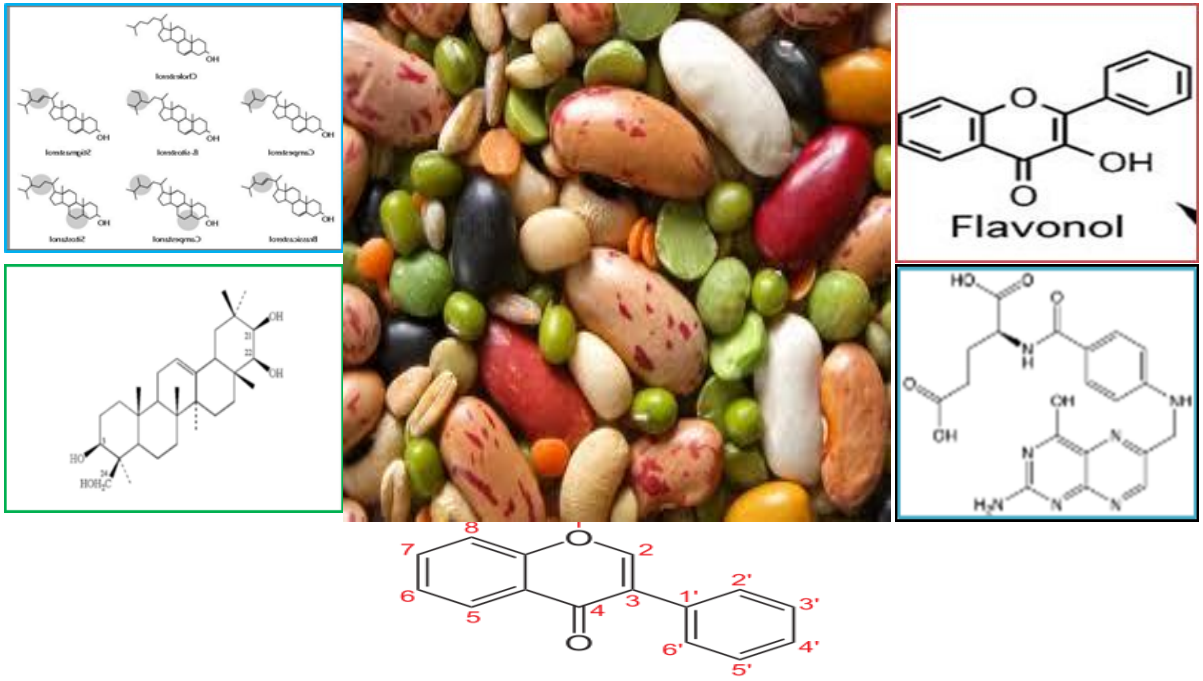
Agrisearch with a human touch

Nutritive and Non nutritive components of Pulses: Implications for Human nutrition & health



Dr. Jagdish Singh

Head, Basic Science Division

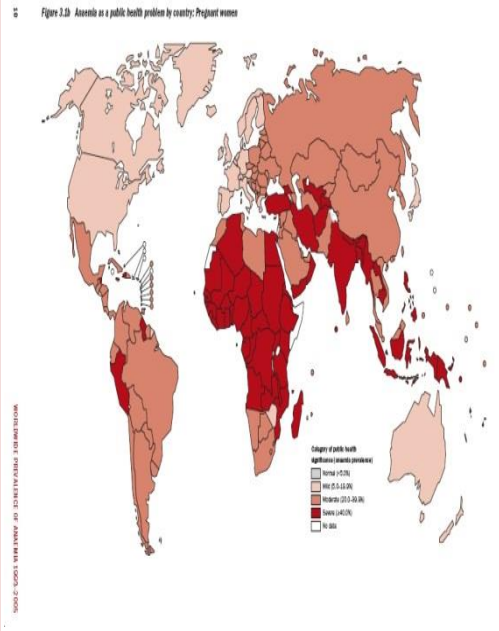
Indian Institute of Pulses Research, Kanpur, India

Pulses-Introduction

- **Pulses – an important component of agricultural food crops and are ideal for simultaneously achieving two important developmental goals:**

Help eliminate hunger, food security and malnutrition:

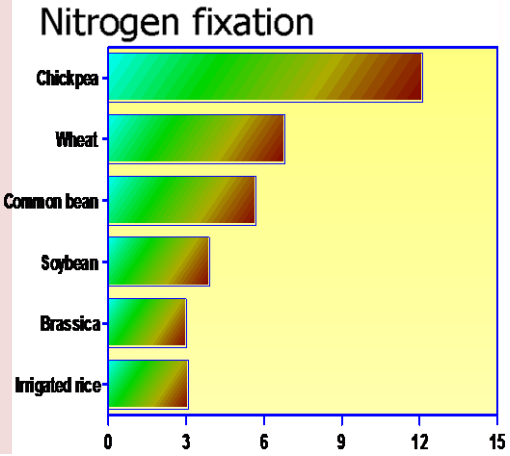
- **1.02 billion people are chronically deprived of adequate food**
- **Approximately 165 million children (26%) are stunted, 101 million (16%) are underweight.**
- **Malnutrition and diet-related non-communicable diseases together are the leading cause of deaths worldwide, accounting for approximately 20 million deaths per year.**
- **Pulses, rich source of protein, dietary fibre, complex carbohydrates, resistant starch and folate, potassium, Se, fe and Zn-powerhouse of nutrients.**



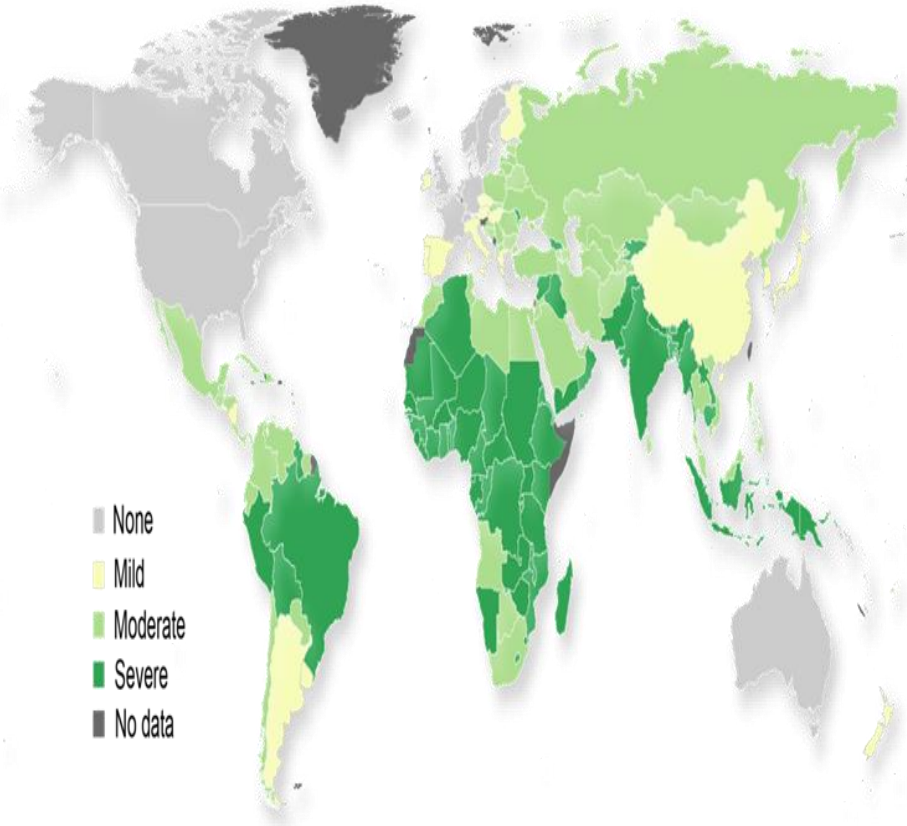
Enhancing ecosystem resilience & Ensuring Environmental sustainability:

- **Pulses contribute to healthy soils and climate change mitigation and improve productivity and water use efficiency of cropping systems.**
- **Using pulse crops in rotation means reduced fertilizer needs and decreased green house gas emissions**

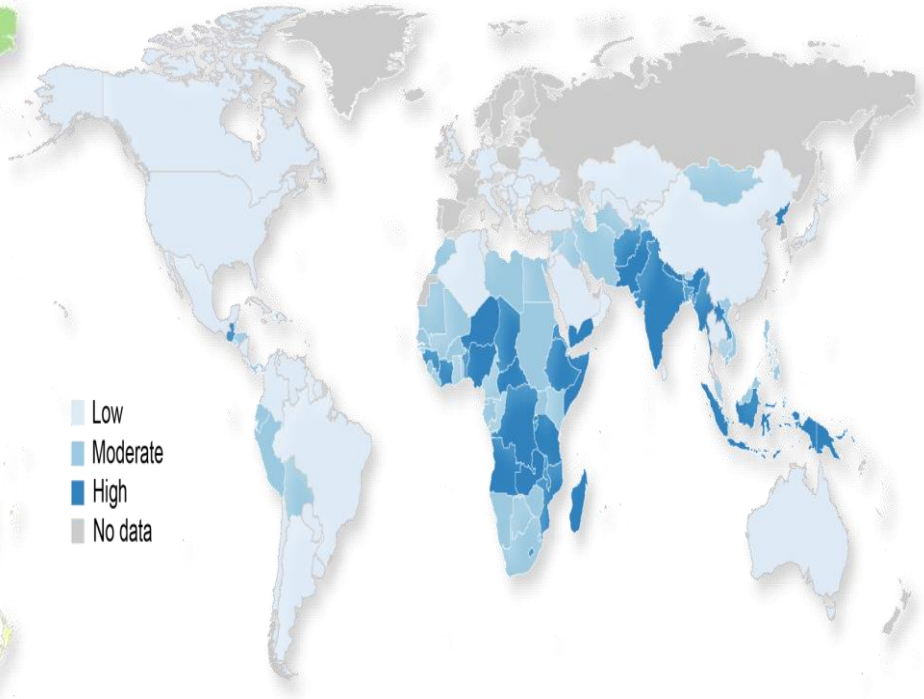
Pulse crop advantage over cereal and oilseed crops:



Severity of Iron Deficiency



Severity of Zinc Deficiency

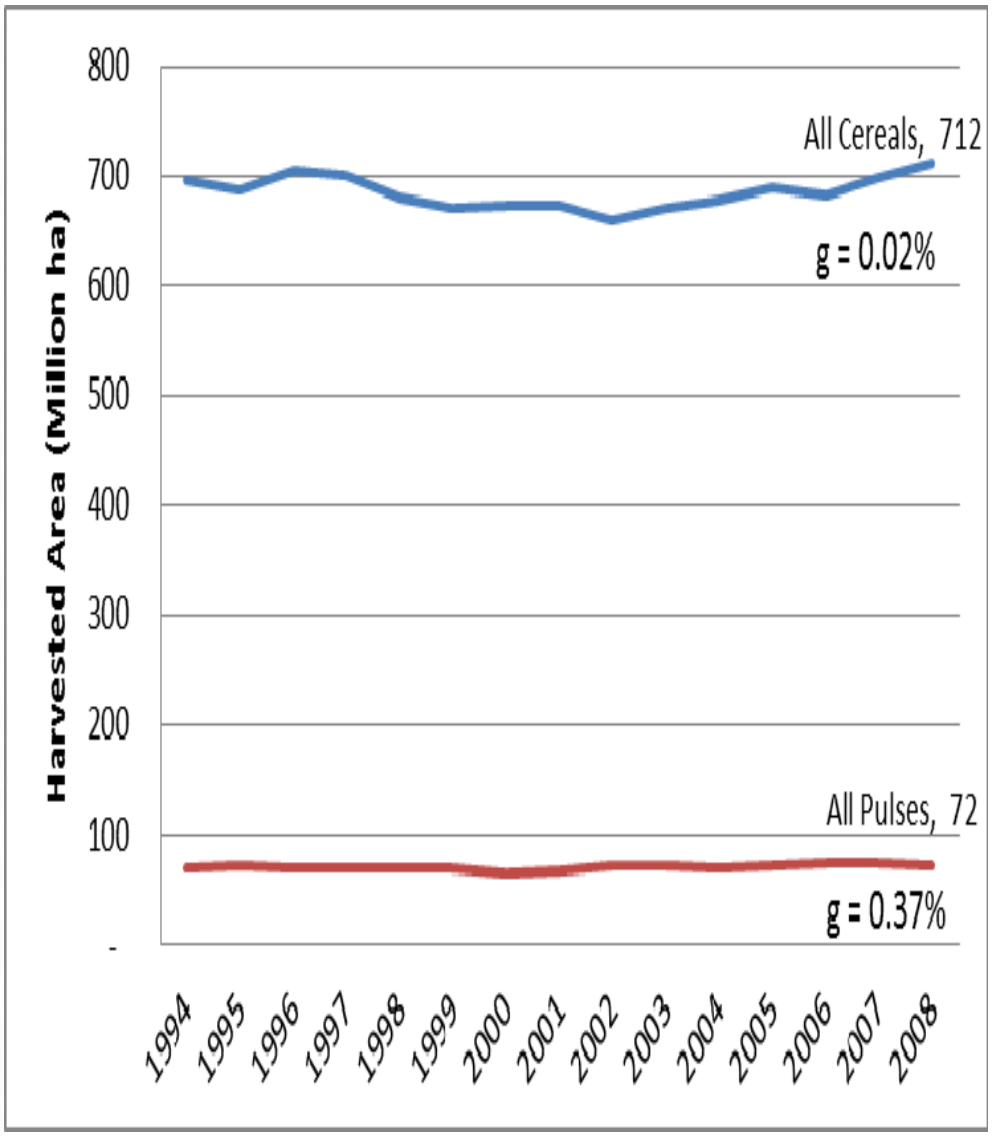


- It is estimated that over 60% of the world's 7 billion people are Fe deficient, over 30% Zn deficient, 30% I deficient, and more than 15% are selenium (Se) deficient.

Source: USAID

Pulses-Global Status

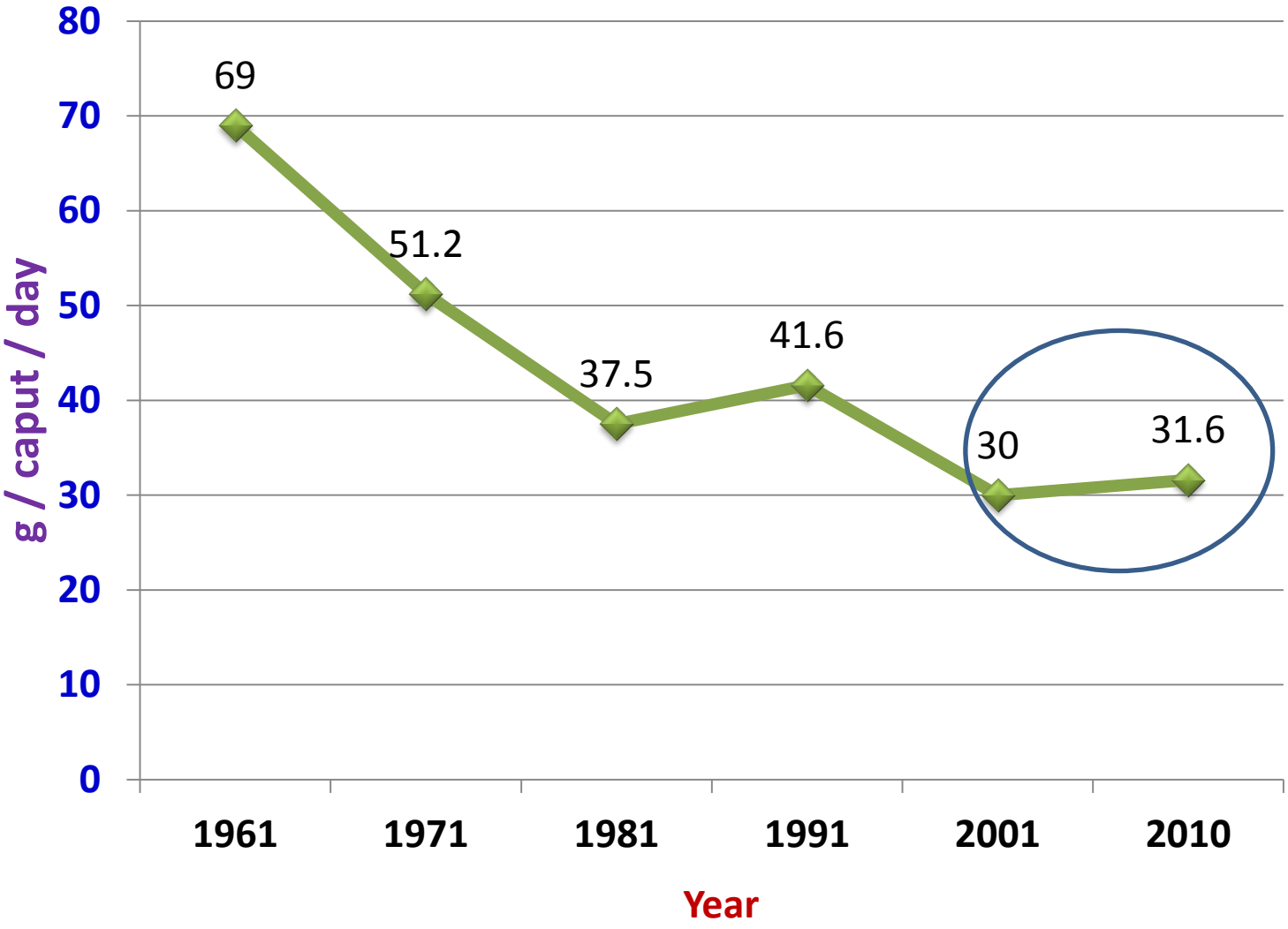
Global area harvested for all cereal and all pulse crops



Source: FAOSTAT

- **Globally, the harvested area under pulse crops is about 1/10th the harvested area under all cereal crops.**
- **The global average yield of pulse crops in 2008 (0.86 t/ha) was only about one-fourth the average yields of cereal crops (3.54 t/ha).**
- **The area harvested under pulse crops has increased @ of 0.4%, which is better than almost a stagnant global trend in area growth rate for cereals, but still not enough to change its status from a secondary to a primary food crop.**

Per Capita Net Availability of Pulses in India



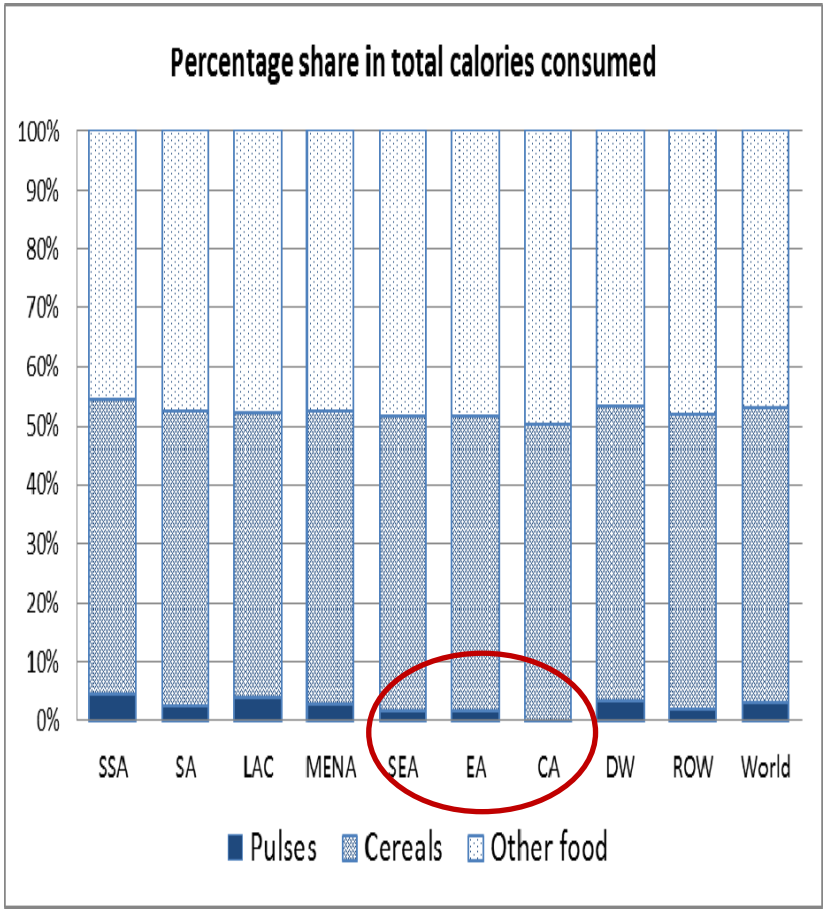
Source: http://www.indaagristat.com

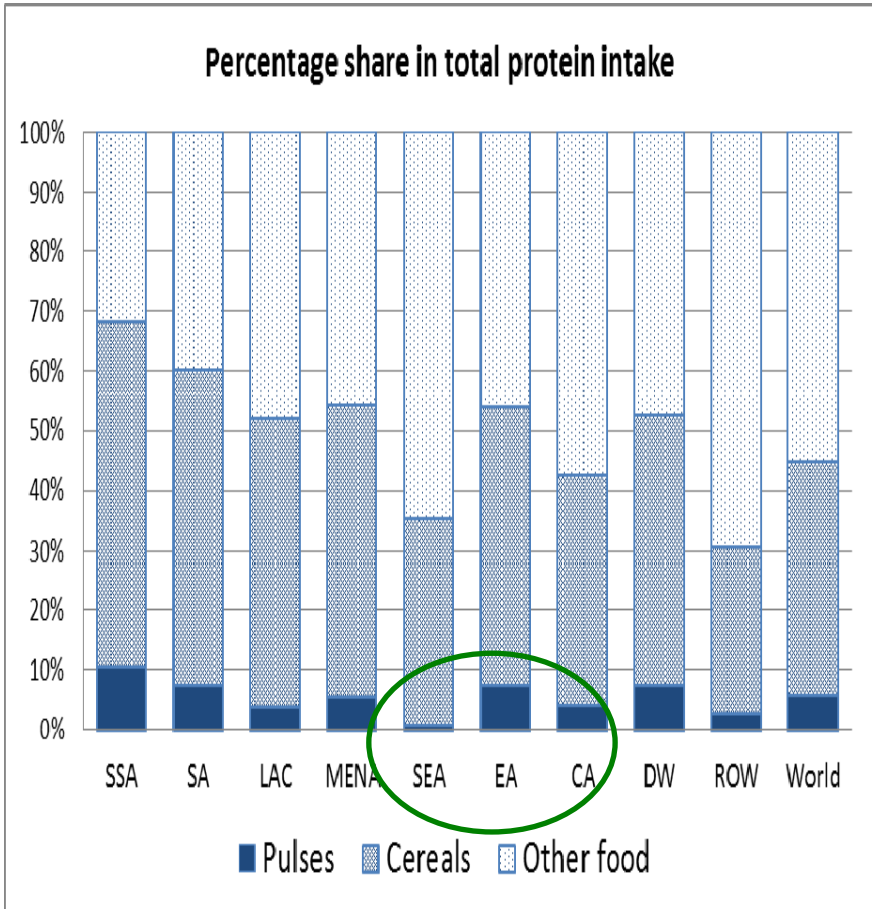
Energy and Protein Content of Major Pulse and Cereal Crops

Crop category	Scientific name	Common name	(Value /100g)	
			Kcal	Protein
Pulses	*Vigna radiata*	Mung bean	347	23.86
	Vigna mungo	Black gram	341	25.21
	Vigna ungiculata	Cowpea	336	23.52
	Vicia faba	Faba bean	341	26.12
	Cicer arietinum	Chickpea	364	19.30
	Lens culinaris	Lentil	353	25.80
	Cajanus cajan	Pigeon pea	343	21.70
Cereals	*Triticum durum*	Wheat, durum	339	13.68
	Triticum aestivum	Wheat, bread	340	10.69* (2-2.5)
	Zea mays	Maize	365	9.42* (2-2.5)
	Oryza sativa	Rice, medium grain	360	6.61* (3-4)
	Pennisetum glaucum	Millet	378	11.02
	Sorghum	Sorghum	339	11.30
	Hordeum vulgare	Barley	352	9.91

Contribution of pulses to total calories and protein consumption

Source: FAOSTAT

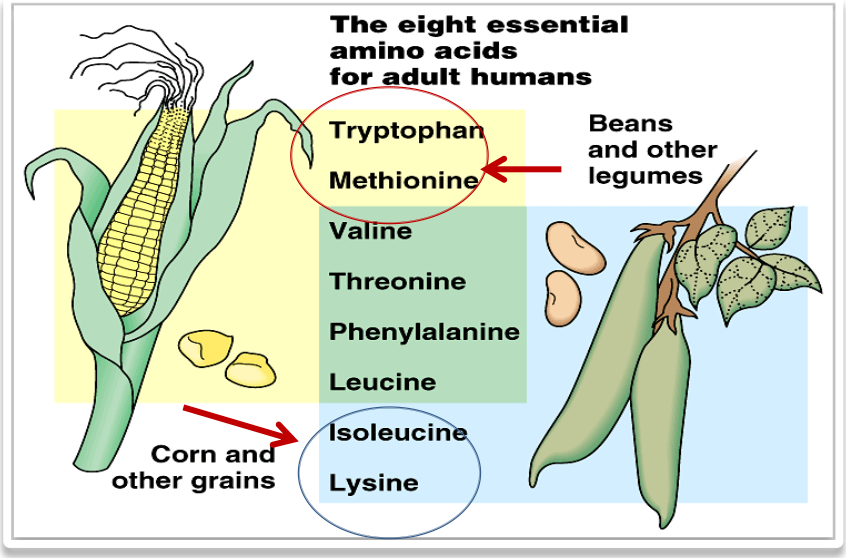




Pulses contribute about 3% of total calories consumed in developing countries and it is less than 1% in Central Asian region

Because of higher protein content, pulses contribute relatively more towards total protein intake (7.5% of total protein intake in developing countries as against 2.5% in developed countries).

Protein Quality - dictated by their limiting amino acid



Biological value (BV): proportion of absorbed protein from a food which becomes incorporated into the proteins of the organism's body.

Protein Digestibility Corrected Amino Acid Score (PDCAAS): based on the amino acid requirements of humans and their ability to digest it.

As compared to animal protein Pulse protein have low biological value.

Food Product	Biological value
Whole egg	93.7
Milk	84.5
Fish	76.0
Beef	74.3
Soybean	72.8
Rice, polished	64.0
Wheat, whole	64.0
Corn	60.0
Beans, dry	58.0

PDCAAS Score	Food	PDCAAS Score	Food
1.00	Casein (milk protein)	0.64	Pea (Yellow, split)
1.00	Egg white	0.50	Pea (Green, split)
0.92	Beef	0.59	Cereals and derivatives
0.91	Soybean	0.52	Peanuts
0.78	Chickpea	0.42	Whole wheat
0.63	Lentil (Green, whole)	0.25	Wheat gluten (food)

Typical Levels of Some Nutrients in Major Staple Food Crops

Crop	Ca	Fe	Zn	Riboflavin	Total folate
(dry weight)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(µg/kg)
Cereal Grains					
Polished Rice	123	18	13	0.61	78
Milled Wheat	170	13	8	0.45	295
Yellow Maize	78	30	25	2.24	212
Legume Seeds					
Kidney Bean	1620	93	32	2.48	4465
Great N. Bean	1960	61	26	2.65	5398
Bengal Gram	1187	71	39	2.40	6296
Mung Bean	1451	74	30	2.56	6872
Cowpea	858	101	62	1.52	4686
Green Pea	1183	70	59	6.24	3075

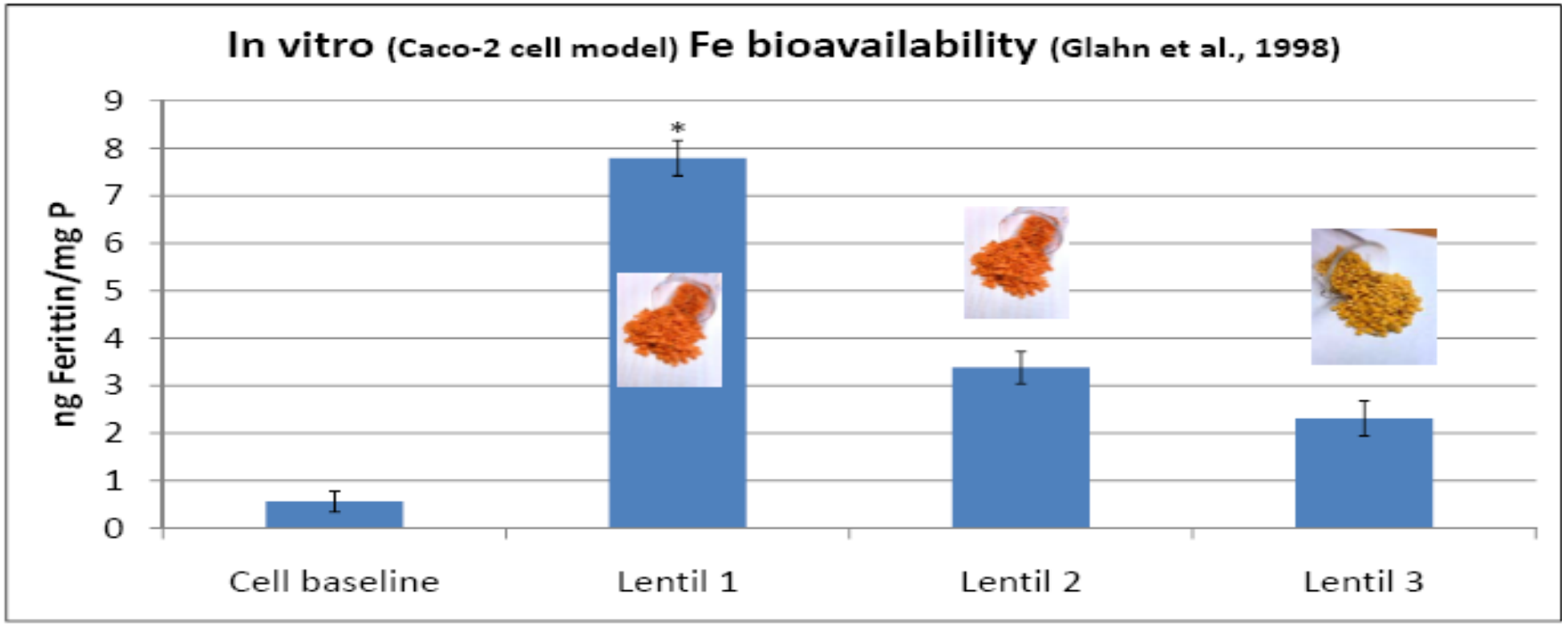
Data from USDA Nutrient Composition Tables of Foods

Iron Rich Lentil can provide adequate Fe:

- **High iron in lentil provides a nutritionally significant increase in iron absorption.**

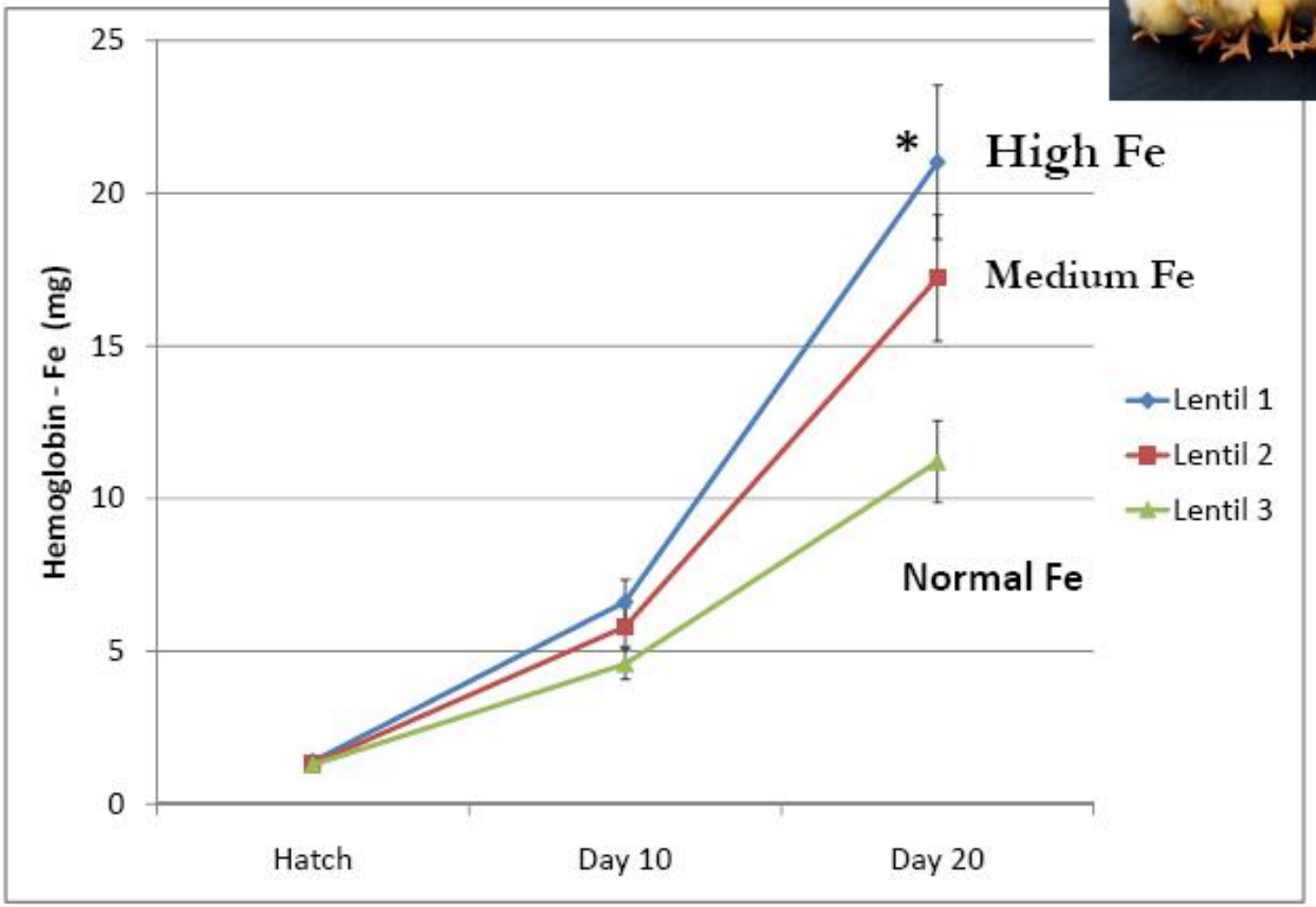
In vitro Fe bioavailability comparison between 3 lentil varieties.

1. "Lentil 1" – 94.8 ppm Fe; Redberry #1
2. "Lentil 2" – 75.4 ppm Fe; Redberry #2
3. "Lentil 3" – 54.8 ppm Fe; Milestone



Poultry Trial: Lentils – 50% in diet (n=9; mean +SE)





Agrisearch with a human touch

Bioactive ingredients with disease-preventing /health promoting activities

I. Nutritive	II. Non-nutritive phytonutrients (ANF's)
Protein	Protease inhibitors Trypsin inhibitor α – amylase inhibitor
Oligosaccharides: (i) RFO's (ii) Sugar Alcohols (iii) Resistant starch, (iv) Dietary Fibre	Lectins
	Phytosterols
	Saponins
Folic acid (Vit B9)	Phytates
Fe, Zn & Selenium	Phenolic acids, (Lignans, tannins, flavanoids)

- Extent of genetic variation.
- Year X Genotype interaction
- Year x Location x Genotype interaction
- Heritability

Beneficial Effects of Anti-nutrients in Pulses

Potential beneficial effects of bioactive components in pulses.

	Beneficial effects	Adverse effects
Protease inhibitors	Anticarcinogenic (?)	↑ Carcinogenesis (?) and growth inhibition (in animals)
Amylase inhibitors	Potentially therapeutic in diabetes (?)	↓ Starch digestion
Lectins	May help in obesity treatment (??), ↓ tumor growth (??)	Growth inhibition (in animals), ↓ nutrient absorption
Phytates	Hypocholesterolaemic effect (?), anticarcinogenic (?)	↓ Bioavailability of minerals
Oxalates		↓ Bioavailability of minerals
Phenolic compounds	↓ Risk factors for menopause (CHD..) (?)	
Flavonoids, isoflavones (phyto-oestrogens)	↓ Risk of hormonedependent cancer (?)	Infertility syndrome (in animals)
Condensed tannins		Astringent taste, ↓ food intake (in animals)
Lignans (phyto-oestrogens)	↓ Risk factors for menopause (?)	
Lignins		↓ Fermentability of dietary fibres
Saponins	Hypocholesterolaemic effect (?), anticarcinogenic (?)	Bitter taste, ↓ foodintake (in animals)

Pulses have a unique Prebiotic Carbohydrate profile:










1. Non-starch polysaccharides: (RFOs, FOS, Inulins) including raffinose, stachyose, ciceritol, and verbascose**. The RFO's account 53.0 % of the oligosaccharides - Stachyose represents the major oligosaccharide, followed by ciceritol, raffinose, and Verbascose .**

2. Sugar alcohols (Polyols) - Hydrogenated mono-, di-, or polysaccharides- - sorbitol (2.6 kcal/g) and mannitol (1.6 kcal/g)-have a low energy contribution

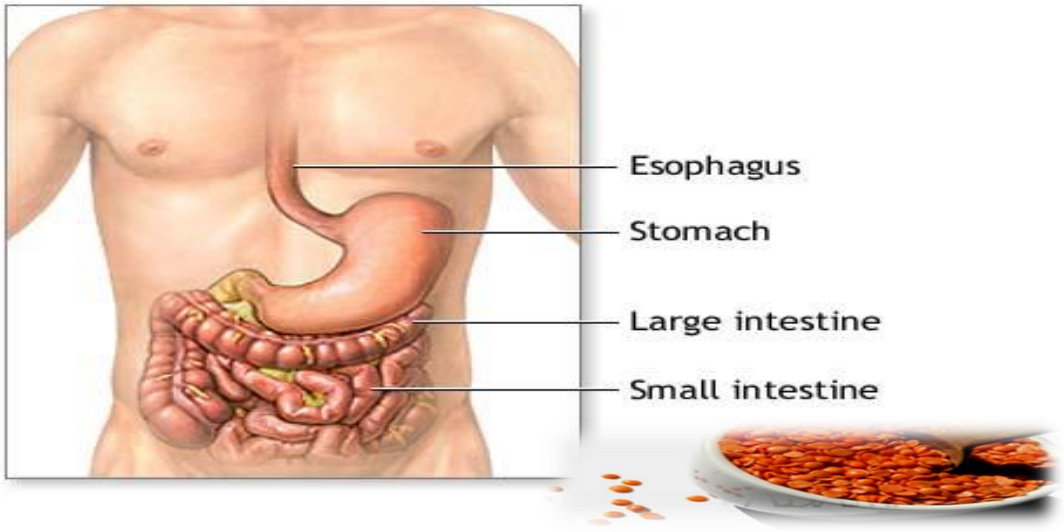
3. Resistant starch (RS): RS1 and RS2 are not absorbed in the small intestine because they are resistant to the effects of certain gut enzymes. Pulses contain 22-45% starch which is mostly amylose.



Pulses and Flatulence

Due to lack of α-galactosidase activity, RFO's are not hydrolysed in the upper gut

In the lower intestine they are metabolised by bacterial action, producing methane, hydrogen and carbon dioxide, which causes abdominal discomfort, flatulence and diarrhoea



Health Benefits of Complex carbohydrate : Prebiotic Effects, Satiety and Weight management

- Two groups of bacteria are present in the human gut: the Bacteroidetes and the Firmicutes and the relative proportion of Bacteroidetes is decreased in obese individuals can be improved with a prebiotic-rich, low-caloric diet with pulses .

- Thus a prebiotic-rich low-caloric diet containing resistant starch, non-digestible carbohydrates, oligosaccharides could play important roles in combating obesity and related diseases.

- Furthermore, the consumption of pulses with prebiotics may stimulate the growth and activity of bifidobacteria and lactobacilli in the colon, producing short-chain fatty acids (acetate, propionate and butyrate). Of these, butyrate is of particular benefit for lowering bowel cancer risk with demonstrated anti-tumor and anti inflammatory activity.

Measurement of prebiotics

- **Chromatographic procedures : High performance anion-exchange chromatography with pulsed electrochemical detection (HPAEC-PED), high performance liquid chromatography- refractive index (HPLC-RI), capillary zone electrophoresis (CZE), gas chromatography with flame ionization detection (GC-FID), and nuclear magnetic resonance (NMR) and low pressure liquid chromatography (using Bio-Gel P2) are available but are tedious and time consuming.**

- **(Biochemical kits for the measurement of raffinose are. The α-galactosidase used in these kits rapidly hydrolyses raffinose, but acts quite slowly on stachyose and verbascose)**

Raffinose, stachyose and verbascose ⟶ D-Galactose + Sucrose

Megazyme Kit

- **Galactosyl-sucrose oligosaccharides are hydrolysed to D-galactose, D-glucose and D-fructose using α-galactosidase and invertase.**
- **The D-glucose is then determined using glucose oxidase / peroxidase reagent.**
- **The method does not distinguish between raffinose, stachyose and verbascose, but rather measures these as a group. Since one mole of each of the raffinose - series oligosaccharides contains one mole of D-glucose, the concentrations are presented on a molar basis.**

Dietary fibre - the edible non-digestible component of carbohydrate and lignin naturally found in plant food

- **Insoluble dietary fibre** (Celluloses, hemicelluloses, lignins)
- **Soluble dietary fibre** (Pectins, gums)

Health benefits:

- Insoluble dietary fiber adds bulk to the stool, appears to speed the passage of foods through the stomach and intestine, reducing the incidence of constipation
- Soluble dietary fiber attracts water and turns to gel during digestion, thus slowing digestion.
- Soluble fiber lowers cholesterol (important in the prevention of heart disease) and delays glucose absorption (important in glucose control).



Dietary fibre content of Cereals and grain legumes

Sr. No.	Cereals	Total Dietary fibre (g/100g)
1	Rice, brown, long-grain, raw	3.5
2	Rice, white, short-grain, raw	2.8
3	Wheat flour, whole-grain, soft wheat	13.1
4	Wheat flour, whole-grain	10.7
5	Corn, Yellow	7.3

Sr. No.	Pulses	Total Dietary fibre (g/100g)
1	Chickpea, mature seeds, raw	17.4
2	Pigeon pea, mature seeds, raw	15.0
3	Lentil, raw	30.5
4	Mung bean, mature seeds, raw	16.3
5	Urd bean, mature seeds, raw	18.3
6	Peas, split, mature seeds, raw	25.5
7	Cowpea, mature seeds, raw	10.7

Source: USDA National Nutrient Database for Standard Reference, Release 26

Total Dietary Fiber Assay (AOAC 985.29)
Enzymatic & Gravimetric methods

Hear stable, Alpha amylase, incubation at pH 6.0, 15 min, 95 °C

↓

Protease inhibition at pH 7.5, 30 min, 60 °C

↓

Amyloglucosidase incubation at pH 4.5, 30 min, 60 °C

↓

Ethanol precipitation

↓

Alcohol and Acetone washings

↓

Drying

↙ ↘

Kjeldahl protein Ash determination

↓ ↓

Calculation of dietary fiber





Dietary Fiber digestor and Filtration Units

Range of variation for Total dietary fiber content

	Total dietary fibre (% dry wt.)
Chickpea	18-22
Lentil	13-20
Pea	14-26
Cowpea	31.2
Urdbean	14-29
Pigeonpea	16-31

Sr. No.	Crop	Insoluble Dietary Fibre (% dry wt.)	Soluble Dietary fibre (% dry wt.)	Total Dietary Fibre (% dry wt.)
1.	Pea (green)	10.2	3.2	13.4
2.	Lentil	9.5	2.0	11.5
3.	Chickpea	17.2	5.5	22.7
4.	Pigeonpea	12.2	3.5	15.5

Source: Khan et al., (2007). Dietary Fibre Profile of Food legumes. *S. J. Agric. Vol. 23, No. 3, 2007*

Diabetes and Pulses (Low glycaemic index foods)

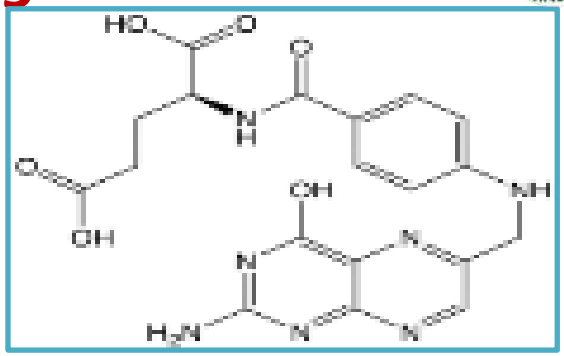
- Foods can be ranked based upon the postprandial glucose response.
- Pulses are low GI food with values ranging from 28-52.
- Low GI of pulses is due to presence of non-starch polysaccharides, and resistant starch
- Dietary intervention with a diet rich in legumes has been shown to be a natural, cost-effective solution for the prevention and treatment of [type 2 diabetes]

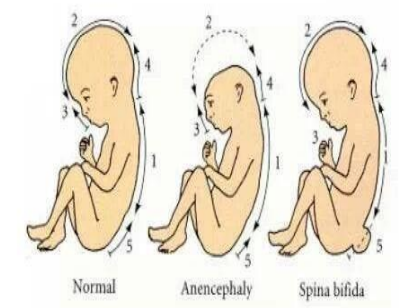
Food	Glycemic Index (GI)
Rice, white (Boiled)	69 ± 15
Maize (Flour)	59
Wheat (Whole Kernel)	39
Chickpea	31
Lentil (red)	32
Mungbean	31
Pigeonpea	22
Split pea (Yellow)	32

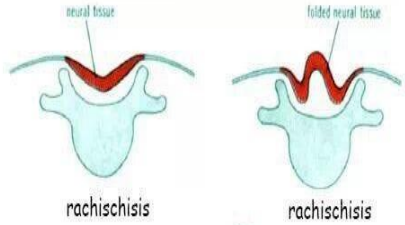


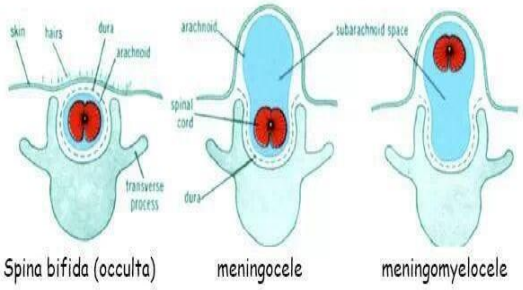
Folic acid-Vitamin B_9

- Folate (Water soluble - Vitamin B9) is essential for several bodily functions.
- Humans cannot synthesize folates de novo; therefore, folate has to be supplied through the diet.
- Inadequate intake of Folic acid during pregnancy increases the risks of preterm delivery, low birth weight, foetal growth retardation, and Neural Tube Defects (NTDs) - Spina bifida (malformation of the spine) and anencephaly (malformed brain).









Who else need extra folic acid:

- Women of childbearing age and pregnant women have a special need for folate ?
- Alcoholics: Folate deficiency is accelerated by alcohol consumption.
- Those with liver disease, or who are receiving kidney dialysis treatment may benefit from a folic acid supplement.
- Those taking drugs/medications that may interfere with the action of folate (dilantin phenytoin and primidone) (Epilepsy) metformin (Type II diabetes) and low dose methotrexate (Anti-allergic diseases-asthma, psoriasis, rheumatoid arthritis).

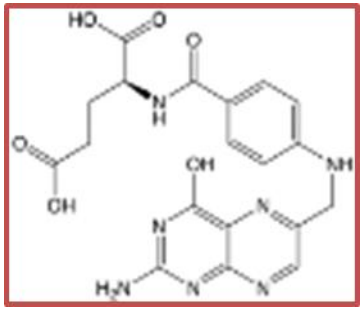
Folate content - Cereals and Pulses

Sr. No.	Cereals	Folate (µg/100 g)
1	Rice, brown, long-grain, raw	20
2	Rice brown long grain, cooked	4
3	Rice white, short grain raw	388
4	Rice white, short grain cooked	99
5	Wheat flour, whole-grain, soft wheat	28
6	Corn, yellow	19
Sr. No.	**Pulse Grains**	**Folate (µg/100 g)**
1.	**Chickpea mature seeds, raw**	**557**
2.	**Lentil, raw**	**479**
3.	**Pigeonpea, immature seeds, raw**	**173**
4.	**Cowpea, mature seeds, raw**	**639**
5.	**Mung beans, mature seeds, raw**	**625**
6.	**Peas, split, mature seeds, raw**	**274**

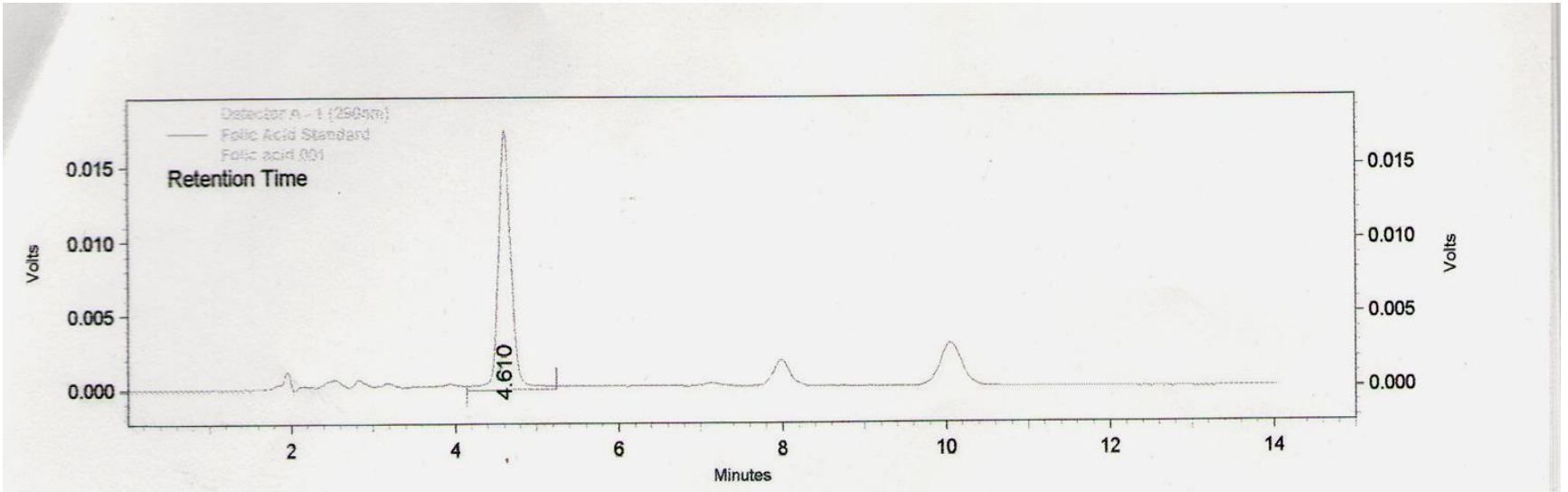
Source: USDA National Nutrient Database for Standard Reference, Release 26

Pulses are excellent source of folate and may have a protective role in colorectal, cervical, breast and pharyngeal cancers.

RP- HPLC Estimation of Folic acid



A simple and sensitive RP-HPLC method for the quantification of Folic acid using heptane sulfonic acid sodium salt as the ion pairing reagent was standardized.



Detector A - 1 (290nm)

Pk #	Retention Time	Area	Area %	Height	Height %
1	4.610	194931	100.000	17567	100.000

- **The retention time was 4.6 minutes as per the chromatogram of the working standard solution.**
- **No interfering peaks were observed near the retention time of folic acid.**

Mean Folic acid content in Lentil and Chickpea

Lentil Genotypes (30)	
Mean Folate (µg/100g) in lentil varieties (13)	184.43
Mean Folic acid content (µg/100g) in Mediterranean landraces (17)	251.31
Range (13 Varieties)	114.4-291.7
Range (17 Landraces)	115.2- 479.0

Chickpea Genotypes (54)	Mean and Range Folate (µg/100g)
Desi (n=36)	148.5 (136.1-152.7)
Kabuli (n=15)	132.7 (128.4-148.6)
Wild accessions (n=03)	120.1 (119.5-120.7)

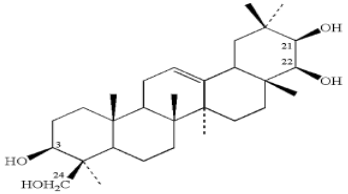
Sen Gupta et al., (2013) J. Food & Agric. Chem (NDSU, USA)	
Mean folate content in 10 commercial lentil cultivars (µg/100g)	255
Range of Folate content in lentil cultivars (µg/100g)	216-290





Agrisearch with a human touch

Saponins- Steroidal glycosides



- **Saponins – Comprise of a steroidal triterpene or aglycone linked to one or more sugar chains (galactose, arabinose, Xylose, glucose) via ester or ether linkages.**

SAPONIN = SUGAR + SAPOGENIN

glycone | **aglycone**

There are more than 11 distinguished classes of saponins

Structurally divided in to two groups:

Soyasapogenol A : Bidesmosidic saponins - two glycosylation sites

Soyasapogenol B : monodesmosidic saponins - single glycosylation sites

- **Within grain legumes the saponin content varies between 0.5-5 % dry weight. Soyabean-6500 mg kg^{-1}, Lentil-1100mg kg^{-1}**

Clinical studies have suggested that saponins have the ability to:

1. Help protect the human body against cancers

- Direct cytotoxicity and growth inhibitory effects against tumour cells
- Immune-modulatory effects-
- Bile acid binding- delays the initiation and progress of cancer.

2. Lowers cholesterol level

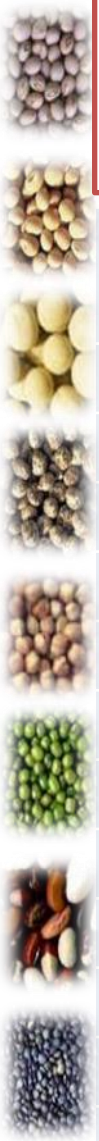
3. It has an inverse relationship with the incidence of renal stones.

(J Med Food. 2004; 7(1): 67-78).



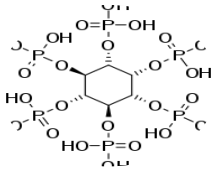
Variability for Saponin in Chickpea and Lentil genotypes

The saponins were quantified by HPLC, isocratically at a flow rate of 0.9ml/min (mobile phase acetonitrile : water) using C-18 reverse phase column and UV detector (205 nm).

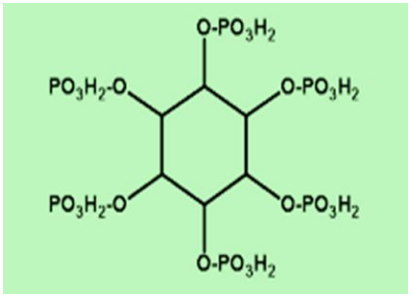


Chickpea Genotypes (09)	Sapogenol A	Sapogenol B	Total Sapogenol
BG 256	322.8±1.2	460.0±1.0	782.8±0.7
JG 74	242.2±1.2	425.2±0.2	667.4±0.4
KWR 108	241.0±1.0	413.5±0.5	654.5±0.5
DCP 92-3	249.0±1.0	435.6±0.3	684.3±0.3
KAK 2	352.2±1.2	490.8±0.8	843.0±0.5
JKG 1	291.5±0.5	568.8±0.3	860.2±0.3
BG 1053	211.9±1.8	439.3±0.3	651.0±0.1
L-550	293.3±0.5	444.3±0.3	737.5±0.5
Sadabahar	262.3±1.2	478.8±0.8	744.0±0.5
Mean	274.0	461.81	736.07
SEm	0.92	0.47	0.37
CD 0.05	1.93	0.98	0.77

Lentil Genotypes (10)	Sapogenol A	Sapogenol B	Total Sapogenol
DPL 15	248.7±1.7	379.6±0.1	628.6±0.6
DPL 58	307.2±0.2	368.8±0.0	676.1±0.5
DPL 62	205.4±0.4	452.9±0.5	658.4±0.4
PL 4	289.6±0.6	369.7±0.8	659.3±0.8
PL 406	291.1±1.1	362.9±1.1	654.0±0.0
PL 639	257.0±0.1	375.7±0.8	632.7±0.7
JL 1	317.6±0.1	361.0±0.3	678.6±0.6
VL 1	226.1±1.1	365.5±0.6	591.6±0.1
K 75	332.8±0.8	367.6±0.2	700.5±0.5
Ranjan	198.1±0.1	371.5±0.6	569.6±0.1
Mean	267.4	377.5	644.9
SEm	0.7	0.5	0.4
CD 0.05	1.4	1.0	0.9



Phytate in pulses



Phytic acid (myo-inositol hexaphosphoric acid, IP6)
Chem. form : $C_6H_{18}O_{24}P_6$
MW: 660.03

- Phytic acid, also known as phytate or myo-inositol-1,2,3,4,5,6-hexakisphosphate (InsP6), is the main storage form of phosphorus.
- **Because of its reactive phosphate groups attached to the inositol ring, It chelates the** essential mineral nutrients and reduces the bioavailability of iron, zinc and other mineral nutrients.

Health benefits

- PA is considered to be a natural antioxidant. (1.6-11.2 µM Trolox equiv (TE)/g of dry matter-dry beans)
- Has been shown to exhibit anti-cancer properties. IP6 is taken up by malignant cells and acts as a broad-spectrum antineoplastic agent.
- It has also been shown to reduce cholesterol and triglycerides, and positively impact the glycemic response of certain foods.

Pulse	Phytate content (%)
Urdbean	1.29 – 1.54
Pigeonpea	6.8 - 17.5
Mungbean	10.2 - 14.8
Chickpea	7.7-12.2
Lentil	7.79- 13.6

Quantification of Phytic acid



The quantitative method for phytic acid measurement is relatively complex, the generally accepted AOAC Method 986.11 has limitations. For each individual analysis the method requires cumbersome anion-exchange purification.

Megazyme has developed a simple, quantitative method (K-PHYT) which does not require tedious anion-exchange purification.

- **This method involves acid extraction of inositol phosphates followed by treatment with a phytase that is specific for phytic acid (IP6) and the lower myo-inositol phosphate (i.e. IP2, IP3, IP4, IP5).**
- **Subsequent treatment with alkaline phosphatase ensures the release of the final phosphate from myoinositol phosphate (IP1) which is relatively resistant to the action of phytase.**
- **The total phosphate released is measured using a modified colourimetric method and given as grams of phosphorus per 100 g of sample material.**
- **The phytic acid content is calculated based on the assumption that the amount of phosphorus measured is exclusively released from phytic acid and that this comprises 28.2% of phytic acid.**

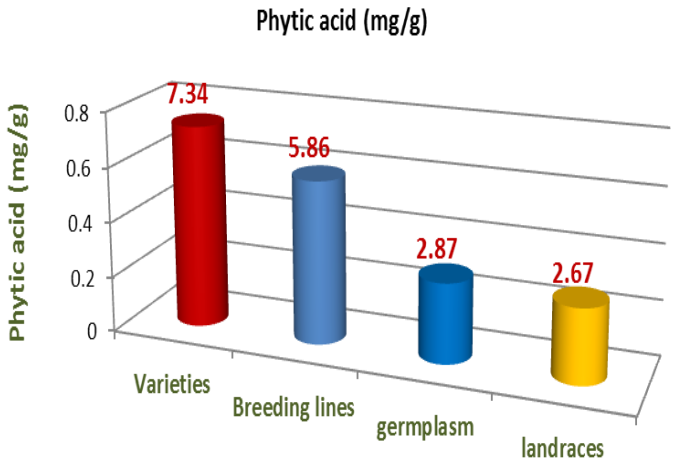
Phytic acid in Chickpea and lentil

Chickpea genotypes (54)	Phytic acid content (mg/g)
Desi type (n=36)	8.61 (6.3-10.69)
Kabuli type (n=15)	9.05 (7.89-10.58)
Wild accessions (n=03)	8.00 (7.75 - 8.28)

Lentil Varieties Tested	20
Mean Phytic acid (mg/g)	7.34
Range	1.3-20.0 mg/g

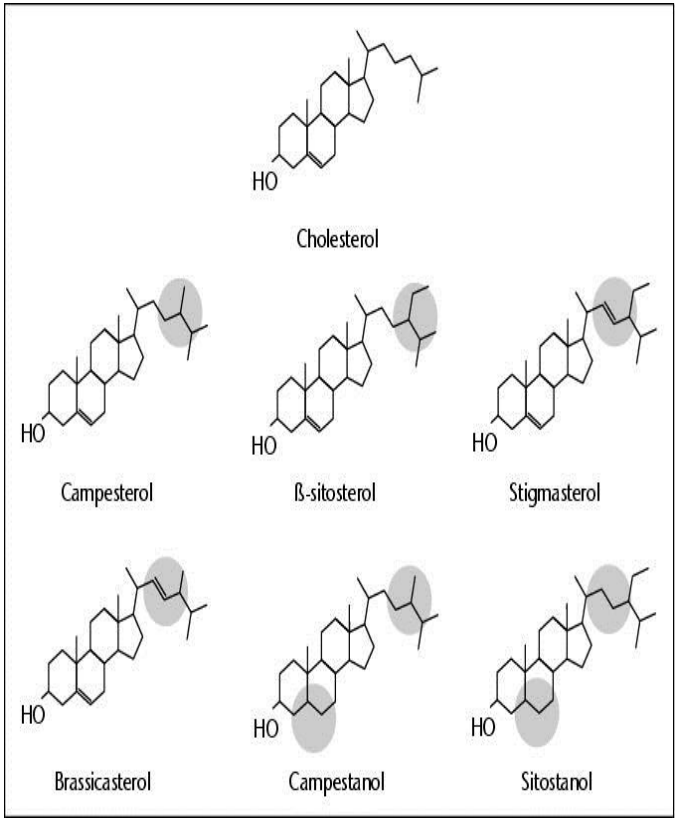
- The phytic acid content of various chickpea accessions showed narrow genetic variation.
- The mean phytic acid content in Kabuli types was higher as compared to the desi types





Phytosterols – Health benefits

- **Phytosterols** (plant sterols and stanols) are structurally similar to cholesterol.
- Absorption is less than 2% for phytosterols, while it is 30-60% for cholesterol.
- **Phytosterols** - the most important benefit is their blood **cholesterol-lowering effect** which may ultimately reduce the risk of **coronary heart disease** and prevents the development of **different types of cancers**, like colorectal, breast and prostate cancers
- Intake of 2 g of phytosterols reduces cholesterol absorption by 30-40% and LDL-cholesterol by 10%.





Pulses and Phyto-sterols

- Pulses are one of the major natural sources of phytosterols, the common phytosterols are β-sitosterol, campesterol, and stigmasterol.
- In Lentil, β-sitosterol represents the predominant phytosterol, ranges 15.0–24.0 mg/100 g

Pulse grains	β-sitosterol (mg/100g)	Campesterol (mg/100g)	Stigmasterol (mg/100g)
Chickpea	159.8 ± 7.1	21.4 ± 0.7	23.4 ± 0.7
Lentil	123.4 ± 4.1	15.0 ± 0.4	20.1 ± 0.6
Pea	191.4 ± 0.4	25.0 ± 6.9	26.0 ± 0.6

Source: R. Campos-Vega et al. / Food Research International 43 (2010) 461–482



Protein inhibitors – Potential Anti-carcinogenic Property

- Protease inhibitors inhibit the actions of trypsin, pepsin and other proteases in the gut, thus impairing the protein digestion and subsequent absorption of protein & inhibits animal growth.
- Amylase inhibitors prevent the action of enzymes that break the glycosidic bonds of starches and other complex carbohydrates, preventing the release of simple sugars and absorption by the body.
- Kunitz and Bowman-Birk . Soybean-both types are present
- In lentil the protease inhibitors have been characterized as members of the Bowman-Birk family

Crop	TIA (TIU/mg)
Pea	6-15
Lentil	3-8
Chickpea (Desi lines) Chickpea (Kabuli lines)	12.7 15-19

Lentil Genotypes tested	93
Mean (TIU/mg protein)	7.49
Range	2.21-13.30

Major antioxidants in Pulses

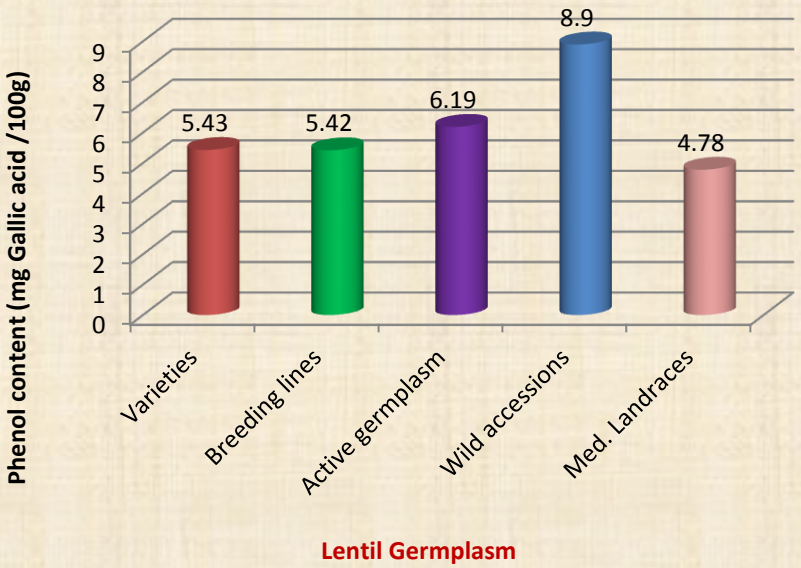
	Phenols		
1	**Flavonoid polyphenols**	Flavones	Apigenin, Luteolin, Tangeritin
		Flavonols	Isorhamnetin, Kaempferol, Proanthocyanidins, condensed tannins, quercetin
		Flavanols and their polymers	Catechin, gallocatechin Epicatechin, Epigallocatechin
		Isoflavone phytoestrogens	Daidzein, Genistein
2	**Phenolic acids and their esters**	Polyphenols Tannins	Chlorogenic acid, Cinnamic acid, Gallic acid, Gallotanins

Phenols with antioxidant and anti-mutagenic activities could inhibit the formation of tumors

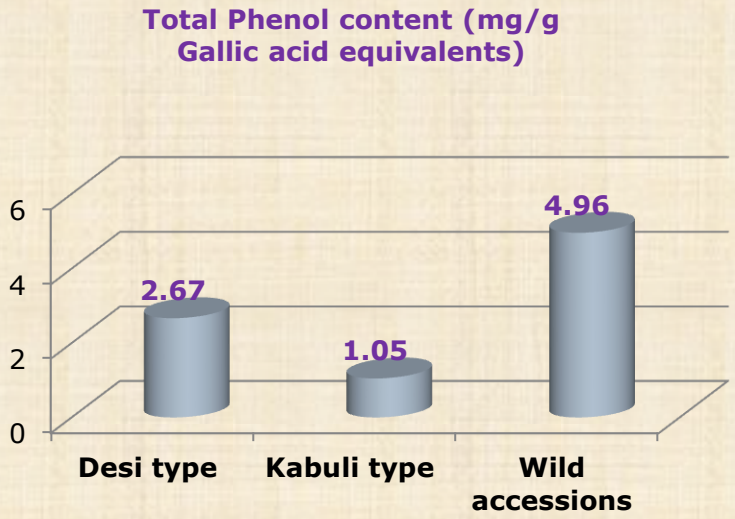
Total Phenol content in Lentil and Chickpea

Lentil Genotypes tested	98
Mean Phenol content (mg Gallic acid/g)	5.63
Min	2.96
Max	11.96

Chickpea genotypes (54)	Total Phenol mg /g Gallic acid equivalents
Desi type (n=36)	2.67 (1.60-3.32)
Kabuli type (n=15)	1.05 (0.51-1.36)
Wild accessions (n=03)	4.96 (4.48-5.64)



Lentil Germplasm



Agrisearch with a human touch

Tannin content in lentil

- In lentil tannins are principal polyphenols which are mainly concentrated in the testa.
- In red lentil the dominant phenolics were quercetin diglycoside, catechin, digallate procyanidin, and p-hydroxybenzoic acid
- In green lentil the dominant phenolics were catechin glucosides, procyanidin dimers, quercetin diglycoside, and trans-p-coumaric acid.

- The distribution of phenolic compounds differs in the cotyledon and the seed coat.
- In the cotyledon, non-flavonoid phenolic compounds, such as free and combined hydroxy benzoic and hydroxycinnamic acids are dominant
- whereas, in the seed coat, flavonoids, such as glycosides of flavonols and flavones, are dominant.
- The coat also contains trans-resveratrol-3-O-glucoside, and large amounts of proanthocyanidins, which are absent in the cotyledon.



Polyphenols and antioxidants

The polyphenolic constituents are effective **Antioxidants** : Singlet Oxygen Quenchers

Methods- Antioxidant activity

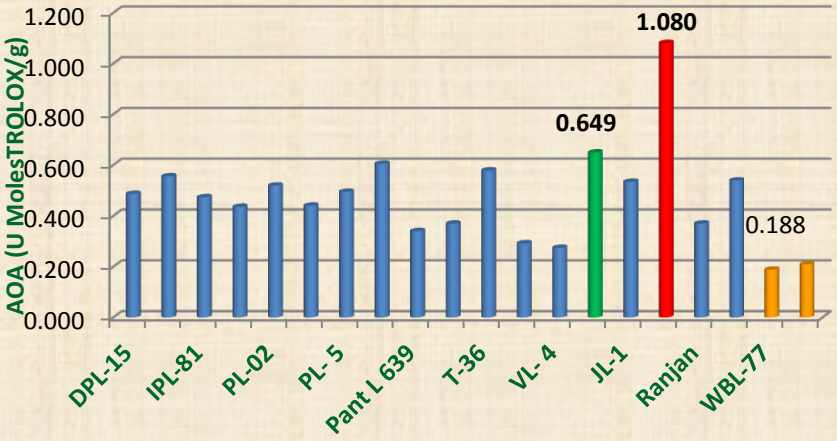
1. **Oxygen Radical Absorbance Capacity (ORAC)**
2. **DPPH Method (1, 1 diphenyl 2, picryl hydrazyl)**
3. **Super oxide radical scavenging activity**
4. **Hydroxyl radical scavenging activity**
5. **ABTS (2,2-azinobis(3-ethyl benzothiazoline-6-sulfonicacid) diamonium salt)**
6. **FRAP Method:** (Ferric Reducing Ability of Plasma)
7. **TRAP Method (**Total Radical Trapping Antioxidant Parameter)
8. **Thiobarbituric acid (TBA) assay**

Antioxidant activity in Lentil and Chickpea

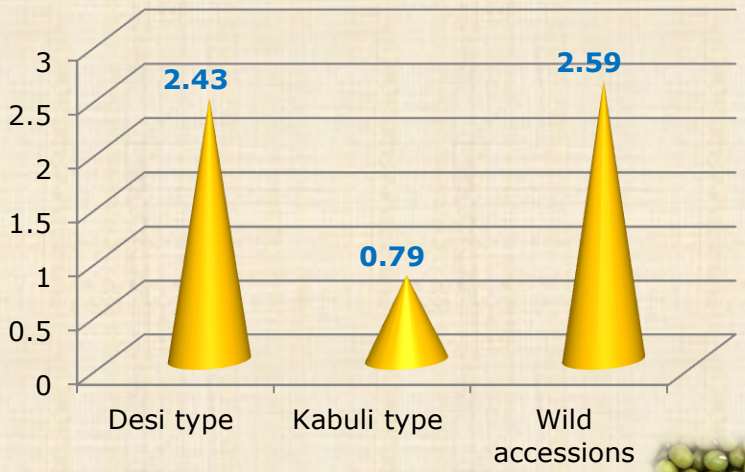
Lentil Varieties Tested	20
Mean AOA (µMol TROLOX/g)	0.471
Range	0.188-1.080

Chickpea genotypes (54)	Antioxidant activity (µM TROLOX /g)
Desi (n=36)	2.43 (1.01-3.09)
Kabuli (n=15)	0.79 (0.41-1.16)
Wild accessions (n=03)	2.59 (2.25-2.89)

Antioxidant activity in 20 Lentil varieties



Total antioxidant activity (µM TROLOX/g)



Agrisearch with a human touch

Phenolic content and antioxidant values

Pulses	Total phenolic (mg Gallic acid equivalents g^{-1})	Total flavonoid (mg catechin equivalents g^{-1})	Condensed Tannin (mg catechin equivalents g^{-1})	DPPH scavenging capacity (µmol Trolox equivalent g^{-1})	FRAP value (mmol Fe^{2+} equivalents 100 g^{-1})	ORAC value (µmol Trolox equivalent g^{-1})
Chickpea	1.81	0.18	1.05	1.05	0.73	5.13
Lentil	**6.56**	**1.30**	**5.97**	**16.79**	**7.78**	**50.06**
Yellow pea	1.67	0.18	0.42	2.13	1.28	23.17

Source: Xu and Chang, 2007

- **Lentil has the highest total phenolic content (TPC).**
- **TPC of lentil exhibited significant correlation with total antioxidant activity, implying that phenolic compounds are major antioxidant compounds in lentil.**




Thanks