Linking Research and Marketing Opportunities for Pulses in the 21st Century

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PROCESSING AND GRAIN QUALITY TO MEET MARKET DEMANDS

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Abstract

Considerable resources have been directed towards improving the nutritional quality of cool season food legumes with respect to protein content and amino acid pattern and to reducing the content of antinutritional factors such as trypsin inhibitors and haemaglutinins. Less attention has been paid to the processing and grain quality factors that affect the utilisation of these legumes. Two important market considerations are the dhal yield and consumer acceptance of the product. These are influenced by the size, shape, colour and, chemical composition of the grain, by storage conditions and any pre-treatment before use. The cooking time, texture, water absorption and dispersibility of solids are determinants of quality of these legumes as food. Under adverse storage conditions, the legumes can develop hard-to-cook defects, depending on genotype and cultural practices. Nutritional quality needs to be considered in terms of protein digestibility, antinutritional factors, availability of carbohydrates and content of essential micronutrients such as vitamin A, iron, copper and zinc. Available technologies such as roasting, steaming, germination, fermentation, and extrusion cooking, and protein isolation/concentration play a role in determining the product quality. These topics are reviewed and future research needs are suggested in the paper.

INTRODUCTION

Nearly 80% of proteins and 90% of calories consumed by humans in developing countries are supplied by plant products. The cool season food legumes are increasingly important in human nutrition, because they are less expensive sources of proteins than the animal proteins, especially in developing countries. In addition, they are valuable sources of carbohydrates, minerals and vitamins. Their protein quality for food is low, however when mixed with cereals the total diet quality can exceed 70% of casein or lactalbumin. In several developing countries, mixing cereals and legumes to provide a good quality diet was in practice long before people understood the nutritional importance of the practice. The world production of cool season food legumes has increased during the past few decades, mostly due to an increase in the area under cultivation. World production of both dry peas and lentils almost doubled in 1980-90 (FAO 1990). However, in recent years per capita availability of pulses has declined in some regions of Asia, mainly due to increases in population. The daily per capita consumption of pulses were reported to be 43 g for Pakistan, 35.7 g for India, 23 g for Indonesia, 42 g for China, and 25-50 g for the Middle East (Singh and Singh 1992).

The majority of pulses are consumed in the regions where they are grown. Those entering international markets do so in the raw or processed forms. Although Asian countries produce nearly 55% of the world's pulse crops, the demand will continue to increase because of the expanding population, particularly on the Indian subcontinent. Consumers in these countries are increasingly aware of the factors that affect the nutritive value of the food they consume. This paper reviews research on processing and grain quality and the needs for further research on end-uses and market requirements.

THE FOOD LEGUMES

Dry beans (*Phaseolus vulgaris*) can be broadly divided into culinary beans, weighing from about 250 mg (e.g. Great Northern, red kidney) to 600 mg (Borlotti, Cannelloni), and navy beans, 120-220 mg. Dry beans are used in a diversity of soup, salad and vegetable dishes. Immature green beans are also harvested green for vegetable use.

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Field peas (*Pisum sativum*) traditionally, are harvested to be eaten fresh or field dried before storage and consumption. A significant proportion is also harvested as green, immature seeds for commercial freezing. There are three main types used for human consumption: 1) vining peas for canning fresh ('garden peas'), quick freezing, or artificial drying; 2) threshed dry peas which may be split after dehulling; and 3) pulling peas sold as fresh peas in pods.

Chickpea (*Cicer arietinum* L.), Bengal gram or garbanzo bean is second to dry beans in area grown and third in production to dry beans and dry peas. Kabuli seeds are generally large and light coloured while desi seeds range from yellow to black. They are generally smaller, and have a rougher surface. Some new desi types have 'large' seeds, approaching the size of kabuli seeds.

Chickpeas have a very low content of antinutritional factors and tend to be richer in calcium and phosphorus than most other pulses. Kabuli types are mostly used as a cooked vegetable and sometimes as a roasted snack. Desi types are used in soups, as dhal and made into flour, besan, for a variety of bread, soup and vegetable uses. Chickpea/cereal blends are used to make a variety of fermented, deep-fried, toasted, baked and puffed traditional foods.

Faba beans (*Vicia faba*) provide significant levels of protein and other nutrients to be important in the diets of developed and subsistence populations. They are grown on nearly four million hectares of land in about 50 countries with total production of 4.7 million tonnes (Anderson et al. 1994).

Lentil (*Lens culinaris*) is used in mujadurra, a lentil and rice dish, and lentil soup. Dhal curry is a common dish in the Indian sub-continent whereas in Western societies lentils are most commonly used in soups. Other uses are in blends with cereals, snack foods, invalid and weaning foods.

Lupin (*Lupinus* spp). Small quantities of the lupini bean (large seeded bitter *L. albus*), and the Albus lupin (medium-sized sweet *L albus*) are consumed as a snack food in Mediterranean countries. Grain of *L. angustifolius* can be used for making tempe, an Indonesian fermented food.

PRIMARY PROCESSING

Dehulling

The testa of pulses, with its high content of cellulose and hemicellulose, is often indigestible, and sometimes has a bitter taste due to the presence of tannins. In view of this, primary processing improves palatability and reduces cooking time. Proper dehulling is essential for marketing and human consumption. Two steps are involved 1) removing the seed coat and 2) splitting the cotyledons.

Methods of dehulling

Dehulling methods include small-scale processing by households in villages or large-scale processing by commercial mills in urban areas. For small-scale processing, wooden pestles and mortar, and stone chakki (quern) are used for dehulling chickpea, field pea and lentil in several Asian countries. For large-scale processing, carborundum rollers and discs are employed by the commercial units. These large-scale processing operations are located in cities in the Indian subcontinent, Australia and Canada.

Attrition-type dehullers and roller mills are particularly suitable for dehulling and splitting legume grains with loose seed coats; whereas abrasive-type dehullers are suitable for dehulling grains with more tightly adhering seed coats. The use of an emery-coated roller is a common practice in commercial dhal mills in India (Singh 1995). The emery-coating, also called carborundum, is made of silicon carbide and used for abrasive or refractory action. Some millers use a carborundum roller for both dehusking and splitting, while others use a roller and disc sheller alternatively for this purpose to reduce dehulling losses. The disc sheller is generally used for wet processing and works on the principle of attrition, which removes the husk and splits the cotyledons simultaneously resulting in excessive breakage of cotyledons. The disc shellers are generally used for dehusking rice.

A comparison of dehulling yields, achieved by commercial processors in India and Australia, is given in Table 1. Dhal yields of chickpea and field pea were higher in India than in Australia, indicating that losses in terms of broken chips, powder, and husk are lower in India. The seed characteristics and agronomic factors that would affect these losses, from crops grown in different countries, need to be examined because they influence the market price of the commodity. In Australia, legume decorticators are typically used for dehulling. The outer layers of the cotyledons are invariably scarified by the abrasive action of the dehulling process resulting in nutrient losses (Singh et al. 1992) of protein, calcium, and iron which are in the powder fraction (Table 2). These losses could be reduced with better methods and by selecting more suitable genotypes. This would improve the market price of processed products and their nutritive value

Table 1. Processing yields (decorticated dry split cotyledons) of different legumes obtained by commercial processing mill

	Seed coat %[a]	Split yield (%)[b]		Theoretical Yield
		Australia	India	
Chickpea	14.2	70.0	80.0	85.8
Faba bean	18.5	60.0	-	81.5
Field pea	10.0	72.0	78.0	90.0
Lentil	8.4	-	73.0	91.6

a Average of values from different sources.

b Average of values from several processing mills in Australia and India.

Table 2. Effect of dehulling on chemical constituents (g/100 g sample) of dhal and powder fractions of chickpea cv Annigeri.[a]

Dehulling time (min)	Dhal					Powder				
	Protein (%)	Sugar (%)	Starch (%)	Calcium	Iron	Protein (%)	Sugar (%)	Starch (%)	Calcium	Iron
0	18.6	6.8	56.2	43.7	5.7	-	-	-	-	-
2	18.0	6.5	57.8	39.5	5.0	23.6	12.1	48.0	85.0	12.0
4	17.5	6.3	57.8	38.0	4.8	21.8	10.5	50.3	65.5	10.5
8	17.5	6.0	58.0	35.5	4.3	19.8	9.5	52.0	45.0	8.5
12	16.4	6.1	60.8	35.0	3.8	18.9	8.6	55.4	45.0	7.0
SE±	0.18	0.21	0.31	0.78	0.21	0.21	0.13	0.51	1.90	0.32

a For each treatment, results are averages of two samples obtained as in Table 1 and analysed separately. Results are expressed on a moisture-free basis. Source: Singh et al. 1992.

FACTORS THAT AFFECT QUANTITATIVE AND QUALITATIVE DEHULLING LOSSES

Conditioning

The loosening of testas by preconditioning, generally results in a higher dhal yield. Soaking in sodium bicarbonate followed by oven-drying may produce the highest dhal yield from chickpea and field pea (Table 3). This pre-treatment loosens the seed coat and reduces the cooking time of dhal. Soaking in water (2-14 hr) followed by sun-drying is a common practice before dehulling small quantities in India. Dehulling is made easier by prolonged soaking in water, but the dhal remains uncooked and tough even after prolonged boiling. Preheating the seeds at a higher temperature helps loosen the seed coat and increases the dhal yield, but excessive heating may result in breakage of cotyledons and reduce the dhal yield. Therefore, the preconditioning treatments needs to be carefully monitored and standardised to increase the dhal yield. Some interactions between preconditioning treatments and legume genotypes may be expected. Newly developed high yielding genotypes should be examined for their preconditioning effects on dhal yield.

Table 3. Effect of preconditioning treatments on dhal/split yields of chickpea and field pea [a]

Treatment	Dhal/split yields	
	Chickpea[a]	Field pea[b]
Control	71.1	79.5
Water	73.6	81.4
Sodium chloride (1.0%)	75.2	82.0
Sodium bicarbonate (1.0%)	76.1	82.8
Edible oil (0.5 w/w)	-	81.7
Preheating	-	81.0

a Source: Iyer and Singh (1997). b Source: Black et al. (1998).

Seed characteristics

Seed characteristics affect the dehulling efficiency in terms of increasing the dhal yield and reducing nutrient losses. Genotypes with lower seed coat contents give higher dhal yields. Other factors are seed size, shape and hardness. Small seeds are generally difficult to dehull. Greater than 75% of the variability in dehulling efficiency could be accounted for by grain hardness and the resistance to splitting into the individual cotyledons (Reichert et al. 1984). This would suggest that losses in terms of the broken and powder fraction are greater, if grains are too hard, requiring more abrasive force during dehulling. If grains are too soft, they tend to break, resulting in more losses in terms of the broken fraction and powder.

Williams et al. (1993) reported that dehulling and splitting of lentil was easier with large seeds, thin testas, short storage periods and correct wetting (conditioning) practices. Very angular seeds lose excessive amounts, because the dehulling process attacks sharper edges. There is a loss also from flat seeds. Generally, rounder seeds split more readily than flatter seeds. Variability in dehulling is influenced by genotype. Results from a study on 24 field pea genotypes indicated a large variability in dhal/split yield (71.1-85.7%) when evaluated by the laboratory type Satake mill (Black et al. 1998). Similar variations have been reported for chickpea (67.7-84.8%) (ICRISAT 1987) and lentil (62.1-80.2%) (Erskine et al. 1991). However, the role of agroclimatic conditions on dhal yield has not been clearly defined. Faba beans usually are not dehulled but are consumed as whole seeds after soaking and cooking, or as bean flour.

SECONDARY PROCESSING AND FOOD USES

Secondary processing to make food products or value-added snack items includes soaking, boiling, frying, roasting, steaming, canning, baking, germination, fermentation and extrusion.. All these processes improve appearance, texture and cooking quality. Some important products, are listed in Table 4.

Pulses are often soaked in water as a pre-treatment to reduce their cooking time. Soaking also completely or partialy reduces the content of undesirable substances such as phytate, trypsin inhibitors, tannins, and flatulence-forming carbohydrates. Boiling is an indispensable process and most commonly used to cook the pulses and their products. Cooking time is therefore important in terms of market requirements. Large differences exist among pulse grains (Table 6). According to Williams and Singh (1987) cooking time is a fairly heritable characteristic, in that if genotypes differing widely in cooking time are grown at different locations, the differences between genotypes persist. Cooking time is positively and significantly correlated with seed size in chickpea (ICRISAT 1987), lentil (Erksine et al. 1985) and field pea (Black et al. 1998). Further, there seems to be no correlation between the cooking time of whole seeds and the dhal components in chickpea (ICRISAT 1987). This indicates that the time taken to cook is greatly affected by the nature of the seed coat. The cooking time is greatly reduced by dehulling these legumes (Table 5). The cooking time of chickpea seed is reduced by soaking overnight to the extent that most of the differences between cultivars are eliminated (Williams et al 1989). Erskine et al. (1985) reported that the genotypic variance for cooking time in lentil was significantly greater than any genotype-location interaction. Genotypes that require less time to cook therfore should be developed. Abas El Faki et al. (1984) reported that cooking improved the protein digestibility of faba bean and chickpea due to inactivation of trypsin inhibitors. Cooking also improves carbohydrate digestibility, possibly by changing the content and chain length of the amylose components.

Table 5 Variability in cooking time of cool season food legumes.

Legume	Component	No. of samples	Cooking time (min.)		Reference
			Range	Mean	
Chickpea	Whole seed (Kabuli)	303	30-296	118.0	(Williams et al. 1989)
	Whole seed (Desi)	125	52-98	78.5	(ICRISAT, 1987)
	Dhal (Desi)	125	26-46	32.0	(ICRISAT, 1987)
Faba bean	Whole seed	16	171-274	220.0	(Singh et al. 1988)
Field pea	Whole seed	24	79.0-150	101.6	(Black et al. 1996)
	Dhal	24	19.0-45.0	29.1	(Black et al. 1996)
Lentil	Whole seed	25	29.9-45.0	33.2	(Erskine et al. 1985)

Soaking and frying could be helpful in expanding the snack-food market for pulses. The usual process is to soak the field peas or chickpeas overnight, and then to fry them in hot oil. Sometimes peas are coated with other materials such as rice flour before frying to provide different flavours.

Germination reduces antinutritional factors such as protease inhibitors and oligosaccharides in legumes (Singh 1984). It also helps develop desirable flavours for certain products. Germinated and boiled faba beans make a very good sauce (Li 1987). Snack items can be prepared by roasting and there are clear cut differences in the roasting quality of chickpea genotypes (Table 6). Although India is the largest producer of chickpea in the world, there is only a limited number of genotypes that are suited for making roasted products such as 'phutana'. The market demand for 'phutana' is very great and the development of genotypes for this purpose would pay rich dividends.

Table 6 Roasting quality of chickpea desi and kabuli genotypes, Hisar 1985/86

	Sensory evaluation[a]				
Genotype	Colour	Texture	Flavour	Taste	General acceptability
G 130	3.8	3.3	3.3	3.2	3.5
ICCV 6 (ICCC 32)	1.7	2.8	2.8	2.5	2.3
SE±	0.18	0.12	0.09	0.13	0.11

a Five point hedonic scale.

Fermented chickpea products are popular in the Indian sub-continent but fermented products of other cool season pulses are less popular. However the use of these pulses to produce tempe, natto, dhokla, kiyit injera and other fermented foods is becoming popular in South-East Asia. Extrusion is a relatively new process involving both pressure and heat. This process has a wide application in making value-added products, particularly from dry peas. Peas are ground into fine flour that is passed through an extruder under pressure to create different sizes and shapes. The extruded shapes may be fried, seasoned, and packaged.

Table 4. Some important and potential food preparations of cool season food legumes around the world

Method	Chickpea		Faba bean		Field pea		Lentil	
	Food	Country	Food	Country	Food	Country	Food	Country
Boiling	Dhal-curry	India, Bangladesh	Kit wot	Ethiopia	Soup	Australia, India, Central Asia, Middle East	Soup	Mediterranean region
	Homos	Syria, Jordan, Lebanon, Egypt, Nepal, Pakistan	MedamisFS	Egypt	Veg. Curry	India, Pakistan, Europe, Middle East	Koshary	Egypt
	Lablebi (whole seed)	Jordan, Tunisia, Turkey	Salty faba beans	Lebanon, China	Flour coated peas	Egypt, China	Dhal curry	Indian subcontinent
	Cocido	Spain	Lablebi	Middle East, Egypt			Nifro	Ethiopia
Frying	Seviya, pakoda	Indian subcontinent	Falafel	Egypt, Syria				
	Falafel	Syria, Jordan, Lebanon, Egypt, Turkey	Orchid bean	China				
Roasting	Phutana (dry seed)	India, Pakistan	Nabet soup	Egypt, Syria, Jordan, China			Kollo	Ethiopia
	Badami safra	Syria, Egypt, Lebanon	Tempe	Indonesia				
	Segared nuts	Turkey	Sauce	Japan				
Germination	Sprouts	India, Nepal	Snacks (sugar coated)	Indonesia				
Fermentation	Tempe, natto, dhokla, kiyit injera	India, Japan, Ethiopia	Shiro wot	Ethiopia, Indonesia				
Baking	Bread/roti	Turkey, India, Pakistan, Turkey	Fool Mekalley	Egypt	Kitta	Ethiopia, Australia		
Extrusion	Noodle	Burma						
Green immature seeds	Veg. Curry	India, Nepal, Pakistan			Veg. Curry	North America, Europe, Middle East		

A greater emphasis must be placed on marketing new products from legumes. For example, quick-cooking dhal, also called instant dhal has a good market potential. Even though dehulling and splitting into dhal reduces the cooking time, the cooking process is time and energy consuming. Special soaking solutions containing inorganic salts have been used for quick-cooking of legumes (Rockland et al. 1979). The cooking time of field peas could be reduced by soaking in sodium carbonate or bicarbonate solutions (Black et al. 1998). However, such treatment adversely affect the quality. Pectinase enzyme treatment significantly decreased the cooking time as compared to salt solutions and it also improved the acceptability of the product (Singh and Rao 1995). The legumes can be used in various foods including noodles, breads, snacks, soups, stews, and purees. Legume flour can be blended up to 20-30% in sausages and beverages with acceptable results. Chickpea flour can be used in tortilla and unleavened bread. Protein concentrates by pin-milling and protein isolates by precipitation of these legumes can be prepared containing approximately 50-60% and 80-90% protein, respectively. They should have a place in second generation functional foods, with and without blending with cereals.

STORAGE

Storage conditions affect the processing and grain quality of pulses which are stored at farmer, trader, or government levels in various structures. Quantitative and qualitative losses occur during storage. The result from interactions among the storage conditions, physiological changes during ageing, and the activity of storage micro-organisms and insects. The pulse beetle (bruchid) is an important pest of chickpea, lentil and field pea. Sometimes, the insect begins its infestation in the field and is carried into the store with the grain. The dehulling yields are considerably reduced by insect infestation as the bruchid causes physical damage to the seed. The greater susceptibility of large-seeded cultivars of soybean to field deterioration was used to explain their poor storability in comparison to small seeded cultivars (Verma and Gupta 1975).

Cultivars differ in their susceptibility to bruchid attack. However, seed size, colour, and texture have not been related to bruchid preferences, but seed-coat thickness may have an influence.

Storage under conditions of high temperature and humidity may render the grain susceptible to the hard-to-cook (HTC) defect. Beans with this defect require long cooking times, they are less acceptable to the consumer and are of lower nutritive value. According to Vindiola et al. (1986), the mechanisms causing HTC could be 1) limited hydration of intercellular protein; 2) pectin insolubilisation in the middle lamella by Ca and/or Mg; and 3) cross-linking of phenolics (lignification) and/or protein in the middle lamella of the cell wall. None of these phenomena has been systematically studied in the cool season food legumes. The accumulation of uric acid in pulses stored for 4-5 months generally make them unacceptable to the consumers. Protein quality is also adversely affected when pulses are stored for long periods.

Fungi and bacteria are also harmful to stored pulses. Chickpeas can become contaminated with mycoflora and mycotoxins (Nahdi et al. 1982). Aflatoxin B1 and B2 were present in 50% of the bean samples tested in Columbia (Usha et al. 1991). The low germination of pea seeds following commercial storage has been attributed to *Aspergillus* infection (Fields and King 1962). Storage effects on some quality parameters such as colour and hydration capacity of faba bean, lentils, and field peas have been noticed (U Singh unpublished). As the storage period increased, the time taken for cooking also increased irrespective of the type of pulse stored and the treatment given (Vimala and Pushpamma 1985). The loss of protein solubility and digestibility, development of off-flavours, and oxidative rancidity as a result of storage, need to be studied.

FUNCTIONAL PROPERTIES AND THEIR APPLICATION

Functional properties are assuming significance in view of the utilisation of legumes in cereal-based composite flours. Functionality can be defined as the set of properties of a protein or protein ingredient that contributes to the desired flavour, texture, and nutritive value of a food. Functional characteristics of defatted flours and concentrates are provided both by the proteins of the seed and by the carbohydrates (Martinez 1979). A better understanding of the functional properties is essential if future genotypes are to be utilised for the development of value-added food products. In this context, chickpea and field pea proteins are expected to have wider applications. Such functional properties as water absorption, oil absorption, emulsification capacity, flour solubility, swelling capacity, gelation capacity, gel consistency (gel spread), nitrogen solubility index (NSI) and paste-viscosity are considered important.

Because of the increasing costs of cooking oil and from a health point of view, the preparation of deep-fried products, using a minimum of oil is desirable. Chickpea proteins greatly reduce oil absorption by deep-fried products (Singh et al. 1993). According to this study, the oil absorption of the product ('Seviya') differed significantly among genotypes and this could be due to differences in the chemical and physical nature of the proteins. Emulsification has been reported to influence the product stability and large differences exist among chickpea genotypes. At ICRISAT, we have observed that the emulsion capacity of desi genotypes was twice that of the kabuli genotypes. However, the emulsion capacity appears to be lower than that of soy flour and winged bean. More importantly, the emulsion capacity of chickpea flour was 2-3 times higher than that of wheat flour (Iyer and Singh 1997). This trait could have a beneficial effect in wheat-chickpea composite.

The nature and type of protein and starch influence the gelling ability of cereal and legume flours. The gel consistency of cereal flour could be decreased by supplementation with legume flours, particularly chickpea and field pea. Unlike wheat starches, no break down of peak viscosity is noticed in chickpea, faba bean, field pea, and lentil. There were large differences in peak viscosity and gelatinisation temperature of pulses as calculated from the Brabender viscoamylograph (Table 7). Generally, cereals contain fragile swollen starches, which first swell and then break down under the continuous stirring of the viscoamylograph. This characteristic is not noticed in cool season legumes (Table 7), indicating that starch granules of these legumes have greater stability against mechanical shear than those of the cereal starches, particularly of hard wheat. Generally, lentil, faba bean and field pea starches have a high water binding capacity (92.4 to 98.0%), being comparable to that of wheat starch (Bhatty 1988). These legumes also show restricted swelling power that result in a type C Brabender curve (i.e. no pasting peak at 95°C). This property is typical of high amylose corn starches. Such starches may have only limited uses in food applications. But they may be modified, for example pea starch, by acetylation and phosphatisation. This destroys the heat and acid stability of the starch granules and makes them functionally similar to corn starch derivatives (Comer and Fry 1978). The addition of chickpea flour to wheat flour may not adversely affect such dough properties, but would enhance product stability due to the higher emulsion capacity of chickpea flour. These are some examples of the improved functional properties of cereal-legume composite flours (Iyer and Singh 1997).

Table 7. Some functional properties of cool season food legume flours[a]

Legume	Water absorption[a] g/g	Swelling capacity[b] g/g		Gelatinisation temp. (°C)	Peak viscosity(BU)
		65°C	95°C		
Chickpea	1.12	2.30	6.14	72.0	340
Faba bean	1.20	1.75	3.80	82.5	80
Field pea	0.83	2.03	4.15	70.5	115
Lentil	1.04	2.46	8.24	73.5	525

a Mixing the flour with water at 30°C for 30 min.

b Heating the sample in a block heater at 65°C and 95°C respectively.

NUTRITIONAL COMPOSITION

There is a voluminous literature on the nutritional composition of pulses, including the cool season pulses. They are good sources of carbohydrates and proteins, which together constitute about 70-80% of the total dry seed weight. Large variations have been reported in the protein content of chickpea, field pea, lentil, and faba bean. Legume seeds contain a considerable amount of non-protein nitrogen (NPN). In one study, chickpea NPN varied between 5.84 and 16.48% of meal nitrogen (Williams and Singh 1987). Any large variation in NPN could affect the estimated true protein of the sample. Agronomic and environmental factors affect the protein content. Salinity may significantly reduce the seed size and protein content in pulses.

Chickpea seed crude protein content ranges between 12.6-30.5% (Williams and Singh 1987). Starch is the principal carbohydrate constituent and generally ranges between 40-50%. The starch contains 20-30% amylose and the remainder is amylopectin (Singh 1985). The bioavailability of carbohydrates is important in terms of calorific value. Unfortunately, the concentration of unavailable carbohydrates in chickpea is the highest among the commonly consumed Indian pulses. Chickpea can add a considerable amount of fat to a consumer's diet. Among the cool -season legumes, chickpea contains the highest fat content ranging between 4.0 and 10.0%. Chickpea is also a good source of minerals and trace elements. Faba beans contain considerable amounts of protein (25-30%), carbohydrates (60-65%), ash (3-4%), and fat (2-3%). Traditionally, beans are utilised by soaking and cooking in the house or consumed as commercially processed canned beans. Generally, beans require a long cooking time to achieve satisfactory palatability and to improve the digestibility of proteins and carbohydrates. Peas contain 25-35% protein, 40-50% starch, 5-10% soluble sugars, 2-4% ash and 4-10% crude fibre, depending on the varieties and growing environments.

The protein content of lentil ranges between 19.5 and 36.4% and about 90% of the protein is present in the cotyledons (Bhatty and Christison 1984). Lentil is lower than most pulses in antinutritional factors such as haemagglutinins, oligosaccharides and favogens. Starch is the major component of lentil carbohydrates and may vary from 35 to 53% (Reddy et al. 1984). Lentil seeds contain < 1.0% lipids. Because of low lipid content, the gross energy of lentil is similar to that of wheat and barley. The low levels of antinutritional factors, together with a higher protein level and a shorter cooking time than other common pulses, make lentil very suitable for human consumption.

The nutritional quality of these legumes is greatly influenced by processing practices. Germination improves amino acid availability, increases the availability of vitamins, and decreases concentrations of phytic acid and trypsin inhibitors. Fermentation improves nutritional quality by solubilising proteins, inactivating antinutritional compounds, and increasing water-soluble vitamins. David and Verma (1981) reported improved nutritional quality of faba bean 'tempe' over non-fermented faba bean. Bhatty and Christison (1984) evaluated the nutritional quality of pea, faba bean, and lentil as meal, protein concentrates and protein isolates and found the products as digestible as casein protein.

ANTI-NUTRITIONAL AND TOXIC FACTORS

Many pulses are known to contain anti-nutritional factors (ANFs). However, recent epidemiological work suggests that some of these compounds may even have beneficial effects for humans. For example; phytate, some tannins and trypsin inhibitors also have an anti-oxidant effect that may help prevent the onset of cancer (McIntosh and Topping, 1998, these proceedings).

Alkaloids: The lupin alkaloids are usually bicyclic (e.g. lupinine), tricyclic (e.g.angustifoline) or tetracyclic (e.g. sparteine) derivatives of quinolizidine. An important exception is gramine, which is found in some cultivars of *L. luteus*. The major alkaloids of commercial cultivars are: *L. albus*: lupanine, 13-hydroxylupanine, sparteine (some European cultivars); *L. angustifolius*: lupanine, 13-hydroxylupanine, angustifoline; *L. mutabilis*: lupanine, sparteine, 13-hydroxylupanine; *L.luteus*: gramine (some cultivars only), lupanine, cytosine.

Modern cultivars of 'sweet' *L. angustifolius* typically contain < 200 mg alkaloids/kg (Harris and Jago 1984) in contrast to 'bitter' wild and green manuring types which may contain 5-40 g alkaloid/kg depending on the species and growing conditions. The typical alkaloid profile of 'sweet' *L. angustifolius* is: lupanine (42-59%), 13-hydroxylupanine (24-45%), angustifoline (7-15%), α-isolupanine (1-1.5%) and traces of other alkaloids (< 1% total). There is an effect of growing environment on seed alkaloid content, and new cultivars are lower in alkaloid than the cultivars they replaced.

Wink et al., (1995) reviewed the alkaloids in lupins and the changes that have occurred with breeding low-alkaloid cultivars. For example, albine is not present in cultivars of *L.albus* grown in Australia, and gramine is present in new cultivars of *L. luteus* being developed in Poland and Australia. These compounds have a low toxicity, LD50 values around 2000 mg/kg. Their pharmacological effects include blocking ganglionic transmission, decreasing cardiac contractility and contracting uterine smooth muscle (Mazur et al,. 1966).

Phytate: Phytic acid is an inositol hexaphosphate which forms complexes with minerals and protein, interfering with their availability. Together with the lesser substituted homologues and their collective salts these compounds are referred to as phytate. Phytate can form insoluble complexes with divalent cations, particularly calcium and zinc, rendering them less available for absorption and utilisation. The net effect of phytates depends on the overall composition of the food or diet, particularly the protein content and characteristics and the total mineral content. The amount of phytate in lupins does not seem to be of major concern. For example, Petterson et al. (1994) found the absorption of Zn from a range of lupin (*L. angustifolius*) based foods to be overall higher than from comparable soy products. They concluded that lupin milk could be an attractive alternative to soy milk for infant formulae (Petterson et al. 1994). The phytate content of lupin seed can be lowered by practices such as germination (Dagnia et al. 1992) and fermentation (Fudiyansyah et al. 1995).

Polyphenols: Polyphenols are loosely or interchangeably termed as tannins. Practically all tannins are polyphenols, but all polyphenols are not tannins. This is particularly true for cool season food legumes which contain significant amounts of polyphenols in their seed coats/husk and small amounts of tannins. Polyphenols of chickpea and pigeonpea reduce the activities of protein and carbohydrate hydrolysing enzymes (Singh 1984).

Tannins: Tannins are compounds of plant origin with molecular weights ranging from about 500 to 2,000 daltons, and with one to two phenolic hydroxyl groups per 100 daltons. This enables them to form cross-linkages between proteins and other macromolecules (Griffiths, 1991). The two sub-groups are hydrolysable tannins, which typically have central glucose core with the hydroxyl groups being wholly or partly esterified with gallic acid or hexahydrodiphenic acid, and condensed or ion-hydrolysable tannins which are higher oligomers of flavan-3-ols with varying degrees of substitution. In lupins, as with other grain legumes, the polyphenols are concentrated in the seed coats and dehulling minimises any effects. The concentration of condensed tannins, those most responsible for protein-binding, is so low in lupins that it is unlikely to affect human nutrition. Concentrations in *L. albus* and *L. angustifolius* are typically < 0.01% (Petterson and Mackintosh, 1994).

Saponins: Saponins can produce a soapy foam even at low concentrations, and are well known for their ability to lyse red blood cells *in vitro*. Saponins are glycosides with the non-sugar moiety being known as a sapogenin, which may be a steroid or a triterpenoid compound. Saponins are generally harmless to humans, and some may be beneficial by lowering blood cholesterol levels (Fenwick et al. 1991). The saponins of liquorice and quinoa are used in the confectionary industry and are among the active ingredients of ginseng and other health foods and tonics (Fenwick et al 1991).

Protease inhibitors: The cool season pulses may contain protease inhibitors. Variations exist in trypsin and chymotrypsin activities of desi and kabuli genotypes of chickpea (Williams and Singh 1987). Lentils contain small concentrations of trypsin (Bhatty, 1988). Trypsin inhibitor activity is very low in lupins, ranging from < 0.01 to 0.28 mg/g in *L. angustifolius* and from 0.1 to 0.2 mg/g in *L. albus* (Petterson and Mackintosh, 1994). Chymotrypsin inhibitor activity was reported at < 0.01 to 0.59 mg/g in *L. angustifolius*.

Lectins: The conventional assay procedure agglutination of at least some of a wide range of different types of red blood cells have not detected any sign of lectin activity in *L. albus* or *L. angustifolius* (B.N. Greirson and D.S. Petterson, 1990, Perth, unpublished results; Liener, 1989). A slight activity can be induced if the red cells are specially treated (A. Pustzai, Aberdeen, 1995, personal communication), however this is not thought significant. Duranti et al., (1995) isolated conglutin γ from *L. albus* seed and showed it was capable of binding to various N-glycosylated proteins. Immunological homology with two bean lectins suggests there could be some lectin activity by this protein, which is almost certainly the activity observed by Pustzai (cited above).

Oligosaccharides: Chickpea is well known for its content of oligosaccharides. Field peas, lentils and faba bean contain lesser amounts. The oligosaccharides of pulses belong to the raffinose family. Raffinose has one galactose moiety linked to a sucrose molecule through an α 1,4 bond, stachyose has an α 1,4 linkage to the galactose unit of raffinose, and so on through verbascose and ajugose. These compounds cannot be metabolised by monogastrics and they pass through to the colon where bacteria break them down to produce carbon dioxide, methane and hydrogen. This causes abdominal discomfort, cramps and flatulence leading to a reduced interest in consuming these pulses in many societies. However the oligosaccharides have a role in osmotic regulation in the gastrointestinal tract which may be beneficial in maintaining flora that help prevent the onset of colonic cancer.

Neurotoxins: Prolonged consumption of *Lathyrus sativus* causes neurolathyrism in humans due to the ODAP present in all parts of the plant. It is highly desirable to develop genotypes free of this toxic compound.

FACTORS INVOLVED IN MARKETING OF COOL SEASON FOOD LEGUMES

In an era where population increase threatens to outstrip food production the dogmas that 'hungry people will eat anything' and 'if you feed the people they will not fight each other' are not necessarily true. People do have taste and texture preferences, and in most countries, including 'developing' countries, provision of foods of inferior quality results in waste. Some of the wasted food is used to feed domestic animals but this is an inefficient use of the funds allocated to the alleviation of hunger.

Food safety is becoming an important factor in marketing. Customers are demanding assurance that grains are either free, or meet specifications on pesticide, herbicide or fumigant residues, mycotoxins and other substances. Monitoring for chemical residues is expensive, and costs usually have to be built into the purchase price. Certification under ISO 9000 is becoming important, and some agencies will not accept analytical data from laboratories unless they have attained the necessary certification.

Scientific institutions should devote more attention to the organoleptic evaluation of foods. Members of taste panels need not be scientists; and other people capable of identifying differences in aroma, taste and texture. The most important attribute of a taste panel member is consistency of evaluation.Institutions, need to establish taste panels, to identify the most important characteristics of foods.

FUTURE CONSIDERATIONS

Genotypes and processing practices influence the nutritional quality and utilisation of pulses. Genotypic variation exists in nutritional factors, cooking time/quality and processability of these legumes. Processability is affected by the chemical and physical nature of the seed coat and by cotyledon hardness, which are influenced by the environment. The heritability of these characteristics needs to be established. Although large-scale pulse processing methods appear to be adequate for dehulling, further studies of preconditioning treatments are needed. To meet the consumer demands in various markets, quick cooking products of these legumes could be developed by combining suitable genotypes with pre-treatments that improve dehulling and efficiency and reduce cooking time. In particular, improving the cookability of whole seeds of cool season food legumes would reduce the need for alternative processing such as sprouting, germination, fermentation or dehulling. The development of quality standards and suitable genotypes for specific consumer needs should be emphasised. The flour, protein concentrate (air-classified fraction), and protein isolate are the three major components of pulses that could be used in value-added food products and more efforts are needed to enhance the use of these fractions in food products. Keeping in mind the new market requirements in pulse importing countries, the development of varieties of these legumes for specific end-uses must be emphasised.

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