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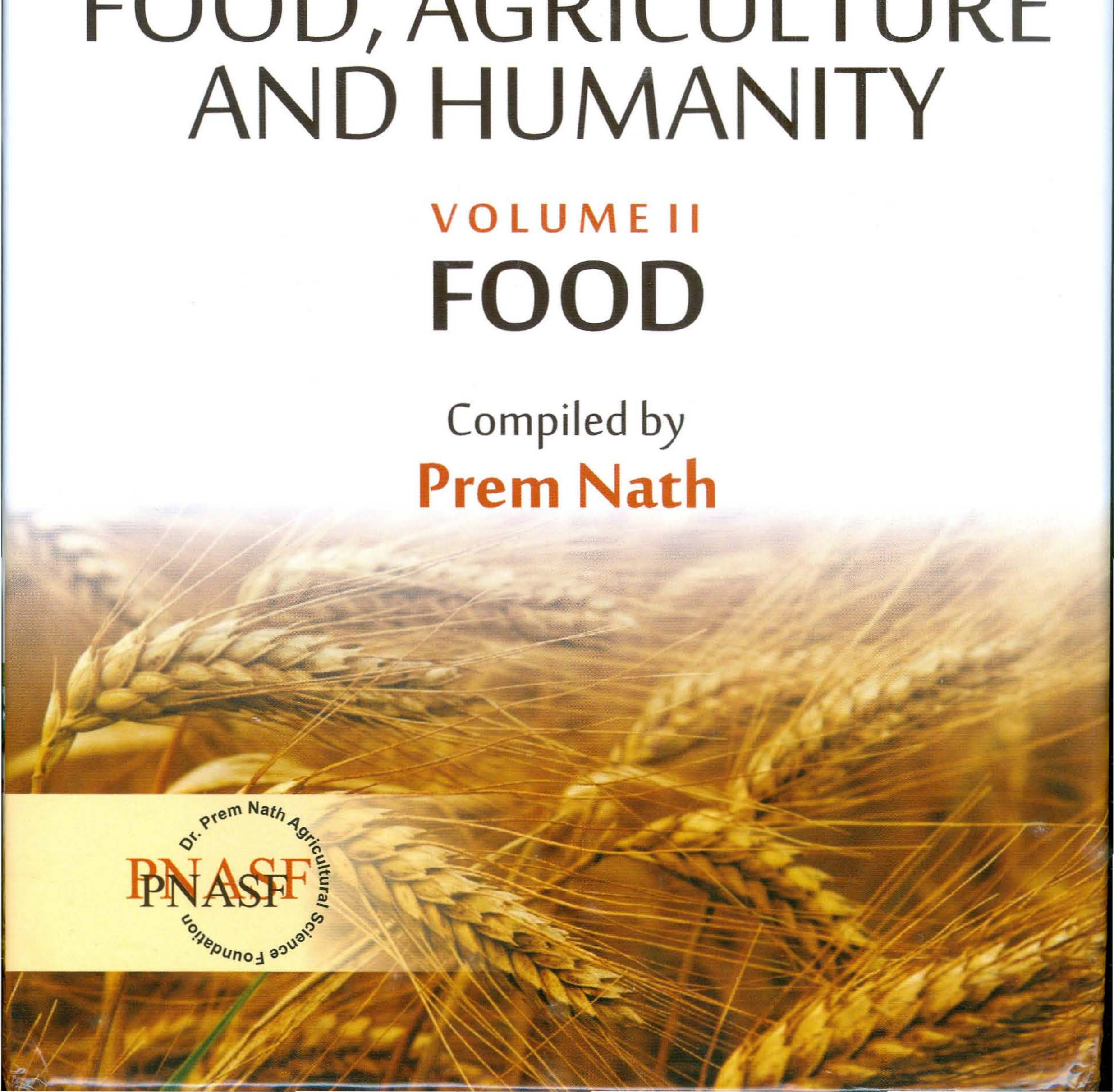

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Contribution of Grain Legumes in Combating Food and Nutrition In-Security in Different Regions of the World

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SYNOPSIS

Food security is a complex issue, linked to availability and access to food, malnutrition in the population, economic development, environment, and local and global trade. Malnutrition hinders healthy growth and proper development of the human immune system affecting neurological and cognitive development especially in children. Protein calorie malnutrition is a major nutritional problem in many developing countries. Considering the projected increase of world population to 9 billion by 2050, it is a huge challenge to meet the food and nutritional security of the growing world. Grain legumes are an important part of Afro-Asian diet and major providers of protein and calories in this region. Grain legumes are considered to be a good source of protein, carbohydrates, vitamins, minerals and other compounds that have significant nutritional and health-related benefits which would very effectively address both malnutrition and food insecurity problems. Under the climate change scenario, there is an urgent need to diversify the cropping pattern by promoting cultivation of grain legumes due to their adaptation to different regions and climates. Important legumes that form a part of our daily diet in various forms include peas, beans, lentils, chickpea, pigeonpea, soybean, and groundnut. In this chapter we have briefly highlighted the global trade and economics-related aspects; and nutritional composition of important food legumes.

Keywords: *Food security, malnutrition, grain legumes, nutritional composition, anti-nutritional factors (ANFs), import & export of legumes, production.*

1. INTRODUCTION

"One billion hungry people, which is one out of every group of six persons in the world, that is 105 million more than in 2008, and five children dying every 30 seconds", said Dr. Jacques Diouf, FAO Director-General at the World Summit on Food Security in Rome (2009). The issue of hunger and food security became a serious concern after the "food riots" in 22 countries across the globe (in 2007 and 2008)that threatened the foundations of governments, global peace and security. The World Food Summit (1996) defined food security as "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life". However, food security is a complex issue, linked to malnutrition, economic development, environment, and trade. Malnutrition refers generallyto "suboptimal food", vis-à-vis the required daily supply of 2500 kcal/day (Roy *et al.*, 2006).Protein calorie malnutrition (PCM) is considered to be the main nutritional problem in manydeveloping nations. Infants and young children in several developing countries suffer from PCM that includes a range of pathological conditions due to lack of protein and calories in their daily diet (Haider and Haider, 1984).About 170 million people, especially preschool children and nursing mothers in south Asia and sub Saharan Africa suffer from malnutrition (Iqbal *et al.*, 2006). Major provider of protein and calories in Afro-Asian dietinclude legumes. Legumes are considered to be a good source of protein, due to high content and bioavailability of protein.

The international community made a commitment ('Millennium Declaration') at the turn of the millennium to reduce by half the proportion of people living in extreme poverty and hunger by 2015 (Ahmad *et al.*, 2007).The population of less developed regions of the world, including large parts of sub-Saharan Africa and South Asia, is projected to be 7.7 billion by 2050, while the world population would be 9 billion during the same period (United Nations Report 2004).Considering this increase it is a huge challenge to meet the food and nutritional security of the growing population in the developing world. Additionally, under the climate change scenario there is a need to diversify the cropping pattern by promoting grain legumes. Legumes are next only to Graminae in their importance to humans; and include about 650-750 genera and about 19000 species (Graham and Vance 2003; Polhill *et al.*, 1981) including important forage, agroforestry and grain species. Important legumes that form a part of our daily diet in various forms include peas, beans, lentils, chickpea, pigeonpea, soybean, and groundnut. This chapter provides a comprehensive overview of the potential role of grain legumes in addressing the food and nutritional in-securities in the developing world. In this chapter the term 'legume' refers to grain legumes.

2. GLOBAL MALNUTRITION AND FOOD INSECURITY

Adequate nutrition during early childhood is a pre-requisite for healthy growth and proper developmentof the immune system that impacts neurological and cognitive development. Malnutrition manifests itself in various forms including stunting, and underweight. Globally,165 million children under the age of five are stunted and about 101 million were underweight in 2011 (UNICEF-WHO-The World Bank Report, 2012; Figs. 1A & 1B). Africa and Asia together accounted for 92%(152 million) and 95% (~95 million) of stunted and underweight children respectively in 2011.The future projections predict a total of 154 million stunted and 93 million underweight in 2015 (Figs. 1A & 1B). Overall the number of stunted and underweight children has decreased significantly since 1990 (by35%).

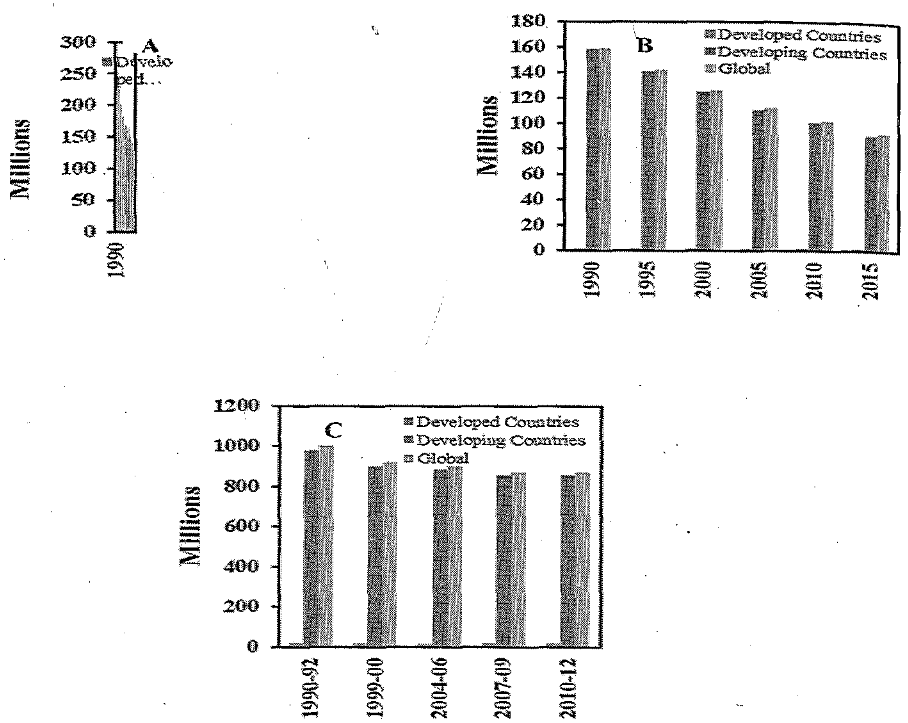

Fig. 1 : The present status and future prediction about the number of stunted (A), underweight (B) and undernourished (C) people in developing/developed countries and globally.

The State of Food Insecurity in the World 2012reports about 870 million people are undernourished in terms of daily dietary energy supply in 2010-12, *i.e.*, 12.5% of the world population (FAO, 2012).South Asia and Sub-Saharan Africa together constitute about 540 million underfed people. Though significant progress has been made in reducing global hunger, it has slowed down and levelled off since 2007-08 (Fig. 1C). Globally, the food production has to increase by about 70% and in the developing countries it has to double between now and 2050 (FAO, 2009).

Why Legumes?

It is a well-established fact that legumes are nutritionally enriched(explained in detail below). Apart from this there are several agronomic and economic reasons that strongly support the cultivation of legumes. Major reasons for increasing their adoption include: (i) suitability for human and animal consumption (pods/seeds, leaves and stems); (ii) relatively easy to manage agronomically; (iii)suitable for intercropping/mixed cropping; (iv) fertilizer requirement is lower in comparison to other crops;and (v) they can be grown in harsh environments. In spite of these advantages legumes suffer from some constraints restricting their expanding cultivation such as (i) inadequate availability of quality seeds of improved varieties; (ii) difficulties in harvesting leading to losses; (iii) highlabour requirement for value addition; and (iv) lack of markets and volatility of prices.

Production, Import and Export of Legumes

Total legume production in the world and in developing countries along with major producers is summarized in Table 1. Legumes are produced on 12-15% of earth's arable land contributing to 30% of total dietary protein requirement of the humans; and under subsistence farming conditions their importance could be much higher (Graham and Vance 2003). About 35% of the vegetable oil requirement of the world is provided by soybean and groundnut (Graham and Vance 2003). South and South-East Asia region is a major producer of chickpea and pigeonpea with India alone producing 71% and 65% of these crops, respectively. India, Myanmar and Brazil account for ~87% of total bean (dry) production among the developing countries(FAOSTAT 2013). India and Nigeria produce 57% (9.9 million tonnes, MTs)of total groundnut produced in developing countries (excluding China). Cowpea is predominantly cultivated in Western Africa with Nigeria and Niger producing 69% of world production (FAOSTAT, 2013; Table 1).

Overall, the global legume production has increased by 1.7 times between 1961 and 2011 and during the same period cereal production has increased by 3 times (Fig. 2A). The yield per hectare of legumes has increased only by 1.4 times, compared to 2.7 times in cereals (Fig. 2B).

Table 1 : Production of important grain legumes in world and developing countries in 2011 (Source: FAOSTAT)

Legume	Latin name	Production (MT)			Major Producers (% of World Production)
			World	DC*	
Chickpea	*Cicer arietinum*		11.62	9.51	India (71) Australia (4.4)
Pigeonpea	*Cajanus cajan*		4.40	3.54	India (65) Myanmar (19)
Groundnut	*Arachis hypogaea*	With shell	38.61	17.36	China (41.7) India (17.9)
Lentil	*Lens culinaris*		4.41	1.44	Canada (34.7) India (21.4)
Beans	*Phaseolus vulgaris* and *Dolichos* and *Vigna* spp.	Dry	23.25	13.36	Brazil (51.8) India (19.2) Myanmar (16)
		Green	20.39	1.09	China (77) Indonesia (4.4)
Field pea	*Pisum sativum*	Dry	9.55	1.44	Canada (22.1) Russia (21.1)
		Green	16.97	4.08	China (60.5) India (21)
Cowpea	*Vigna unguiculata*	Dry	4.92	4.63	Nigeria (37.8) Niger (30.9)
Soybean	*Glycine max*		260.91	149.85	USA (31.6) Brazil (28.4)
Broad beans	*Viciafaba*	Dry	4.03	0.85	China (38.5) Ethiopia (17.3)

DC* - includes countries fromAfrica (East, West, South & Middle), South Asia and South America.

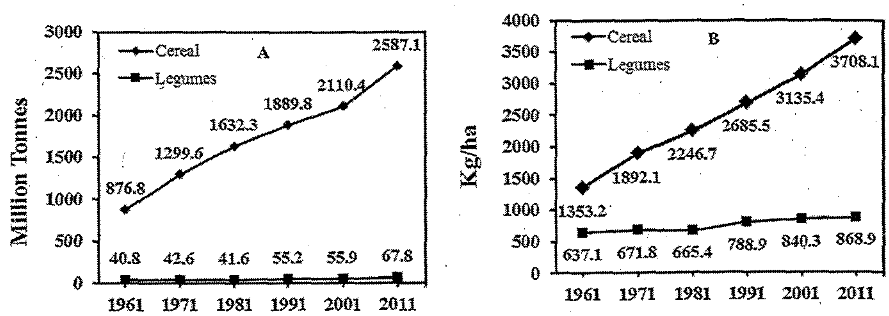

Fig. 2 : Global production (A) and yield trends (B) of cereals and legumes

Though South and South-East Asia are major producers of legumes, they also import large quantities to meet their daily requirements. Among the developing regions of the world,South Asia is the largest importer of legumes followed by South America in 2010 (Figs. 3A). The import of legumes by south Asian countries increased by 3.7 times (by volume) and 6.0 times (in value, US$) in 2010 compared to 2000 (Figs. 3A& 4A). The amount of legumes imported by South Asian countries is 2.25 times (in volume) and 1.75 (in value, US$) in comparison to all other regions put together (Sub-Saharan Africa, South and Central America, and South-East Asia). Overall, legumes imported by the nations of sub-Saharan Africa (SSA), South/Central America (CSA), and South/South-East Asia (SSEA) have increased from 2.3 million metric tonnes (MMT) in 2000 to 5.7 MMT in 2010 (2.5 times higher). The value of legume imports increased from US$ 867 million in 2000 to US$3.6 billion in 2010, *i.e.*, an increase of 76% (FAOSTAT 2013).In spite of producing large quantities coupled with huge imports, south Asia still has the largest number of malnourished people in the world.

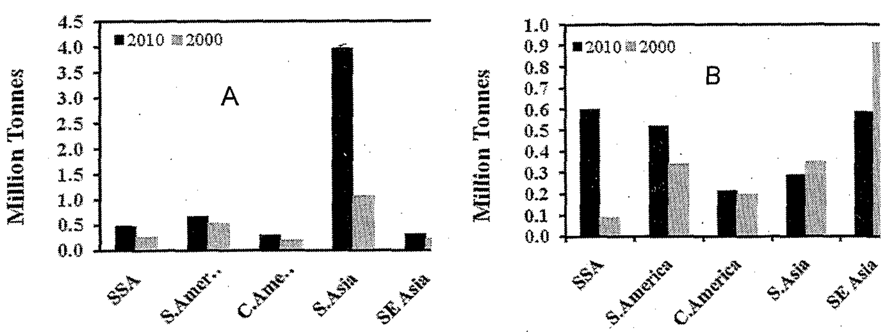

Fig. 3 : Quantity of import (A) and export (B) of legumes in different regions of the world

The export of legumes by SSA, CSA and SSEA regions in 2010 was 2.2 MMT compared to 1.9 MMT in 2000. SSA region recorded the highest increase in exports from just 0.09 MMT in 2000 to 0.6 MMT in 2010 (Fig. 3B). Interestingly, during the same period SSEA region has recorded a steep decrease in exports from 1.3 MMT (2000) to 0.9 MMT. In terms of value, SSA registered an increase of about 10 times in 2010 (US$ 370 million) compared to 2000 (US$ 39 million; Fig. 4B). But, the largest exporter of legumes in value terms during 2010 was South-East Asia (mostly Myanmar and Thailand) amounting to US$ 0.5 billion. The overall value of legume exports from these developing regions of the world was about US$ 1.8 billion in 2010 (FAOSTAT 2013).The *per capita* production of legumes was 13.2 in 1961 and 9.2 kg/person/yr during 2009. Similarly, the average consumption in 1961 was 9.5 kg/person/yr as compared to a low of 6.6 kg/person/yr during 2009 (FAOSTAT, 2013; Fig.5). To address these issues we need to understand the importance of nutritionalcontent of the legumes and the role they play in upkeep of human health.

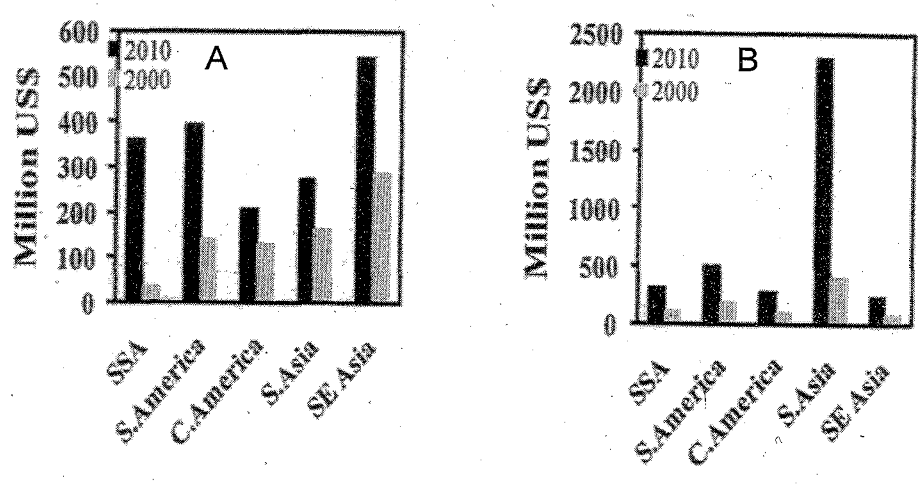

Fig. 4 : Import (A) and export (B) values of legumes in different regions of the world

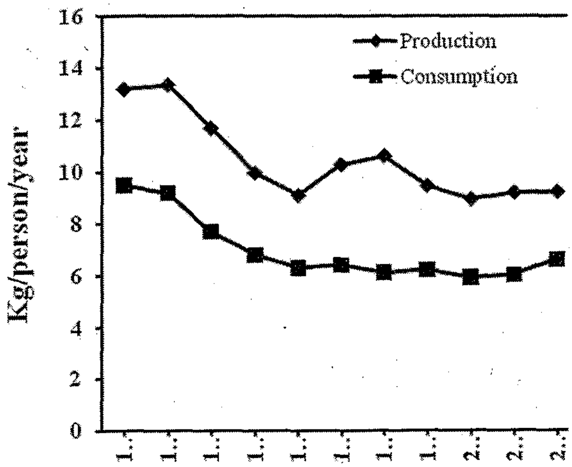

Fig. 5 : Global *per capita* production and consumption of legumes in the past five decades

3. GRAIN COMPOSITION OF IMPORTANT LEGUME CROPS

Protein Content

Infants, young children and nursing mothers in developing countries are the most vulnerable groups to be affected by PCM.Legumes form an integral part of Afro-Asian diet providing a major share of protein and calories.Among the food legumes (excluding groundnut and soybean)the protein content is in the range of 20-25%.The protein content in legumes is significantly higher (19-36%; Table 2) compared to major cereals like rice (5.8-7.7%; Champagne *et al.,* 2004), wheat (8-15% Shewry 2009), maize (9-11%; Zuber and Darrah 1987) and barley (8-15% Shewry 1993).Protein quality is better in some legumes like chickpea, compared to others such as urdbean [*Vigna mungo* L.], mungbean[*Vigna radiata* L.] and pigeonpea [*Cajanus cajan* L.] (Kaur *et al.,*2005). The protein concentration in some legumes like chickpea, mungbean, urdbean, lentils, and beans do not show significant differences (Rehman and Shah, 2005).

Table 2 : Proximate composition of different legumes

Crop	Carbo -hydrate(‡) (g/100g)	Fat(‡) (g/100g)	Protein(‡) (g/100g)	TDF(‡) (g/100g)	TS(‡) (g/100g)	Ash(‡) (g/100g)	Starch	Energy(‡) (kcal/100g)
Chickpea	60.7	6.0	19.3	17.4	10.7	2.5	41.1 (§)	364.0
Pigeonpea	23.8	1.6	21.7	5.1	3.0	3.5	48.4 ()	343.0
Groundnut	16.1	49.2	25.8	8.5	4.0	2.3	11.5 ()	567.0
Lentil	60.1	1.1	25.8	30.5	2.0	2.7	45.0 (§)	353.0
Bean	60.3	0.9	23.4	15.2	2.1	4.2	38.0 (§)	333.0
Field pea	60.4	1.2	24.6	25.5	8.0	2.7	46.0-49.5 (*)	341.0
Cowpea	59.6	2.1	23.9	10.7	-	3.4	39.1-54.9 (±)	343.0
Soybean	30.2	20.0	36.5	9.3	7.3	4.9	0.8-6.9 (†)	446.0

TDF - Total Dietary Fibre; TS-Total Sugars; (‡)USDA 2013;(§)-Wang &Daun 2004, g/100g; (¶)-Singh &Diwakar 1993, in percent (%);(*)-Wang *et al.* 2008, g/100g dry matter; (±) -Omueti& Singh 1987, g/100g; (†)-Jeong *et al.* 2010, in percent (%)

In vitro Protein Digestibility

The *in vitro* protein digestibility (IVPD) of legumes also exhibits wide variability. High IVPD values were recorded for various legumes: chickpea [65.3-79.4%],pigeon pea, [60.4 to 74.4%], mungbean [67.2 to 72.2%], soybean [62.7 to 71.6%]. (Chitra *et al.*, 1995), groundnut (73.4; Embaby 2011) and lentil (92.3%; Awada *et al.*, 2005). Sangronis and Machado (2005) have reported 76.3-77.9% IVPD for bean and 76.8% for pigeonpea. The IVPD of legumes was found to increase by different treatments like boiling, microwave cooking, autoclaving, and roasting (Awada *et al.* 2005; Embaby 2011)

Amino Acid Composition

The amino acid composition of different legume seeds is presented in Table 3. Methionine and cystine, the two sulfur-rich amino acids are generally limiting in pulses. Commonly consumed food legumes are low in these two amino acids(Jukanti *et al.*, 2012), the exceptions being cowpea and green pea which have higher values (Iqbal *et al.*, 2006). Some minor variations are observed in the quantity of a few amino acids such as phenylalanine,leucine,arginine, and glutamic acid. The amino acid content of groundnut is lower in comparison to other legumes (Table 3). Aspartic and glutamic acid are the two dominating amino acids in majority of the legumes (Table 3). Cereals are rich in sulphur-containing amino acids and could complement the amino acid deficiencies in legumes (Haq *et al.*, 2007).

Fat Content and Fatty Acid Profile

The total fat content of different food legumes along with two oilseeds is presented in Table 2. Among the different legumes chickpea has the highest fat content compared to others, the exceptions being the two oilseed crops groundnut and soybean. The fat content in most of the legumes (excluding chickpea, groundnut, and soybean) and in cereals like wheat [1.70 g 100-g] and rice [0.60 g 100-g] is almost similar (USDA 2013; Table 2). Polyunsaturated fatty acids (PUFA's) are the major fatty acids (40-60%) followed by monounsaturated (MUFA's; 20-25%) and saturated fatty acids (15%) among the different legumes (Table 4). Chickpea, lentil, and soybean have high percentage of linoleic and linolenic acid, while groundnut, chickpea and field pea are good sources of oleic acid. Cowpea and lentil are rich sources of palmitic acid (Table 4). Overall, legumes are a good source of two nutritionally important PUFA's (linoleic and linolenic acids) and oleic acid along with saturated fatty acid, palmitic (Table 4).

Minerals

Legumes, apart from being a good source of essential vitamins and minerals, also provide variety to the cereal-based diet (Cabrera *et al.* 2003; Duhan *et al.,* 1999). The different minerals present in important legume crops is presented in Table 5. About 200 g of chickpea, lentil and bean seed can meet recommended daily dietary requirement of calcium (1000 mg/day in both men and women), whereas, 100 g of lentil, bean, cowpea and chickpea could meet the necessary daily zinc requirement (4.2mg/day for men and 3.0 mg/day for women; FAO 2002). Generally,most of the legumes (100 g) can provide the iron requirement (1.05 mg/day for men and 1.46 mg/day for women). The recommended daily intake of magnesium for adults (260 mg/day for male and 220 mg/day female) can be obtained from 100-150 g of bean, soybean, pea, pigeon pea or chickpea.

Table 3 : Amino acid content of important legumes.

Amino Acid	Chickpea	Pigeonpea	Groundnut	Lentil	Bean	Field pea	Cowpea	Soybean
Lysine	4.9-6.9 (*1)	7.8 (‡1)	1.0 (†)	6.8-7.2 (¥1)	5.9-6.7 (Δ)	4.3-5.1 (±1)	7.5 ± 0.04 (1)	2.5-2.8 (§)
	7.7 (*2)	5.9-6.8 (‡2)	-	3.8-5.1 (¥2)	-	3.9-8.3 (±2)	2.8 (2)	-
Methionine	0.7-2.1	1.2	0.3	0.6-0.9	1.0-1.3	0.4-0.7	2.2 ± 0.04	0.5-0.6
	1.6	1.3-1.4	-	0.2-0.7	-	0.4-1.2	1.7	-
Cysteine	0.7-2.0	1.2	0.4	0.5-0.9	0.06-0.1	0.5-1.0	0.5 ± 0.03	0.5-0.7
	1.3	1.0-1.2	-	-	-	1.0-1.9	0.4	-
Phenylalanine	4.5-6.2	6.2	1.5	4.3-5.0	4.9-5.6	2.7-3.2	7.5 ± 0.06	1.8-2.2
	5.9	8.1-8.6	-	2.4-3.6	-	2.9-5.2	3.7	-
Tyrosine	2.0-3.3	2.6	1.1	3.0-3.3	2.3-2.9	1.5-2.1	3.0 ± 0.05	1.4-1.6
	3.7	3.7-4.0	-	1.1-2.2	-	1.7-4.1	2.6	-
Isoleucine	2.6-4.5	3.5	1.0	3.9-4.4	4.0-4.3	2.2-2.8	4.5 ± 0.03	1.7-2.0
	4.1	4.0-4.2	-	1.9-2.7	-	2.4-4.8	3.1	-
Leucine	5.6-7.7	6.8	1.8	7.3-7.9	7.1-7.6	4.1-4.7	7.7 ± 0.08	2.8-3.4
	7.7	7.4-8.0	-	3.5-5.4	-	5.1-7.8	5.9	-
Threonine	3.0-5.1	3.1	1.0	3.2-3.7	3.8-4.0	2.2-2.6	3.8 ± 0.05	1.5-1.7
	3.6	3.8-4.1	-	1.7-2.8	-	3.8-5.1	2.3	-
Valine	2.9-4.6	5.9	1.2	4.8-5.3	4.8-5.4	2.6-3.3	5.0 ± 0.06	1.7-2.0
	3.6	4.7-5.2	-	2.1-3.2	-	2.9-5.4	3.1	-
Arginine	8.1-13.7	5.9	3.3	7.5-7.8	4.9-5.8	4.6-7.1	7.5 ± 0.04	2.6-3.5
	10.3	6.5-7.2	-	3.1-3.9	-	6.5-12.6	3.5	-

Contd.

Histidine	1.7-3.3	3.7	0.7	1.9-2.5	2.3-2.6	1.4-1.7	3.1 ± 0.03	1.0-1.2
	3.4	3.0-3.2	-	1.3-1.8	-	1.4-2.9	2.0	-
Alanine	3.2-4.7	3.8	1.1	4.0-4.6	3.7-3.9	2.5-3.0	4.2 ± 0.03	1.6-1.9
	4.4	5.5-6.2	-	1.1-1.8	-	2.8-4.6	2.9	-
Aspartic Acid	8.9-12.9	11.6	3.4	11.2-11.8	10.6-11.5	6.6-8.6	10.8 ± 0.08	4.2-5.0
	11.4	10.4-11.0	-	4.3-6.7	-	7.3-14.8	5.1	-
Glutamic Acid	13.1-17.6	9.2	5.9	20.9-22.0	13.3-13.8	10.5-11.9	17.2 ± 0.06	6.6-8.2
	17.3	16.5-17.3	-	8.2-13.0	-	11.0-20.0	15.8	-
Glycine	2.9-4.5	3.1	1.7	3.0-3.7	3.2-3.3	2.7-3.2	3.8 ± 0.01	1.6-1.9
	4.1	3.9-4.2	-	1.4-2.7	-	3.2-5.2	3.0	-
Proline	2.9-6.5	3.2	1.2	3.1-3.9	3.2-3.5	2.3-2.7	4.0 ± 0.13	1.9-2.2
	4.6	3.9-5.0	-	2.9-4.5	-	3.5-6.9	3.7	-
Serine	4.0-6.7	3.6	1.4	4.9-5.4	4.8-5.1	2.6-3.1	4.5 ± 0.06	2.0-2.3
	4.9	4.4-4.6	-	2.5-4.0	-	2.1-6.2	2.4	-
Tryptophan	0.3-1.6	ND	0.3	0.7-0.8	-	0.5-0.9	0.7 ± 0.02	0.5-0.6
	1.1	0.9	-	-	-	0.6-0.9	ND	-

(*1)-Wang &Daun 2004/(*2)-Alajaji& El-Adawy 2006, both in g/16g N; (‡1)-Akande *et al.* 2010/(‡2)-Apata &Ologhobo 1994, g/16g N; (†)-USDA 2013, g/100g;(¥1)-Zia-ul-Haq *et al.* 2011, g/16g N, (¥2)-Khan *et al.* 1987, g/g N; (Δ)-Pirman *et al.* 2001, g/100g;(±1)-Holt &Sosulski 1979, g/g N, (±2)-Wang &Daun 2004, g/16g N; (1)-Iqbal *et al.* 2006, % of protein, (¶2)-Olaleke *et al.* 2006 g/100g crude protein; (§)-Padgette *et al.* 1996, g/100g dry weight.

Table 4: Fatty acid profile of different legumes

Fatty Acid	Chickpea	Pigeonpea	Groundnut	Lentil	Bean	Field pea	Cowpea	Soybean
Lauric	- (*1)	- (Ω1)	0.000 (§1)	0.000 (±1)	0.000 (1)	0.003 (¥1)	0.001 (†1)	- (‡1)
(C12:0)	ND (*2)	- (Ω2)	- (§2)	- (±2)	0.82±0.19(2)	- (¥2)	- (†2)	- (‡2)
Myristic	-	-	0.025	0.003	0.001	0.002	0.004	0.055
(C14:0)	0.1-0.26	-	-	-	3.97±0.06	-	-	-
Palmitic	18.9-20.4	0.307	5.154	0.133	0.205	0.125	0.417	2.116
(C16:0)	7.9-10.30	20.5	5.26-10.4	13.67-14.57	17.4±0.65	3.67-9.01	26.59-31.60 11.69	10.63-
Palmitoleic	0.3-0.5	-	0.009	0.003	0.000	0.000	0.006	0.055
(C16:1)	0.2-0.34	ND	-	0.03-0.09	9.65±0.46	-	Traces-0.2	-
C17:0	-	-	-	-	-	-	-	-
	-	-	-	0.09-1.17	6.24±0.27	-	-	0.11-0.14
Stearic	1.3-1.7	0.024	1.100	0.015	0.013	0.031	0.087	0.712
(C18:0)	0.1-5.30	6.9	2.18-4.36	1.17-1.32	9.03±0.88	3.44-7.31	3.44-5.09	3.85-4.55
Oleic	21.6-22.2	0.012	23.756	0.180	0.074	0.232	0.144	4.348
(C18:1)	18.6-42.46	10.5	52.8-82.2	21.87-22.65	14.60±0.55	25.52-54.90	4.43-7.09 31.19	15.02-
Linoleic	54.7-56.2	0.778	15.552	0.404	0.198	0.411	0.563	9.925
(C18:2)	42.25-56.59	56.3	2.87-27.1	46.89-47.21	9.4±1.37	21.38-44.78	35.98-40.35 54.96	44.03-
Linolenic	0.5-0.90	0.035	0.003	0.109	0.166	0.084	0.326	1.330
(C18:3)	2.23-3.91	5.0		10.99-11.77	-	6.01-14.01	18.96-23.19 10.26	5.08-

Contd.

Arachidic	1.0-1.4	-	-	-	-	-	-	-
(C20:0)	0.59-0.90	0.8	1.14-1.78	0.19-0.44	0.94±0.03	0.85-1.90	1.05-1.44	0.31-0.43
Gadoleic	-	-	0.661	0.006	0.000	0.010	0.002	-
(C20:1)	0.48-0.70	ND	0.74-2.45	0.44-0.70	2.57±0.47	0.30-2.76	-	0.14-0.26
Eicosadienoic	-	-	-	-	-	-	-	-
(C20:2)	0.0-0.009	-	-	-	6.47±0.32	-	-	-
Behenic	-	-	-	-	-	-	-	-
(C22:0)	0.29-0.60	-	2.23-3.90	0.13-0.31	0.15±0.02	0.46-1.67	-	0.46-0.59
Erucic	-	-	0.000	0.000	0.000	0.000	0.019	-
(C22:1)	0.0-0.16	ND		-	2.04±0.23	0.18-0.50		-
Lignoceric	-	-	-	-	-	-	-	-
(C24:0)	0.0-0.50	ND	1.00-1.86	-	-	1.07-3.88	-	0.13-0.24
Nervonic	-	-	-	-	-	-	-	-
(C24:1)	ND	-	-	-	-	0.5±0.16	-	-

(*1)-Zia-ul-Haq *et al.* 2007/(*2)-Wang &Daun 2004, both in % in oil;(Ω1)-USDA 2013, g/100 g, (Ω2)-Aykroyd&Doughty 1982, % of total Fas;(§1)-USDA 2013, g/100 g, (§2)-Andersen *et al.* 1998, weight %;(±1)-USDA 2013, g/100 g, (±2)-Zia-ul-Haq *et al.* 2011, mg/100 g of dry matter;(1)-USDA 2013, g/100g,(2)-Akpinar *et al.* 2001, in percent (%);(¥1)-USDA 2013, g/100 g,(¥2)- Solis *et al.* 2013, % of FA in extracted oil;(†1)-USDA 2013, g/100 g,(†2)-Islam et al.2010, in percent (%); (‡1)-USDA 2013, g/100 g, (‡2)-Padgette *et al.* 1996, g/100 g

Table 5 : Mineral concentration in important grain legumes

Mineral	Chickpea	Pigeonpea	Groundnut	Lentil	Bean	Fieldpea	Cowpea	Soybean
Calcium	154.0-210.0 [*1]	1.24 [1]	2.28±1.94 [±1]	120±6.24[‡1]	160.4±0.1[Ω1]	75.0-91.0[¥1]	176±4.58[†1]	0.8±0.14 [§1]
	80.5-226.5 [*2]	140.0[2]	92.0[±2]	168.0-170.0 [‡2]	321.0-377.0[Ω2]	0.7 [¥2]	29.0-51.0[†2]	277.0[§2]
Iron	4.5	47.8	7.0±1.62	3.1±0.26	5.7±0.002	4.2-5.2	2.6±0.20	48.9±0.6
	4.3-7.6	5.5	4.6	6.6-7.3	8.6-10.7	67.2	6.1-8.1	15.7.0
Magnesium	122.0-128.0	1.6	4.0±0.04	4.5±0.04	195.3±0.003	117.0-128.0	4.8±0.10	1.33±0.04
	143.7-212.8	89.0	168.0	4.6-5.2	289.0-311.0	1.3	131.0-169.0	280.0
Phosphorus	-	4.3	10.6±0.68	294.0±3.61	-	283.0-319.0	303±7.94	-
	276.2-828.8	290.0	376.0	301.0-341.0	185.0-210.0	5.1	-	704.0
Potassium	878.0-926.0	12.8	705.1±0.86	874.0±6.43	741.3±0.3	888.0-953.0	1280±8.62	2.07±1.16
	816.0-1580.0	-	705.0	978.0-1024.0	1151.0-1319.0		957.0-1251.0	1797.0
Sodium	21.0-23.0	0.05	42.0±0.71	79.0±2.65	84.7±0.05	-	102±5.29	2.61±0.02
	-	-	18.0	65.0-81.0	23.0-27.0	-	9.0-17.7	2.0
Zinc	3.5-3.6	38.3	3.2±0.11	4.4±0.20	4.5±0.04	2.4-3.7	5.1±0.20	23.9±1.19
	2.8-5.6	-	3.3	4.2-4.3	2.5-2.8	39.0	2.7-4.4	4.9
Copper	1.2-1.3	12.4	-	9.9±0.10	0.6±0.07	0.6-0.8	9.7±0.20	11.4±4.13
	0.5-1.4	1.1	1.1	4.6-6.1	0.5-0.7	4.8	2.0-2.2	1.7
Manganese	1.7	20.9	-	1.6±0.03	15.8±0.23	0.9-1.3	1.7±0.04	6.7±0.02
	2.3-4.8	2.9	1.9	1.4-1.6	2.2-2.9	26.3	1.7-2.9	2.5
Selenium(††)	-	-	-	-	-	-	-	-
	8.2	8.2	7.2	8.3	12.8	1.6	9.1	17.8

(*1)- Ibanez *et al.* 1998, (*2)-Wang &Daun 2004, both in mg/100g; (1)-Apata&Ologhobo 1994, g/kg DM (Ca, P, Na, K, Mg), mg/kg DM (Mn, Zn, Fe, Cu), (2)-Oloyo 2004, mg/100g; (±1)-Atasie *et al.* 2009, (±2)-USDA 2013, both in mg/100g; (‡1)-Iqbal *et al.* 2006, (‡2)-Gharibzahedi *et al.* 2012, both in mg/100g; (Ω1)-Alayande *et al.* 2012, (Ω2) Numair *et al.* 2009, both in mg/100g; (¥1)-Wang *et al.* 2008, mg/100g, (¥2) Brand *et al.* 2004, g/kg (Ca, P, Mg), mg/kg (Cu, Zn, Mn, Fe); (†1)-Iqbal *et al.* 2006, (†2)-Carvalho *et al.* 2012, both in mg/100g; (§1)-Plaza *et al.* 2003, g kg-1 DM (Ca, K, Mg, Na), mg kg^{-1} (Cu, Fe, Mn, Zn), (§2)-USDA 2013, mg/100g; (††)-USDA 2013, µg/100g

Most of the legumes are a good source of calcium (>125 mg 100-g), field pea and groundnut being the only exceptions (70-90 mg 100-g) but, even these two legumes contain higher calcium in comparison to cereals like wheat (45 mg 100-g; Plaza *et al.*, 2003). Magnesium and phosphorus content in legumes is similar to that in wheat (135 mg 100 g and ~350 mg 100-g, respectively; Murphy *et al.*, 2008). Legumes have high quantities of manganese, zinc and also trace element like selenium compared to wheat (~0.5 mg 100-g, ~0.3 mg 100-g and ~0.2 µg 100-g respectively; Murphy *et al.*, 2008).

Vitamins

Though vitamins are required in tiny quantities (e.g. Vitamin A), deficiencies are common especially in SSA and SSEA regions of the world. The vitamin content in different important food legumes is shown in Table 6. Majority of the legumes are a good source of folic acid which is important in prevention of neural tube defects, low birth weight, some cancers and osteoporosis (Relton *et al.*, 2005; Eichholzer *et al.*, 2006). These risks can be prevented by daily consumption of 100-200 mg of legumes that meet the daily recommendation of 0.4 mg (Eichholzer *et al.*, 2006). Legumes contain different types of Vitamin B (B_1, B_2, B_3, B_5, B_6 and B_{12}) along with good tocopherol (α and γ) content (Table 6). Among the legumes, groundnut is a good source of niacin (Vit B3) and tocopherols (α and γ).

Carbohydrates

Carbohydrates are classified into (i) available -- enzymatically digested in the small intestine, *e.g.* mono and disaccharides; and (ii) unavailable -- not digested in the small intestine, *e.g.*,. oligosaccharides, resistant starch, non-cellulosic polysaccharides, pectins, hemicelluloses and cellulose (Chibbar *et al.*, 2004).The total carbohydrate content in majority of the legumes is high (30-60%) except groundnut and pigeon pea (Table 2). Legumes have: (i) monosaccharides- fructose, galactose, glucose, ribose; (ii) disaccharides -maltose and sucrose, and (iii) oligosaccharides -ciceritol, raffinose, stachyose, and verbascose (Han and Baik, 2006). The amount of these various fractions is shown in Table 7.

Table 6 : Vitamin content in different legumes

Vitamins	Chickpea	Pigeonpea(†)	Groundnut	Lentil (†)	Bean	Field pea (†)	Cowpea (†)	Soybean
Retinol (A; RE/100g)	ND [*1] - [*2]	0.0	0.0[1] -[2]	ND	ND[±1] - [±2]	ND -	- - [§2]	18.8±4.15 [§1]
Vitamin C	0.3-2.4	0.0	0.0	0.3-2.2	3.1-5.1	0.3-1.0	0.4	99.5±6.44
	4.0	-	5.8		-			6.0
Vitamin (D2+D3)	ND	-	-	ND	ND	ND	-	-
					55.7±2.9			-
Thiamin (B1)	0.4-0.8	0.6	0.6	0.1-0.5	0.4-0.9	0.3-1.0	0.2	0.5±0.02
	0.5		1.0		-			0.9
Riboflavin (B2)	0.1-0.3	0.2	0.2	0.2-0.5	0.1-0.2	0.1-0.4	0.05	1.3±0.14
	0.2		0.1		-			0.9
Niacin (B3)	0.5-1.5	3.0	1.8	0.7-2.1	0.3-0.4	0.7-0.3	0.4	-
	1.5		2.7					0.8
Panthothenic acid (B5)	0.7-1.2 1.6	1.3	1.8 2.7	0.7-2.1	0.3-0.4 -	0.7-3.0	0.4	- 0.8
Pyridoxine (B6)	0.2-0.5	0.3	0.4	0.2-0.3	0.04-0.3	0.01-0.1	0.1	7.8±0.66
	-	-	0.3		-			0.4
Cyanocobalamin (B12)	ND 0.0	0.0	0.0 -	ND	ND -	ND	-	- 0.0
Tocopherol (α)	9.2-13.6	-	8.3	3.1-6.4	3.1-5.1	5.3-8.5	-	0.9±0.24
	0.8		11.9-25.3		ND			0.9
Tocopherol (γ)	1.4-2.8	-	-	0.4-0.9	ND	0.0-0.2	-	-
	-		0.6-2.5		82.4±7.6			-
Choline, total	-	-	52.5		-		-	-
	95.2		165.0174.0		-			115.9

Contd.

(In µg 100^{-g})								
Folic acid	153.8-486.5	456.0	240.0	100.0-217.0	72.7-149.3	ND	142.0	-
	557.0		280.0		-		-	375.0
Vitamin A, RAE	-	1.0	-		-		1.0	-
	3.0		-		-		-	1.0
β-carotene	-	-		-	-		-	-
	40	-			79.2±5.6			13.0
Vitamin K	-		0.0		-		-	-
	9.0		-		67.4±8.4			470

(*1)-Wang &Daun 2004, (*2)-USDA 2013, both in mg 100-g; (†)-USDA 2013, mg 100-g; (1)-USDA 2013,(2)-Cobb & Johnson 1973, both in mg 100-g; (§1)-Plaza *et al.* 2003, mg kg-1,(§2)-USDA 2013, mg 100-g;(±1)-USDA 2013 mg 100-g, Ciftci *et al.* 2010, µg/100g

Mono-, Di-, and Oligosaccharides

Legumes contain important monosaccharides at varying concentrations (Table 7). Maltose and sucrose are reported to be the most abundant free disaccharides in legumes along with some minor disaccharides like melbiose. Since humans lack α-galactosidase (which degrades oligosaccharides; Han and Baik, 2006), oligosaccharides are not hydrolyzed or absorbed in the large intestine of human digestive system thereby accumulating in the intestine. Therefore, α-Galactosides undergo fermentation by colonic bacteria releasing gases that lead to flatulence(Kozlowska *et al.*, 2001).

α-Galactosides occur in two important groups in legumes: (i) raffinose family of oligosaccharides (RFOs) such asraffinose (trisaccharide), stachyose [tetrasaccharide], and verbascose [pentasaccharide] (Frias *et al.*, 1996, Sako *et al.*, 1999, Gulewicz *et al.*, 2000, and Peterbauer and Richter 2001);and (ii) galactosylcyclitols - including ciceritol, that was isolated for the first time from chickpea seeds by Quemener and Brillouet (1983). Ciceritol has also been isolated from lentils (Frias *et al.*, 1996, Peterbauer and Richter 2001). Compared to other legumes gas production is higher in chickpea, due to higher oligosaccharide content (Jaya *et al.*, 1979; Rao and Belavady, 1978).

Polysaccharides

Polysaccharides are high molecular weightpolymers with atleast 20 monosaccharides; often contain 200-3000 monosaccharide units (BeMiller 2007). Polysaccharides occur in legumes as storage polysaccharides (starch, the major source of energy in germinating seeds), as gums (galactomannans and glucomannans) and structural polysaccharides (cellulose and hemicelluloses), that provide structural integrity in plants (Chibbar *et al.*, 2010). In legumes, starch is the main storage carbon reserve in seeds (Chibbar *et al.*, 2010). Starch is constituted by two types of polymerized glucose molecules- amylose and amylopectin.Amylose content in legume starches is relatively higher (24-72%) in comparison to cereal crops like wheat and maize (22%). The *in vitro* starch digestibility values (ISDV) of legumes in general are lower than cereals due to higher amylose content (Madhusudhan and Tharanathan, 1996).

Table 7 : Carbohydrate content of different grain legumes

Carbohydrate	Chickpea	Pigeonpea	Groudnut	Lentil	Beans	Field pea	Cowpea	Soybean
Sucrose	15.2[*1]	1.2±0.15[Ω1]	28.0-38.0[±1]	1.0-1.5[†1]	28.9±1.2 [§1]	2.5±0.059[‡1]	1.3±0.02[¥1]	57.2-212.1[1]
	4.3[*2]	15.6-30.2[Ω2]	36.5[±2]	1.1±0.026 [†2]	1.4-2.0[§2]	1.3±0.013[‡2]	9.9-18.3[¥2]	- [2]
Raffinose	3.2	0.4±0.06	0.3-0.4	0.7-0.8	1.9±0.8	0.5±0.000	0.78±0.06	1.0-16.7
	1.0	10.3-17.3	0.4	0.4±0.005	0.3-0.5	0.2±0.004	1.25-2.46	60.1
Stachyose	17.7	0.9±0.07	3.7-4.2	1.6-1.7	24.8	0.6±0.083	3.5±0.1	3.3-133.6
	2.8	12.3-19.4	2.3	2.3± 0.065	1.7-2.5	0.4±0.014	5.8-10.8	35.0
Verbascose	-	1.1±0.11	-	-	-	-	-	1.6-6.9
	Traces	21.0-28.0	-	-	-	-	-	ND
Ciceritol	27.6	-	-	1.4-1.8	ND	-	-	0.3-9.2
	-	-	-	-	-	-	-	ND
Fructose	3.1	-	0.19-0.23	0.03-0.1	1.2±0.3	-	-	0.3-5.8
	0.1	-	0.3	0.2 ±0.074	0.17±0.005	Undetected	-	-
Galactose	0.1	-	-	Traces	0.5±0.1	-	-	-
	-	-	-	-	0.03-0.07	-	-	-
Glucose	0.5	-	0.09-0.11	Traces	0.8±0.1	0.07±0.021	-	0.3-1.8
	0.1	-	0.14	0.08 ± 0.005	-	Undetected	-	-
Maltose	3.3	-	-	0.1-0.2	ND	0.12±0.012	-	2.8-5.5
-	-	-	-	0.3±0.030	0.4-0.9	0.09 ±0.004	-	-
Manninotriose	-	-	-	-	-	-	-	-
	3.4	-	-	-	-	-	-	-

Contd.

Ribose	-	-	-	0.65±0.175	-	0.62±0.059	-	-
	-	-	0.04	-	0.05-0.2	-	-	-
Melbiose	-	-	-	-	-	-	-	-
	-	-	-	Traces	0.09±0.000	0.05-0.2	-	-
Glucose +	-	-	-	-	-	-	-	-
Fructose	-	0.8-4.0	-	-	-	-	-	-

(*1) Aguilera *et al.* 2009, g kg^{-1}, (*2)-Aman 1979, % of dry weight of seed; (Ω1)-Oboh *et al.* 2000, mg/100g, (?2)-Singh *et al.* 1984, g/100 g;(±1)-Oupadissakoon *et al.* 1980, mg/g, (±2)-Som 1984, mg/g;(†1)-Sánchez-Mata *et al.* 1998, (†2)-Hernández *et al.* 1998, both in g 100-g; (§1) Aguilera *et al.* 2009, g kg-1, (§2)- Sánchez-Mata *et al.* 1998, g 100-g; (‡1)-Sánchez-Mata *et al.* 1998,(‡2)-Hernández *et al.* 1998, both in g 100-g; (¥1)-Egounlety&Aworh 2003, % of dry weight of seed,(¥2)-Islam *et al.* 2010, mg/g;(1)-Obendorf *et al.* 2008, (2)-Han &Baik 2006, both in mg g-1

Dietary Fibre

Complex carbohydrates are classified into two groups: (i) available, which is easily digested and absorbed by humans and animals, *e.g.* starch; and (ii) unavailable/resistant carbohydratesthat are not absorbed/assimilated in the intestines, *e.g.* cellulose, hemicellulose, galactomannans, glucomannans and xylans (AACC 2001, Chibbar *et al.*, 2010). Unavailable/resistant carbohydrates are commonly referred to as 'Dietary Fibre (DF)'. Based on solubility, total dietary fibre consists of:(i) soluble fibre that gets digested slowly in the colon; and (ii) insoluble fibre that is metabolically inert and aids in bowel movement (Tosh and Yada, 2010). Total dietary fibre content (DFC) in most of the edible legumes is 8-27.5%, which includes 3.3-13.8% of soluble fibres (Guillon and Champ, 2002).

Anti-Nutritional Factors (ANFs)

Most of the legumes contain biologically active compounds commonly referred to as 'anti-nutritional factors [ANFs]' (Singh 1988); that are known to have both positive and negative impact on human/ animal health and nutrition (Jukanti *et al.*, 2012). A list of ANFs present in different legumes is given in Table 8.ANFs make the legume seeds unpalatable when consumed in raw or unprocessed form and also affect digestion (Domoney, 1999). In general, ANFs occur as protein and non-protein ANFs (Duranti and Gius, 1997). Protein ANFs include lectins, antifungal peptides, and two protease inhibitors (trypsin and chymotrypsin inhibitors). Alkaloids, saponins, tannins, phytic acid and phenolics are non-protein ANFs(Roy *et al.*, 2010, Muzquiz and Wood, 2007). Protease inhibitors interfere with digestion by irreversibly binding with trypsin and chymotrypsin in the human digestive tract (Jukanti *et al.*, 2012). But, most of the α-amylase inhibitors are active against animal amylases (Champ, 2002).

Grain legumes are an important source of lectins/haemagglutinins. Most bean species including Phaseolus vulgaris are good sources of lectins. Lectins are specific sugar binding proteins that bind and clump together red blood cells (Bond and Duc, 1993; Champ 2002). Phytates and oxalates present in legume seed reduce the bioavailability of minerals, therefore, they are considered to be ANF's (Table 8; Sandberg; 2002). Saponins are found in several legumes (Table 8) and give a bitter taste and make them less preferable for human and animal consumption (Birk and Peri, 1980).Tannins form insoluble complexes with both protein and carbohydrates leading to astringency of tannin-rich foods

(Champ, 2002). Though ANF's are considered to be limiting factors in legume consumption, their content can be reduced by processes such as soaking, boiling, cooking, and autoclaving (Alajaji and El-Adawy, 2006).

4. CONCLUSIONS

Legumes have multitude of compounds that have significant nutritional and health related benefits which could aid very effectively in reducing malnutrition and food insecurity. It can be observed from the above discussion that though the cereal production has almost reached 2500 million tonnes [MT] in 2011, the legume production has only marginally risen from 41 MT in 1971 to 68 MT in 2011. Since legumes can fit into different cropping systems under varying environments including tree/forest-based systems and cereal-based cropping systems, they have a very high potential for large-scale cultivation. The data presented in the paper unambiguously demonstrate the importance of legumes in human nutrition and health, and the need for their increased production in the near future, especially under the climate change scenario to successfully feed nutritionally-rich food to the ever-growing human population.

Table 8 : Anti-nutritional factor content in different grain legumes

ANFs	Chickpea	Pigeonpea	Groundnut	Lentil	Bean	Field pea	Cowpea	Soybean
Trypsin	6.7-14.6(*1)	8.1-12.1(‡1)	16.3±1.2(¥1)	8.4 (Ω1)	15.0 (±1)	0.2-10.8(†1)	15.0-28.0 (1)	27.5(#1)
Inhibitor (TI)	1.0-15.0(*2)	15.4 (‡2)	ND(¥2)	-(Ω2) (#2)	9.6(±2)	5.4-7.8(†2)	2.2-4.8 (2)	17.5-28.7
Chymotrypsin	5.7-9.4	2.1-3.6	-	-	-	0.7-10.2	-	-
Inhibitor (CI)	-	-	ND	-	-	2.7-11.7	-	-
Amylase	0-15.0	22.5-34.2	62.5±5.4	-	-	14.0-80.0	-	-
Inhibitor (AI)	-	-	-	-	-	7.4-102.4	-	-
Haemagglutinins	-	-	-	-	2.2	5.1-15.0	5.1-83.0	-
(Units mg-1)	-	-	1.1	-	24.5-35.6	80.0	-	4.5-12.8
Tanins	Traces	0.0-0.2	0.09±0.01	-	15.0	0.2-1.3	2.1-4.2	0.3 mg g-1
(mg g-1)	-	0.02	4.1	3.8	0.2-1.9	0.0-1.3	1.6-6.0	-
Phenols	1.55-6.10	3.0-18.3	-	1.0	-	13-27 mg kg^{-1}	-	-
	-	22.8 µg100-g	-	-	-	-	-	-
Phytic acid	-	-	14.7±0.5	-	16.5	2.2-7.4	2.6-3.9	2.1
(mg g-1)	-	8.1	-	5.67		0.2-1.3	3.0-8.5	-
Saponins	-	-	-	-	-	-	-	0.6 (#3)
	0.40	-	-	3.7-4.6mg g^{-1}	-	-	3.6-9.7	-
Genistein	-	-	-	0.0-0.02	-	-	-	-
(mg 100-g)	0.07-0.21	-	-	-	0.07-0.2	0.0-0.05	-	28.6-138.0

Contd.

Daidzein	-	-	-	0.0-0.01	-	-	-	-
(mg 100-g)	0.01-0.19	-	-	-	0.01-0.2	0.0-0.05	-	21.9-119.0
Oxalate	-	-	-	0.16	-	-	0.6-1.0 mg g^{-1}	-
	0.07	15.4 g 100-g	0.2	-	0.07	0.7	2.1-6.2 mg kg^{-1}	-

(*1)-Singh 1988, TI/CI-units/mg, AI-units/g, Phenols-mg/g, (*2)-Champ 2002, TI-units/mg, CI-units/g; (‡1)-Singh 1988, TI/CI-units/mg, AI-units/g, Phenols-mg/g, (‡2)-Oloyo 2004, TI-units/mg;(¥1)-Ejigui *et al.* 2005, TI-units/mg, AI-units/g, Tanins-mg/100 g, (¥2)-Ingale & Shrivastava 2011, Oxalate-g/100 g;(Ω1)-Champ 2002, TI/CI-units/mg, AI-units/g, oxalate-% DM, (Ω2)-Ayet *et al.* 1997; (±1)-Barampama&Simard 1993, TI-TUIx10^{-3}/g,(±2)-Champ 2002 TI/CI-units/mg, AI-units/g, oxalate-% DM; (†1)-Castell *et al.* 1996,TI/CI/AI-units/mg, (†2)-Champ 2002, TI/CI-units/mg, AI-units/g, oxalate-% DM; (1)-Celestine *et al.* 2012, TI-units/mg, (2)-Owolabi *et al.* 2012, TI-mg/100 g; Saponin-mg/100 g,(#1)-El-Shemy et al 2005, TI-units/g, (#2)-Padgette *et al.* 1996, TI-mg/g DM, (#3)-Savage &Deo 1989, Saponin-% DM

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