Food Legumes for Nutritional Security and Health Benefits

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Abstract

In India, over a dozen of pulse crops, viz. chickpea, pigeon pea, cowpea, mung bean, urdbean, lentil, French bean, horse gram, field pea, moth bean, lathyrus, etc., are grown in one or on the other part of the country. Pulse seeds contain 16–50 % protein and provide one third of all dietary protein nitrogen. Therefore, pulses in combination with cereals provide one of the best solutions to protein calorie malnutrition, especially in the developing countries. These are also an important source of the 15 essential minerals needed by humans. Despite their importance in human health and nutrition, the global food legume production has witnessed only a marginal annual increase of 0.95 % with fluctuations only from 40.78 to 70 million tonnes. The slow growth in global pulses production along with rising population, diversified uses for end products and improved purchasing capacity of people has put tremendous pressure on per capita availability of pulses. In addition, decreasing cultivable land and factor productivity, biotic and abiotic stresses and unavailability of quality seeds have further strained the pulse supply chain. Nevertheless, this may be compensated to some extent by proper storage and pre- and postharvest management of pulses, value addition and manufacturing of value-added products. This chapter discusses the role of pulses for nutritional quality and health benefits.

Keywords

Biofortification • Cancer • Health • Nutrition • Pulses

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4.1 Introduction

Pulses – with high protein content and 15 essential minerals – are the most important constituents of cereal-based vegetarian diets of

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the Indian subcontinent. Owing to their diverse uses as atmospheric nitrogen fixing agents, green manure and cover crops, catch crops in short season cropping windows, breakfast grains and ingredients of specialty diets, pulses are rightly a subject of agricultural, environmental and biotechnological research. In India, over a dozen of pulse crops including chickpea, pigeon pea, cowpea, mung bean, urdbean, lentil, French bean, horse gram, field pea, moth bean, lathyrus, etc. are grown in one or on the other part of the country. The most important pulse crops grown here are chickpea (41 %), pigeon pea (15 %), urdbean (10 %), mung bean (9 %), cowpea (7 %) lentil (5 %) and field pea (5 %).

Pulse seeds contain 16–50 % protein and provide one third of all dietary protein nitrogen. Therefore, pulses in combination with cereals provide one of the best solutions to protein calorie malnutrition, especially in the developing countries. Besides proteins, these are also an important source of the 15 essential minerals needed by humans (Wang et al. 2009). Consumption of pulses on a regular basis has been associated with lower risks for the development of type 2 diabetes, coronary heart disease and some forms of cancer (Chibbar et al. 2010). Those who consume pulses also tend to have lower rates of obesity and metabolic syndrome (Rizkalla et al. 2002). Therefore, a number of countries recommend that people should consume pulses as part of a healthy diet (USDA 2013).

Despite their so much importance in human health and nutrition, the global food legume production except groundnut and soybean has witnessed only a marginal annual increase of 0.95 % with fluctuations only from 40.78 to 70 million tonnes. The slow growth in global pulse production along with rising population, diversified uses for end products and improved purchasing capacity of people has put tremendous pressure on per capita availability of pulses. In addition, decreasing cultivable land and factor productivity, biotic and abiotic stresses and unavailability of quality seeds have further strained the pulse supply chain. Nevertheless, this may be compensated to some extent by proper storage and pre- and postharvest management of pulses, value addition and manufacturing of quality nutritional products.

4.2 Statistics of Pulses

Globally, the major pulses are grown over an area of 80.75 million ha with a production of 73.07 million tonnes. The major pulse-growing countries of the world include Myanmar, Brazil, China, Canada and Australia besides India which is the largest producer as well as consumer of pulses with 25 % share in the global production. Among different pulses, dry beans are the most widely cultivated pulses in the world, grown over 29.23 million ha with a production of 23.14 million tonnes. This is followed by chickpea (13.54 million ha), cowpeas (dry, 11.32 million ha), peas (6.38 million ha) and pigeon pea (6.22 million ha) (Table 4.1). However, as far as productivity is concerned, field pea (1721 kg/ha) records highest productivity globally followed by lentil (1140 kg/ha) and chickpea (968 kg/ha).

India has 23.47 million ha area under pulses during 2012–2013 (Table 4.2). Over a dozen

Table 4.1 Area, production and productivity of different pulses in the world

Crops	Area (m. ha)	Prod. (m.ton)	Yield (kg/ha)
Beans (dry)	29.23	23.14	792
Chickpea	13.54	13.10	968
Cowpeas (dry)	11.32	5.72	505
Peas (dry)	6.38	10.98	1721
Pigeon pea	6.22	4.74	762
Lentil	4.34	4.95	1140
Others	9.72	10.44	1074
Total	80.75	73.07	904

Table 4.2 Country-wise area, production and productivity of pulses in the world during 2012–2013

Countries	Area (m. ha)	Production (m.ton)	Yield (kg/ha)
India	28.17	19.27	781
Myanmar	3.88	5.44	1398
Brazil	2.85	2.95	1032
China	2.87	4.46	1550
Canada	2.42	6.10	2520
Australia	1.92	2.70	1410
USA	1.09	2.23	2038
Others	37.55	29.88	796
Total	80.75	73.07	904

Table 4.3 Crop wise area, production and productivity of pulses in India

Crops	Area (m. ha)	Production (m.ton)	Yield (kg/ha)
2013–2014			
Chickpea	9.19	9.53	1075
Pigeon pea	3.88	3.17	817
2012–2013			
Mung bean	2.75	1.19	432
Urdbean	3.19	1.90	596
Lentil	1.42	1.13	797
Peas	0.76	0.84	1105
Lathyrus	0.58	0.43	742
2011–2012			
Horse gram	0.24	0.10	485
Moth bean	1.37	0.47	346

pulse crops including chickpea (*Cicer arietinum*), pigeon pea (*Cajanus cajan*), mung bean (*Vigna radiata*), urdbean (*Vigna mungo*), cowpea (*V. unguiculata*), lentil (*Lens culinaris* ssp. *Culinaris*), lathyrus (*Lathyrus sativus* L.), French bean (*Phaseolus vulgaris*), horse gram (*Macrotyloma uniflorum*), field pea (*Pisum sativum*), moth bean (*V. aconitifolia*), etc. are grown in one or on the other parts of the country. However, the most important pulse crops grown here are chickpea (48 %), pigeon pea (15 %), mung bean (7 %), urdbean (7 %), lentil (5 %) and field pea (5 %). Crop wise, chickpea (9.19 million ha) occupies the largest area in the country with a production of 9.53 million ha and productivity of 1075 kg/ha (Table 4.3). This is followed by pigeon pea (3.88 million ha) and urdbean (3.19 million ha).

The production of pulses in India has tremendously improved during the last 2 years recording an all-time high record of 19.27 million tonnes during 2013–2014 (Table 4.4). Still, to meet the current demand, about two to three million tonnes of pulses need to be imported every year. Due to a production gap, increasing population and diversity of uses of pulses, the per capita availability of pulses has declined progressively from 41.6 g/day/capita in 1991 to 38 g in 2009 (against ICMR recommendation is 65 g/day/capita). Therefore, the production has to be increased to meet the domestic requirement. In order to ensure self-sufficiency, the pulse requirement in the country is projected to be about 39 million tonnes by 2050 which necessitates an annual growth rate of 4.0 %. This requires a paradigm shift in research, technology generation and dissemination and commercialization along with capacity building in frontier areas of research. To meet the projected requirement of pulses, the productivity needs to

Table 4.4 Trends in area production and productivity of pulses in India

Year	Area (m. ha)	Production (m. ton)	Yield (kg/ha)
2007–2008	23.63	14.76	625
2008–2009	22.09	14.57	659
2009–2010	23.28	14.66	630
2010–2011	26.28	18.24	694
2011–2012	24.78	17.09	690
2012–2013	23.47	18.34	781
2013–2014	NA	19.27	NA
2014–2015	NA	18.43[a]	NA

[a]Advance estimates

be raised to about 1200 kg per ha, and about three to six million ha additional area has to be brought under pulses.

4.3 Constraints in Increasing Pulse Production

The existing varieties of pulses have tremendous yield potential as demonstrated in experimental field and demonstrations. Nevertheless, the realized yield in most of the pulses is far from the potential yield ultimately leading to a shortfall in their total production. This shortfall has been attributed to a number of factors: geographical shift, abrupt climatic changes, complex disease-pest syndrome, socioeconomic conditions of the farmers and less market opportunities. The major constraints that limit the realization of potential yield of pulses include biotic and abiotic stresses prevalent in the pulse-growing areas besides socioeconomic factors. Among biotic stresses, *Fusarium* wilt coupled with root rot complex is probably the most widespread disease causing substantial losses to chickpea. While *Fusarium* wilt, sterility mosaic and phytophthora blight cause substantial losses in pigeon pea, yellow mosaic, *Cercospora* leaf spot and powdery mildew are considered as the most important diseases in both mung bean and urdbean. In lentil, the rust, powdery mildew and wilt cause considerable damage. Among key insect pests, gram pod borer (*Helicoverpa armigera*) in chickpea and pigeon pea, pod fly in pigeon pea and whitefly, jassids and thrips in dry beans cause severe damage to the respective crops. Weeds also cause substantial loss to pulses. Recently, nematodes have emerged as potential threat to the successful cultivation of pulses in many areas.

Among abiotic stresses, drought and high temperature at terminal stage, cold and sudden drop in temperature coupled with fog during the reproductive phase and salinity/alkalinity throughout the crop period inflict major yield losses and instability in production. All these stresses make pulse crops less productive with unstable performance in one or the other way.

4.4 Nutritional Composition of Pulses

Numerous studies have been conducted for estimating genetic variability for protein content as well as other micro- and macronutrients among a number of accessions of various pulses. A large amount of genetic variability was found to be available for these traits (Table 4.5). For example, protein content in different pulses varied from 26.5 to 57 % in soybean (Dwivedi et al. 1990), 20.9 to 29.2 % in common bean, 15.8 to 32.1 % in pea, 22 to 36 % in faba bean, 19 to 32 % in lentil, 16 to 28 % in chickpea, 16 to 31 % in cowpea, 21 to 31 % in mung bean and 16 to 24 % in pigeon pea (Burstin et al. 2011).

Pulses provide from 1040 to 1430 kJ per 100 g (similar to cereal grains), mostly by carbohydrates rather than fat. The carbohydrate content in pulses is about 60 %. The mono- and oligosaccharides represent only a small per cent of total carbohydrate in pulses, whereas starch is

Table 4.5 Range of variation (% of seed weight) in principal constituents of seeds of pulses

	Content (%)				
Protein	Oil	Starch	Fibre	Sucrose	Reference
Soybean					
35.1–42	17.7–21	1.5	20	6.2	Hedley (2001)
0–45	19–21.5	–	–	–	Hyten et al. (2004)
41.8–49.4	15.2–20.7	–	–	–	Chung et al. (2003)
40.4–50.6	13.4–21.2	–	–	–	Brummer et al. (1997)
26.5–47.6	–	–	–	–	Vollman et al. (2000)
Common bean					
20.9–27.8	0.9–2.4	41.5	10	5	Hedley (2001)
23–29.2	–	–	–	–	Coelho et al. (2009)
Pea					
18.3–31	0.6–5.5	45	12	2.1	Hedley (2001)
24–32.4	–	45.5–54.2	8.9–11.9	–	Gabriel et al. (2008)
20.6–27.3	–	–	–	–	Burstin et al. (2007)
Faba bean					
26.1–38	1.1–2.5	37–45.6	7.5–13.1	0.4–2.3	Duc et al. (1999)
22.4–36	1.2–4	41	12	3.3	Hedley (2001)
26–29.3	–	42.2–51.5	–	–	Avola et al. (2009)
Lentil					
23–32	0.8–2	46	12	2.9	Hedley (2001)
25.1–29.2	–	46–49.7	13.1–14.7	2.1–3.2	Wang et al. (2009)
Chickpea					
15.5–28.2	3.1–7	44.4	9	2	Hedley (2001)
18.7–21.1	–	42–45.1	–	–	Frimpong et al. (2009)
17.1–19.8	–	48–54.9	–	–	Frimpong et al. (2009)
Cowpea					
23.5	1.3	–	–	–	Hedley (2001)
24.8	1.9	–	6.3	–	Kabas et al. (2006)
20.9–36	2.6–4.2	–	–	–	Oluwatosin (1997)
16–31	2.4–4.3	–	–	–	Adekola and Oluleye (2007)
Mung bean					
21–31.3	1.2–1.6	–	8.9–12.9	–	Anwar et al. (2007)
23.7–31.4	–	–	–	–	Lawn and Rebetzke (2006)
Pigeon pea					
19.5–22.9	1.3–3.8	44.3	10	2.5	Hedley (2001)
15.9–24.1	–	–	–	–	Upadhyaya et al. (2007)

Modified from Burstin et al. 2011

the most abundant carbohydrate. Pulses generally have high amylose content. Among the sugars, raffinose, stachyose, verbascose, ajugose and pentosans predominate in most of the pulses. These sugars escape digestion in the gut and are fermented in the large bowel and can cause abdominal discomfort and flatulence if pulses are consumed in abundance. Soaking pulses overnight in plenty of water helps to reduce the content of these sugars. Pulses are low in fats (1–6 %), most of which is provided by polyunsaturated and monounsaturated fatty acids (Table 4.6). They are also fairly good sources of thiamine and niacin and provide calcium, phosphorus and iron. When consumed with the seed coat, pulses are much higher in dietary fibre than those that have been dehulled prior to consumption. There is a significant increase in nutrients in sprouted pulses when compared to their dried embryo. In the process of sprouting,

Table 4.6 Nutritional profile of pulse grains (per 100 g)

Pulses	Energy kcal	Protein (g)	Fat (g)	Carbohydrate (g)	Total dietary fibre (%)
Chickpea (*Cicer arietinum* L.)	368	21.0	5.7	61	22.7
Pigeon pea (*Cajanus cajan* L.)	342	21.7	1.49	62	15.5
Lentil (*Lens culinaris* Medik)	346	27.2	1.0	60	11.5
Mung bean (*Vigna radiata* L.)	345	25.0	1.1	62.6	16.3
Urdbean (*Vigna mungo* L.)	347	24.0	1.6	63.4	–
Field pea (*Pisum sativum* L.)	345	25.1	0.8	61.8	13.4
Rajmash (*Phaseolus vulgaris* L.)	345	23.0	1.3	62.7	17.7
Cowpea (*Vigna unguiculata*)	346	28.0	0.3	63.4	18.2
Horse gram (*Macrotyloma uniflorum*)	321	23.6	2.3	59.1	15.0
Moth bean (*Vigna aconitifolia*)	330	24.0	1.5	61.9	

the vitamins, minerals and protein increase substantially. Sprouting of the pulses not only improves nutritive value but also digestibility (Health Canada 2015). The nutritional profile of major pulses is described in Table 4.6.

4.4.1 Minerals and Vitamins

Pulses supply adequate vitamins and minerals. They are rich in iron, zinc, magnesium and phosphorus and contain more calcium than cereals. Pulses also contain more potassium which is important for the management of hypertension. They also contain some amount of manganese and copper. Beans and lentils have the highest iron content. Lentil contains 425–673 μg/kg of Se depending on location, soil characteristics and growing conditions. This potentially provides 80–120 % of the minimum recommended daily Se intake in only 100 g of dry lentil.

Pulse grains are a good source of B vitamins, especially thiamine, riboflavin, niacin, pyridoxal and pyridoxine (Table 4.7). The embryo of pulses contains vitamin E, a strong antioxidant. Dried pulses contain some amount of vitamin C, but pulse sprouts are good source of vitamin C. The vitamin C content rises from negligible levels to 12 mg/100 g after 18 h of germination. Pulses are also a good source of thiamine, riboflavin, niacin, pyridoxamine, pyridoxal and pyridoxine. Tocopherol content is higher in pulses than cereals. Peas contain greater amounts of α-than β + γ-tocopherols, and chickpea contains similar levels of α- and β + γ-tocopherols. The following table summarizes the content of vitamins in pulse grains.

4.4.2 Minerals

Beans and lentils have the highest iron and zinc contents, respectively (Table 4.8). Selenium (Se) is another essential micronutrient in human nutrition and is involved in important regulatory and protective mechanisms. It has been reported that lentil contains 425–763 ug/kg of Se depending on location, soil characteristics and growing conditions. This potentially provides 80–120 % of the minimum recommended daily Se intake in only 100 g of dry lentil. Chromium is involved in carbohydrate and lipid metabolism; the most frequent sign of Cr deficiency is altered

Table 4.7 Vitamin content in pulses (per 100 g)

Pulses	Thiamine (mg)	Riboflavin (mg)	Niacin (mg)	Pantothenic acid (mg)	Vitamin B6 (mg)	Folate (ug)	Vitamin C (mg)	Vitamin E (mg)
Chickpea	0.5	0.2	1.5	1.6	0.5	557	4	0.8
Pigeon pea	0.6	0.18	2.9	1.26	0.28	456	–	–
Lentil	0.8	0.2	2.6	2.21	0.54	479	4.4	0.3
Mung bean	0.6	0.2	2.2	1.9	0.4	625	4.8	0.5
Urdbean	0.6	0.2	2.3	–	0.2		4.8	
Field pea	0.7	0.2	2.9	1.8	0.2	274		0.3
Rajmash	0.53	0.22	2.08	0.79	0.4	399	1.8	–
Cowpea	0.94	0.22	2.36	1.39	0.44	545	4.6	–
Horse gram	0.4	0.2	1.5	–	–	–	–	–
Moth bean	0.4	0.09	1.5	–	–	–	–	–

Table 4.8 Mineral content in pulses (mg/100 g dried weight)

Pulses	Iron (mg)	Zinc (mg)	Calcium (mg)	Magnesium (mg)	Potassium (mg)	Sodium (mg)	Selenium (μg)
Chickpea	6.2	3.4	105	115	875	24	8.2
Pigeon pea	5.2	2.7	130	183	1392	17	–
Lentil	7.5	4.7	56	122	955	6	8.2
Mung bean	6.7	2.7	110	189	1246	15	8.2
Urdbean	8.4	3.5	55	–	–	–	–
Field pea	4.4	3.0	186	115	981	15	1.6
Rajmash	3.4	1.9	80.3	188	1316	18	12.9
Cowpea	7.54	3.77	287	250	1450	23	–
Horse gram	7.0	–	202	–	–	–	–
Moth bean	9.6	–	–	–	–	–	–

glucose tolerance. This nutrient has also been associated with diabetes and cardiovascular diseases. Provisionally, daily intake of 0.05–0.2 mg Cr has been recommended for adults. The level of Cr in pulses generally ranges between 0.05 and 0.60 Cr/g. Table 4.7 elaborates the content of different minerals in pulses.

4.4.3 Dietary Fibres

Pulse grains typically contain more dietary fibre (15–32 TDF) than cereals, and of this approximately one third to three quarters is insoluble and the remaining is soluble fibre. Insoluble fibre is associated with faecal bulking through its water-holding capacity, whereas soluble fibre ferments, positively affecting colon health through production of SCFA, lowered Ph and helps to slow gastric emptying rate.

4.4.4 Folic Acid

Beans have the highest folate content followed by mung bean, lentil and pea. Folate contents in raw chickpea and pea are 149.7 and 101.5 μg/100 g, respectively, and 78.8 and 45.7 μg/100 g in boiled chickpea and pea respectively, indicating that some folates might get leached in the water used for processing.

4.4.5 Nonnutritive Bioactive Components

A variety of phytochemicals are increasingly being recognized for their potential benefits for human health, which includes polyphenolic compounds, lectins, phytates and trypsin inhibitors, among others. Lignans and isoflavones have anticarcinogenic, weak oestrogenic and antioxidant properties. Phenolic compounds, including tannins found mainly in the seed coat, have antioxidant activity. Phytoestrogens in pulses may play a role in the prevention of hormone-related cancers, such as breast and prostate cancer. The lectins or haemagglutinins in some pulses are toxic when taken orally. They can cause vomiting, diarrhoea, nausea and bloating in humans. The enzyme inhibitors and lectins can even reduce protein digestibility and nutrient absorption, respectively, but both have little effect after cooking. Phytic acid can diminish mineral bioavailability. Some phenolic compounds reduce protein digestibility and mineral bioavailability, while galacto-oligosaccharides may induce flatulence. The lathyrus toxin in certain drought-resistant chickpeas can cause lathyrism, a neurological disorder, when consumed in large amounts. On the other hand, the same compounds may have protective effects against cancer. Phytic acid has antioxidant and DNA protective effects.

4.5 Health Benefits

4.5.1 Cardiovascular Health

Consumption of pulses has been shown to decrease serum LDL cholesterol and triglycerides (two major risk factors for CHD) as well as other risk factors, such as hypertension, diabetes and obesity. Among the food legumes, chickpea is the most hypocholesterolaemic agent; germinated chickpea was reported to be effective in controlling cholesterol level in rats. Further epidemiological data also suggest that pulse consumption could reduce the risk of cardiovascular disease.

4.5.2 Diabetes Management

Inclusion of pulses in a healthy diet can benefit those with diabetes and help prevent healthy people from becoming diabetic. Epidemiological studies strongly support the suggestion that high intakes of wholegrain foods protect against the development of type 2 diabetes mellitus. People who consume three or more servings of wholegrain foods per day are less likely to develop type 2 diabetes mellitus than low consumers with a 20–30 % risk reduction. Pulses share several qualities with whole grains of potential benefit to glycaemic control including slow release carbohydrate and a high fibre content. Pulses are low GI foods with GI values ranging from 28 to 52. Consumption of low GI foods (<55) results in moderate levels of glucose as opposed to high GI foods (>70), which causes rapid elevation in blood glucose.

4.5.3 Weight Management

Pulses are high in fibre and protein, low in fat and moderate in calories. About 100 g of cooked lentils or dry peas contains about half of the daily fibre recommendation for adults. Therefore, a combination of pulses with cereals helps people feel satisfied for a long time and therefore may help with weight management.

4.5.4 Celiac Disease

Celiac disease is the one in which the absorptive surface of the small intestine is damaged by glutens. Glutens are generally found in wheat, rye and barley. As compared with gluten-free alternatives of cereals, pulses are an excellent source of dietary proteins, minerals, vitamins and fibres. Pulses being rich in iron also supplement the celiac patients who otherwise suffer with iron and vitamin B deficiencies. Therefore, pulse flours are an excellent alternative to gluten-containing flour of cereals and provide valuable proteins and fibres in the form of baked foods prepared using the flours of pulses.

4.5.5 Pulses and Cancer Risk

Inverse correlations between pulse consumption and colon cancer mortality and risks of prostate cancer, gastric cancer and pancreatic cancer have been reported in several epidemiological studies. Many phytochemicals and bioactive components in pulses, viz. dietary fibre, oligosaccharides, folate, selenium, protease inhibitors, phytic avid, lignans, phenolics, saponins and isoflavones, are associated with anticarcinogenic activity.

4.6 Conclusions

Food legumes are the best option after cereals, not only because of their importance for humans and animals but also due to their soil ameliorative values and their ability to thrive under harsh and fragile environments. Keeping in view their importance for diversification and intensification of contemporary agriculture, systematic national and international efforts towards their genetic improvement have been taken which led to the development of a number of improved cultivars and development of their production technologies and also of crop management and protection. With the advent of modern techniques and availability of alien variations, precise and target-oriented research in genetic improvement of pulses has been underway globally towards the development of high-yielding, input-responsive, early maturing and high-nutrition varieties in pulses. This has led to production expansion of major pulses throughout the world. However, this is not sufficient to meet the ever-increasing demand. Intensified efforts must be initiated not only to increase the area and production of pulses but also to increase their nutritional quality better postharvest management and value addition besides suppressing their anti-nutritional factors. There is still a strong need of developing new references on nutritional aspects and health promoting values of pulses to promote their cultivation and industrialization throughout the world. Pulses in combination with cereals offer a miraculous solution to protein calorie malnutrition in the developing nations and, if given due attention, may definitely help in eradication of this prolonged predicament from the world.

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