profile. A review has been published about processing, incorporation, and utilization of cowpeas in developing countries, which indicates the possibilities of using the pigeon pea and other peas to be used in new product development for commercialization (Uzogara and Ofuya, 1992).

In human nutrition, pigeon peas play a promising role. Plant protein provides 80% of the protein requirement in developing countries while only 43% is consumed by the population living in the developed part of the world. Pigeon peas help in overcoming malnutrition and deficiencies of mineral and other micronutrients. Malnutrition, a major cause of many diseases, is prevailing rapidly in developing countries of the world. In this case, pigeon pea in a poor man's diet may play its part in overcoming malnutrition especially the protein deficiencies. The fermented pigeon pea has further improved the bioavailability of certain nutrients and the fermented pigeon pea when supplemented in pasta increased its PER and true protein digestibility by 72% and 6%, respectively (Torres et al., 2006).

The cream color bean known in Hindi and Urdu as Arhar is a tropical grain legume having huge industrial importance. The most common use of pigeon peas is the preparation of curry, popularly known as "dal" in India, Pakistan, and Bangladesh. It is prepared in most of the households as well as restaurants, dhabas, canteens, hotels, and even during social ceremonies. Certain other food and snack preparations are also made from pigeon peas. The pigeon pea is suitable for growing in adverse environmental conditions as it is drought tolerant, and grows in the semiarid tropics. It is unique among the pulses, which show optimal nutritional profiles, high tolerance to eliminate stresses, providing high-biomass productivity, and simultaneously it contributes moisture and nutrient to the soil (Odeny, 2007). In view of its excellent nutrient profile, the pigeon pea was incorporated in an isocaloric and isonitrogeous diet for broiler chicks. The results indicated decreased feed intake, weight gain, and gain in serum proteins. The feed appeared to be suitable for a nutraceutical product development as the total serum triglycerides of the birds was decreased after a few weeks (Saeed and Abdel, 2007). The processing (boiling and toasting) of pigeon pea seeds significantly improved nutrient utilization and crude

Table 7 Effect of adding pigeon pea flour on different attributes of extrudates

Pigeon pea flour (%)	Expansion	Bulk density g/cm^3	WAI* g gel/g sample	WSI**%
0	1.68^a	0.27^d	4.0^d	35.8^a
5	1.55^b	0.29^c	4.5^c	34.6^b
10	1.38^c	0.30^b	4.8^b	32.6^c
15	1.18^d	0.33^a	6.0^a	30.6^d

Note: Mean followed by different superscripts in the same column are different ($P < 0.05$).
*Water absorption index.
**Water solubility index.

protein retention of pigeon pea seed meals and pigeon pea seed meal-based diets by pullets (Amaefule and Nwagbara, 2004).

In the West Indies, pigeon pea—also known as congo bean, or goongopea is grown on small farms of less than 2-hectare farm size and more than 60% of production is processed into canned pigeon pea, about 15% is sold as mature, green, fresh peas; and negligible quantities are frozen (Muller et al 1990). Rampersad et al. (2003) investigated the effects of pigeon pea flour in addition to cassava flour on the sensory and physico-chemical quality of extrudates. They found that products with added pigeon pea flour were more yellow, had higher protein, bulk density, and WAI with lower expansion. Extrudates with 95% cassava flour and 5% pigeon pea flour had a suitable crisp to hard texture. All enrobed products were liked moderately to very much in overall acceptability. Chocolate extrudates were most liked ($P < 0.01$) for flavor and color over paprika, hickory, and cheese/onion (Table 7).

Dry green Peas (Pisum sativum L.)

The green peas or garden pea weighs between 0.1 and 0.36 g and is mostly used fresh, however dried, frozen, or canned products are also available. The functional properties of peas and its products are suitable for industrial product developments. The metabolic utilization of proteins and carbohydrates was significantly improved by mild hydrothermal treatment without adding phytase as indicated by PER and food transformation growth indices in feeding experiments on rats (Urbano et al., 2003). It has been documented that raw green peas are hypocholestrolemic in view of their impact on increased fecal bile acids excretion and elevated biliary bile acid concentration (Martins et al., 2004). The scope of germinated peas significantly improved the nutritive utilization of proteins and carbohydrates in terms of digestibility, palatability, and nutrient availability as compared to the raw peas (Urbano et al., 2005). The antinutrient proteins are also found in peas and a mitogenic, dimeric lectin of molecular weight of 49,000 with 0.5% carbohydrates by weight has already been isolated. The lectins are recognized much earlier as specific reagents to probe the distribution of saccharide residues at the surface of the cells present in biological fluid and play a useful role in nutrition, especially to stimulate lymphocytes by binding with sugars (Trowbridge, 1974).

The favorable production of traits needs elimination or detoxification of ANFs. A methodology based on treatments with vapors, organic acids, and selected oxides reduced the activities of ANFs, especially trypsin inhibition units were reduced by 83.8%, 80.5%, and 83.8% respectively (Dvorak et al., 2005). It is also suggested that application of hurdle technology will be a better choice to face the problem of removal of ANFs. The protein-rich pea flour mixed with wheat flour is a suitable raw material for making novel products from extrusion, baking, frying, etc.

The pea plant has successfully been grown in a salinity area after putrescine application that improved all metabolic activities in the plant under induced salty stress conditions. The treatments not only give the plant more tolerance but increased the amount of certain amino acids (Hussein et al., 2006). The green pea proteins are highly functional and good emulsifying, gelling, and water absorption properties have enabled the pea powder to be used for supplementation in soups, bakery, and puffed products. The legume shows potentials to be used in food industries for a variety of purposes.

Total carbohydrates, mono-, di-, and oligosaccharides, and soluble and insoluble dietary fiber were determined before and after extrusion cooking under specific processing conditions for different legumes. Dry pea showed the highest concentration of total available carbohydrates (TAC), followed by chickpea and lentil. Extrusion processing did not significantly affect the TAC content of dry pea and lentil flours. However, extrusion processing decreased the concentration of the raffinose family of oligosaccharides (raffinose and stachyose) in pulse extrudates. Formulated pulse flours demonstrated a beneficial increase in dietary fiber. This research indicates that value-added, nutritious snacks with reduced levels of flatulence factors and higher contents of dietary fiber can be fabricated successfully by extrusion processing of formulations based on lentil, dry pea, or chickpea, and represent good alternatives to traditional cereal-based snacks. Also, the commercialization of value-added, pulse-based snacks would increase pulse consumption (Berrios et al., 2010).

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