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## Pulses And Legumes As Functional Foods

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Legumes and pulses have long been a part of traditional diets in Asia, Africa and South America, which include most of the world's developing countries. More than 1,000 species of legumes are known to be grown<sup>1</sup>. Of these, only 20 or so have been cultivated for use as food. They have been consumed as a rich source of protein supplementing the cereal – or tuber-based diets and have an important role in human nutrition<sup>2,3</sup>. Some legumes such as groundnut and soybean are also good sources of oil.

In India, from time immemorial, many legumes and pulses (Table 1) have been consumed as part of a primarily cereal-based diet. They are consumed as whole gram or as split pulses (*dhals*). Pulses are the main source of protein in the primarily vegetarian Indian diet. Besides proteins, pulses are also good sources of vitamins, minerals,  $\omega$ -3 fatty acids and dietary fibre or non-starch polysaccharides (NSP). Charaka<sup>4</sup>, the physician of ancient India, has identified a number of pulses as important dietary components in disease management. In recent years, pulses and legumes have also been recognised as part of functional foods<sup>5</sup>.

Several legumes contain non-nutrient bioactive phytochemicals<sup>6,7</sup> that have health-promoting and disease-preventing properties. The important health promoting 'non-nutrient' compounds present in pulses and legumes include non-starch polysaccharides (NSP), phytosterols, saponins, isoflavones, a class of

phytoestrogens, phenolic compounds and antioxidants such as tocopherols and flavonoids.

### NSP IN PULSES AND LEGUMES

Pulses and legumes are a rich source of NSP<sup>8,9</sup>. The NSP component of some of the commonly consumed pulses<sup>10</sup> is as shown in Table 2. The NSP content of pulses and legumes is 13 to 15 g of NSP per 100 g. Thus, they contribute significantly to the total NSP intake of habitual Indian diets. The NSP in pulses consists of soluble and insoluble non-cellulosic fibres. The average content per 100 g of water-soluble fibre is 4 to 7 g and that of insoluble fibre is 5 to 7 g. The NSP content of pulses is similar to that of cereals and millets (8-20 g/100 g). A combination of cereals and pulses in a diet provides 50-85 g of NSP depending on the quantity and the type of cereal (or millet) and pulse used (Table 2).

Epidemiological observations and a number of human and animal studies have shown that the NSP in pulses have a role in protecting against degenerative diseases such as diabetes, cardiovascular disease and cancer. NSP protects against chronic diseases such as diabetes by controlling blood glucose levels. Their hypocholesterolemic property protects against cardiovascular disease. They also help prevent bowel cancer by binding carcinogens and toxins<sup>11,12</sup>. The disease-preventing potential of NSP depends upon the proportion of various fractions of NSP and their actual

content in a given food<sup>11</sup>. Some legumes such as fenugreek, which contains 40 per cent gum, can exert the expected beneficial effect on a daily intake of about 50 g<sup>13</sup>.

The NSP components exert their beneficial preventive effects through several mechanisms. One of the mechanisms is through their swelling properties, consequently reducing the transit time in the small intestine and reducing the rate of release and their absorption of glucone from dietary carbohydrates and of cholesterol and fat. The second mechanism is through the binding of carbohydrate carcinogens and toxins in the intestinal tract by the insoluble NSP. This prevents or slows down the absorption of the carcinogens and toxins. The NSP can also bind bile acids and thereby promote the excretion of cholesterol from the liver through bile. It must be remembered that through this binding property, NSP can also have some adverse effects on the availability of dietary calcium, magnesium, zinc and iron.

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**TABLE 1**  
**Food Legumes**

Bengal gram	( <i>Cicerarietinum</i> )	Adzuki bean	( <i>Phasedus angularus</i> )
Black gram	( <i>Phaseolus mulugo rorb</i> )	Lima bean	( <i>Phaseolus lunatus</i> )
Cowpea	( <i>Vigna catana</i> )	Winged bean	( <i>Phosphocarpus tetragonobolus</i> )
Field bean	( <i>Dalichos lab lab</i> )	Bambera groundnut	( <i>Voandzeia subtaerranea</i> )
Green gram	( <i>Phaseolus aureus rorb</i> )	Jack bean	( <i>Canavalia eusiforonis</i> )
Horse gram	( <i>Dolidios biflourus</i> )	Sword bean	( <i>Canavalia gladiata</i> )
Lentil	( <i>Lens esculanta</i> )	Lablab bean	( <i>Lab lab purpureus</i> )
Moth bean	( <i>Phaseolus aconitifolius B Jacq</i> )	Rice bean	( <i>Rigna umbellata thunb</i> )
Peas	( <i>Pisum sativus</i> )	Tepery bean	( <i>Haseolus acutifolis</i> )
Rajmah	( <i>Phaseolus vulgaris</i> )	Groundnut <sup>a</sup>	( <i>Arachis hypogaea</i> )
Red gram	( <i>Cajanus cajan</i> )	Fenugreek <sup>b</sup>	( <i>Trigonella foemin graecum</i> )
Soyabean <sup>a</sup>	( <i>Glucine max merr</i> )	Kesari dhal	( <i>Lathyrus sativus</i> )

<sup>a, b</sup> Source of oil and protein.

The third mechanism by which NSP exert beneficial effects on chronic diseases is through their fermentation in the large intestine (colon)<sup>14</sup>. While soluble NSP are completely fermented, the insoluble fibres are partially fermented. As a result of this fermentation, bacterial cell mass increases and reduces the transit time due to increased bulk. Also as a result of colon fermentation of NSP, short chain fatty acids such as butyrates, propionates and acetates are produced. Butyrates serve as a source of energy and thus help in rejuvenation of colon mucosal cells. They also promote differentiation and inhibition of cell proliferation in human carcinoma cells and promote DNA repair. NSP, through the release of free fatty acid like butyrate on fermentation in the colon, reduce the risk of colon cancer and inflammatory bowel disease.

The short chain fatty acids, particularly propionates and acetates, enter into splanchnic circulation and are transported to the liver where they exercise a direct inhibitory effect on the release of glucose and synthesis of cholesterol. Thus, they contribute indirectly to the hypoglycaemic and hypocholesterolemic effects of NSP.

### ISOFLAVONES (PHYTOESTROGENS)

Isoflavones are phytoestrogens that exhibit weak oestrogen activity and are present in significant amounts

in pulses and legumes<sup>5,6</sup>. Isoflavones can protect against hormone-dependent diseases such as breast cancer and cardiovascular disease<sup>6</sup>. Recent studies have detected their anticancer activity in a number of animal carcinogenesis model experiments. Isoflavones also possess biological functions other than oestrogen-related activity, for example, antioxidant activity. The important isoflavones are daidzein, genistein, daidzin, genistin, biochinin A, protensin, formononetin, etc.

Sharma<sup>15,16</sup> has studied the isoflavone content of common pulses and legumes used as food in India; the values are given in (Table 3). There have been earlier reports on the blood cholesterol lowering potential of chickpea (Bengal gram)<sup>17</sup> and other legumes including soybean<sup>5,6</sup>. The hypocholesterolemic potential of these legumes have been attributed to their isoflavone content<sup>6,15</sup>. The isoflavone content of pulses is reported to increase after germination. However, the potency of isoflavones decreases after the legumes have been cooked<sup>16</sup>.

Recent studies on soy have suggested that a combination of soy protein and isoflavones is necessary to produce the greatest cholesterol-lowering effect<sup>5,6</sup>. In addition to being a high-quality protein, soybean protein is now thought to help prevent and treat cardiovascular disease. There were also earlier reports that Bengal

gram proteins also has a cholesterol-reducing property<sup>17</sup>. It is likely that pulse proteins act in conjunction with their isoflavone content to reduce blood cholesterol. The oestrogenic activity of isoflavones are in the following order: biochinin A < daidzein < formononetin, and the isoflavone content varies with the variety of legume.

There have been extensive studies on the health promoting and disease preventing potential of soy isoflavones<sup>5,6</sup>. The two primary isoflavones, daidzein and genistein, the latter exclusively present in soybean, are reported to be most biologically active phyto-estrogens. Daidzein, present in high concentration in soybeans, is known to modulate hormone-related conditions such as heart disease, osteoporosis, breast and prostatic cancers and menopausal symptoms<sup>5,6</sup>. There is currently considerable interest in soy as a health food because of these biological functions. Isoflavones extracted from soy are commercially marketed. Similarly, a combination of 6.25 g of soy protein with 12.5 mg of total (extracted) isoflavones, equivalent to 25 g of soy alone, is marketed as a health food<sup>5</sup>.

Although a lot of work has gone on during the past decade on soy isoflavones, hardly any work, except for a limited study by Sharma<sup>15,16</sup>, has been done on the isoflavone content of Indian pulses. Several commonly consumed pulses, particularly Bengal gram, contain high concentration of isoflavones (152 mg/100 mg)<sup>16</sup>. Green gram and black gram also contain 80-90 mg of isoflavones, made up of mostly protensin and daidzein. There is, therefore, considerable scope for future research on the isoflavones of Indian pulses, their content, structure and bioactivity to exploit isoflavone-rich pulses as health foods, in the same way that soy has been exploited. These isoflavones with phenolic groups in the molecule can also act as antioxidants along with other antioxidants such as tocopherols and flavonoids present in these pulses.

### OTHER PHYTOCHEMICALS

Several other phytochemicals such as saponins, flavones, phenolic acids and precursors of mammalian lignan with anticarcinogenic potential are reported to be present in soybean and their biological function have

been extensively studied<sup>6</sup>. Saponins, which are hypocholesterolemic agents, are reported to be present in soy at high concentration. The presence and content of these phytochemicals in Indian pulses do not appear to have been studied to any significant extent. These pulses, unlike soy, are widely consumed in India. Occurrence of these phytochemicals in Indian pulses, their identification, content, chemistry and their health benefits require a systematic study. There is also a need to study the bioavailability of isoflavones and other phytochemicals present in Indian pulses.

### ANTIOXIDANT CONTENT

Pulses contain tocopherols, flavonoids and isoflavonoids, all of which can act as antioxidants. Although dry pulses do not contain any ascorbic acid, the germinated pulses and immature green pulses do contain ascorbic acid which also has antioxidant activity. The isoflavone content of pulses has been shown to increase two to three times after germination<sup>16</sup>. Thus, both dry legumes and green and germinated pulses are good sources of antioxidants. Pulses contain about 3.5 mg of vitamin E per 100 g as compared to 1.2 mg in cereals. On the basis of total daily intake of 400 g of cereals with 50 or 75 g of pulses, the

total antioxidant tocopherol intake works out to 7.1-7.7 g. The flavonoids are reported to have four to five-fold antioxidant activity as compared to ascorbic acid. However, the exact levels of flavonoids and their antioxidant patency have not been studied in Indian pulses. Although pulses may not be a major source of antioxidants in a cereal-pulse-based diet, they can contribute significantly to the total daily intake of antioxidants on a diet based on cereals, pulses, fruits and vegetables.

### CURRENT PRODUCTION OF PULSES AND LEGUMES IN INDIA

Considering the nutritional importance of legumes and pulses in Indian diets, their production and per capita availability is rather depressing<sup>20</sup>. While cereal production has dramatically increased to self-sufficiency since Independence, pulse production and per capita availability has actually gone down since 1950. Per capita availability of pulses has decreased from 60 g in 1950 to 38 g in 1990, a reduction of nearly 40 per cent. On the other hand, the per capita availability of cereal and millets has increased from 330 g to 470 g in spite of a four-fold increase in population. The cereal-to-pulse ratio, which should be ideally 8:1, has risen from 6:1 to 12:1. There is an urgent need to im-

prove pulse production in the country to yield at least 60 g of pulses per capita per day. In order to provide adequate protein in the cereal-based Indian diets, the intake of pulses has to be 50-75 g per day and it should be higher (75 g) in diets based on rice and millets (ragi), with protein content of 6-7 per cent, than in diets based on wheat and other millets with 10-12 per cent proteins (50 g). On this basis, the production of all pulses and legumes should increase from the current 14 million tonnes to at least 27 million tonnes. This can perhaps be achieved by growing pulses in irrigated areas, after the rice or wheat crop, using better variety of seeds and exploiting less commonly used and unfamiliar legumes. The production of groundnuts and soy, which are also important sources of edible oil, should be taken into account while considering per capita availability of proteins from legumes. In the present agricultural policy on food production, the emphasis should shift from cereals to pulses.

There is also a need to cultivate minor legume seeds such as rice bean, moth bean, goa bean and tropical lima bean after establishing their nutritional quality and safety. Several of these unfamiliar legume pulses have in fact been investigated at NIN for

**TABLE 2**  
Dietary Fibre in Pulses and Legume Foods (g/100 g)

Foods	Total	Non-cellulose polysaccharides			Cellulose	Lignin
		Total	Water soluble	Water insoluble		
<b>Legumes with husk</b>						
Bengal gram	26.0	10.1	3.7	6.4	13.4	2.5
Soya bean	20.8	9.9	3.4	6.5	8.2	2.7
Winged bean	35.2	17.0	9.7	7.3	13.3	4.9
Kesari <i>dhal</i>	18.6	6.4	2.6	3.8	9.1	3.1
<b>Dhals</b>						
Red gram	13.4	10.3	—	—	2.1	1.0
Black gram	13.6	9.5	—	—	2.9	0.9
Bengal gram	13.4	7.1	—	—	5.5	1.2
Green gram	13.2	8.6	—	—	3.7	1.0
Rice	8.3	4.1	—	—	2.7	1.6
Wheat	17.2	10.6	—	—	5.5	1.2
400 g rice + 75 g blackgram <i>dhal</i>	43.4	23.5	—	—	13.0	7.1
400 g wheat + 50 g blackgram <i>dhal</i>	75.6	49.2	—	—	23.5	5.3

**TABLE 3**  
**Isoflavone Content of Pulses and Legumes**  
**(mg/100 g fresh weight)**

Isoflavones	Soyabean	Bengal gram	Greengram	Black gram	Red gram
Daidzein	2.7 (49)*	5.1	80.7 (81)	88.0 (98.0)	85*
Protensin		4.8			12
Formononetin		44.1			
Biochinin A		98.6			
Genistin	95.4				
Genistein	2.4				
Daidzin	40.6				
Total	67.8 - 388.6	152.6	80.7	88.8	97

\*Content on sprouting

their chemical and nutritional quality and safety. More studies on their use in Indian cooking and their functional components require to be initiated. The possible use of lathyrus seeds as a pulse with daily intake not exceeding 25 g with low toxin content obtained by growing low-toxin varieties<sup>21</sup> or by the removal of toxin<sup>9</sup> can be explored.

### SOY AS A LEGUME FOOD IN INDIA

The production of soy bean has increased significantly in recent decades in India. Currently, it occupies a prominent place among pulses and legumes grown in India, current production being 6.52 million tonnes.

The soy bean grown in India is exclusively used as a source of oil and the meal as a protein source in animal feeds. There is an urgent need to promote soy bean as a legume grain for human use in India, not only to meet our shortage in pulses but also to use it as a functional food. However, several problems need to be overcome before soy bean can be used as a legume food in India, where it is completely unfamiliar, unlike in countries of East and South East Asia.

There are several limitations for the use of soy bean as a food legume in Indian diets. These are the antinutritional factors (trypsin inhibitors) which are not destroyed on ordinary cooking used for pulses, the unfamiliar organoleptic factors such as flavour and odour, and the presence of flatulence factors. Special processes are available to eliminate or at least reduce these factors to a more acceptable level<sup>20</sup>. These prob-

lems with soya have been overcome in other Asian countries through fermentation to convert it to temphe or soya sauce which is widely used in Japanese and Chinese cuisine.

Simple processing such as germination or the use of green immature pods can also help in utilising soy as a food legume or as a vegetable. In India, soya can, however, be introduced as processed flour, which, through appropriate nutrition education, can be successfully incorporated into various familiar dishes that use *dhal* flours.

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