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efficient system of aspiration. There being a little difference between the weight of the husk and the splits, the system requires provisions for very minute adjustments so that no splits are carried away by the air with husk, and at the same time no husk should remain with the splits. The new type of aspiration equipments are well designed to adjust the air to the required amount and pressure, and when the same is passed at cross currents with the flow of the stocks to be treated it efficiently draws off the husk and lets the cleaned dehusked splits flow to the packing. The equipment comprises (a) Cascade (s) : where the stocks meet at cross current the air at required pressure and speed; (b) Junction box: which is also a low pressure box to recover the small kibblings which are carried away by the air; (c) Cyclone dust collector; (d) Air locks; (e) Air filters etc., all suitably arranged. For still finer separations vibro aspirators are recommended in place of the cascades.

3. CONCLUSION

There is need of a proper conditioning system to enable dehusking and splitting without causing processing losses. Various conditioning systems under different names were developed and adopted by the pulses processing industries ever since 1930s. Improved system of conditioning, incorporating therein all the good features of the exiting conditioning systems came into being as a result of the research and development work done by CFTRI, Mysore, followed by substantial inputs by their licensees M/s S.K. Engineering & Allied Works, Bahraich. The system as available now, eliminates the processing losses almost completely and there is no powdering and kibbling adding yield by 2 to 8 percent (depending on the variety of pulse processed and the processing losses occurring there in). The quality of the product namely, the dehusked splits, is much better. Complete automation in the processing has been achieved and there is no dependence on weather conditions or sunshine.

GRAIN QUALITY IMPROVEMENT IN PULSES : CURRENT STATUS AND FUTURE RESEARCH NEEDS

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ABSTRACT

Pulses are valuable sources of proteins, vitamins, and minerals in the human diet, especially in developing countries. Increasing population growth has resulted in a sharp decline in the per capita availability of pulses in recent years in India. Therefore, the improvement of productivity, adaptability, and yield stability of pulses have become priority areas of research. Considerable efforts have been made to improve the grain quality of pulses with respect to their nutritive value, antinutritional factors, dehulling quality, cooking quality and consumer acceptability. These topics are reviewed and discussed in this paper. Some approaches to grain quality improvement in pulses are also presented, and future research needs emphasized.

1. INTRODUCTION

Pulses are the edible seeds of legumes; they are processed into dhal (decorticated dry split cotyledons) for use as human food. Pulses, also called food legumes or grain legumes, are among the earliest food crops cultivated by man. Sometimes called the "poor man's meat", they are a valuable source of calories, proteins, vitamins and minerals (Singh and Singh 1992). In view of dietary deficiencies in many parts of India, pulses will play an increasing role in human nutrition.

Nearly two decades ago, Dr. Norman E. Borlaug, at a conference sponsored by the UN Protein Advisory Group, called for a "protein revolution" in the developing world for pulses and oil-seed legumes. This was emphasized in view of the complementary role of pulses as rich sources of protein in cereal-based diets. Unfortunately, no significant progress has been made since then in this direction. It is a matter of great concern that protein intake is very low in India, with no significant imporvement during the last three decades (Table 1). Also, the availability of animal protein is declining for economic and social reasons. Efforts have been made in recent years to develop high-yielding varieties of pulses suitable for different agroclimatic zones in India, and improved genotypes are

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Table 1 : Trends in supply of total proteins (vegetable proteins and animal proteins) in different countries.

Year	Proteins (g/caput/day)				
	India	China	Japan	Germany	USA
1961-63	51.4	42.9	73.6	82.0	97.7
1969-71	51.0	47.5	82.1	90.7	102.0
1979-81	51.4	54.5	87.0	103.5	101.3
1988-90	55.4	64.2	95.1	108.2	109.9

Source : FAO 1991.

now available for use in many developing countries. Besides the improvement of productivity, adaptability, and yield stability of pulses, the imoprovement of nutritional quality including dehulling quality and cooking quality has been the subject of several studies in the recent past. This paper summarizes the information on such topics as availability of pulses, genetic improvement of protein content/quality, digestibility and amino acids, antinutritional factors, dehulling, and cooking quality of pulses, and highlights the future possible research areas.

2. AVAILABILITY OF PULSES

In India, the per capita availability of pulses has fallen during the last two decades for three reasons : 1) pulse production is stagnant or declining, 2) imports were negligible until very recently, and 3) population has been expanding at the rate of 2.1% per annum (World Bank 1991). The daily per capita availability of pulses has decreased from 50.5 g in 1978/79 to about 46 g/day in 1988/90 against the FAO/WHO (1991) recommended dose of 80 g/day. Per capita availability varies considerably between regions and from year to year. A recent calculation indicates that the daily intake of total pulses in different parts of India ranges from 25 to 118 g/day/person, the highest being in Madhya Pradesh and the lowest in Bihar. Per capita availability of chickpea is the highest, followed by pigeonpea, urdbean, and mung bean (Table 2). Different pulses show different trends: per capita availability of mungbean and urdbean has increased slightly, while that of chickpea and pigeonpea has considerably decreased in recent years. The overall decrease in availability is largely due to the reduced availability of chickpea, the major pulse crop. The decline in production and availability in turn has led to significant increases in pulse prices.

The low intake of pulses is primarily due to their high cost (approximately three times as high as cereal grains). Other factors that reduce availability are poor and inefficient processing and storage, lack of distribution systems, and high transportation cost.

Table 2 : *Availability of pulses (g per caput per day) in India.*

Year	Pulses	Chickpea	Peas and beans	Pigeonpea	Mung-bean	Urd-bean
1978/79	50.5	23.8	1.5	7.8	3.6	3.0
1980/81	42.2	17.2	1.2	7.8	3.9	3.8
1981/82	44.7	18.0	1.2	8.7	4.1	3.9
1982/83	45.1	20.1	1.3	7.6	4.4	3.8
1983/84	48.0	17.7	1.4	9.6	5.1	4.4
1984/85	43.6	16.6	1.2	9.4	3.8	4.2
1985/86	47.8	20.7	1.5	8.7	4.2	4.4
1986/87	41.0	15.9	1.4	8.0	3.8	4.4
1988/89	46.0	16.4	1.4	7.7	4.5	5.2

Source : Agricultural Statistics Compendium 1990, Techno Economic Research Insititute, New Delhi.

3. GENETIC IMPROVEMENT OF PROTEIN CONTENT

Genetic variation in protein content can be exploited to develop high-protein genotypes, and several efforts have been made to study this aspect (Salunkhe 1983, Singh and Eggum 1984, Singh 1985). For example, chickpea has a large variation in protein content of whole seed (12.4 to 32.5%, Williams and Singh 1987), as do mung bean (18-29%, Savage and Deo 1989), and urd bean (23.0 to 28.4%, Savage and Deo 1984). Among pulses, lentil has the highest protein content, ranging between 19.5 and 36.4% (Bhatty 1988). Saxena *et al.* (1987) have successfully used wild pigeonpea species to develop high-protein genotypes. They have suggested that protein content in pigeonpea is a dominant character and is not correlated with seed size. Gupta and Wagle (1978) have developed an urdbean-mungbean cross with higher protein and tyrosine contents than the two parents. Such data on locational and varietal differences could provide useful information to plant breeders in developing high-protein cultivars of these pulse crops.

Generally, genotype X location interactions influence the various quality factors such as seed size, protein content, and cooking time. Singh *et al.* (1983) found that cultivar x location interactions on protein content were nonsignificant while there were good correlations for protein content among locations, suggesting that breeding for improved seed protein content in chickpea could be effectively carried out at a single location. But this may not be true for other pulses. For example, Erskine *et al.* (1985) reported a significant effect of location on protein content in lentils. To date, there have been no reports of major genes that either control total protein synthesis or alter the amino acid composition of legume seeds in a manner similar to the opaque genes of maize and sorghum, and the genes altering lysine content of barley. Despite the rather large environmental effects, heritable differences for protein content and levels of sulphur-containing amino acids have been reported in beans (Bliss and Hall 1977). There is relatively little information available on the heritability of protein quality factors in pulses. Increased yields of protein *per se* can be obtained either by increasing the overall yield or by increasing protein content. In pulses, both approaches might work as the previously assumed negative correlation between protein content and yield may not be generally valid (Saxena *et al.* 1987).

4. PROTEIN DIGESTIBILITY AND AMINO ACIDS

The biological evaluation of seed protein quality is essential because chemical analysis does not always reveal how much of a protein is biologically available to humans. The most commonly used criterion for protein evaluation is the protein efficiency ratio (PER). According to Williams and Singh (1987), PER values for some pulses are as follows : chickpea 2.64, soybean 2.55, horsebean 1.42, followed in decreasing order by pigeonpea, black gram, and green gram. Comparative net protein utilization (NPU) values were highest for chickpea (55-60% in different cultivars) followed in decreasing order by soybean, peas, beans, lentils, cowpea and mungbean (Pak and Bajra 1973 ; Khan *et al.* 1979).

The digestibility of both protein and carbohydrate fractions is much lower in pulses than in cereals. Storage proteins, i. e., globulins, constitute a major proportion of pulses seed proteins. These proteins are quite compact and globular in shape; this may be responsible for their resistances to enzyme digestion (Romero and Ryan 1978).

Protein quality of a crop is also assessed by comparing its amino acid composition with standard reference patterns, the most limiting amino acid determining the nutritive value (FAO/WHO 1973). By applying this calculation to the essential amino acid composition of pulses, it is clear that two sulphur amino acids, methionine and cystine are the first limiting amino acids in pulses. In addition, tryptophan and threonine are also deficient in some cultivars of pulses (Williams and Singh 1987). Lentil has the lowest amount of methionine whereas pigeonpea has the lowest amount of tryptophan (Table 3). The negative relationship between protein content and methionine in grain legumes has generally hindered breeding efforts (Bliss and Hall 1977; and Bressani and Elias 1979). However, the magnitudes of this relationship in chickpea and pigeonpea have been small enough to suggest that high-protein strains, even if they have high

Table 3 : Protein and essential amino acid contents of some food legume seeds.

Species	Protein	Lysine	Methionine	Tryptophan	Thereonine
	(g/100g whole see)				
Pea (dried)	22.5	1.75	0.29	0.26	0.91
Chickpea	20.1	1.47	0.28	0.17	0.76
Lentil	24.2	1.57	0.20	0.20	0.91
Pigeonpea	20.9	1.54	0.24	0.10	0.82
Cowpea	23.4	1.67	0.47	0.15	0.85
Green gram	23.9	1.69	0.28	0.20	0.78

Source : Williams and Singh (1987).

methionine contents, can be used in breeding programs in these two pulses. However, high-protein genotypes, though desirable, cannot ensure protein quality; a balanced amino acid pattern with respect to methionine is needed. At ICRISAT, our results showed that methionine content of 500 germplasm accessions of chickpea varied from 0.81 to 1.59 g/100 protein and of 636 pigeonpea germplasm accessions between 0.82 and 1.45 g/100 g protein. This variability in methionine content needs to be confirmed and high methionine sources be developed and used in breeding programs.

5. NUTRITIVE VALUE OF NEWLY DEVELOPED GENOTYPES

Grain quality improvement in pulses could be achieved by two approaches : 1) breeding nutritionally superior genotypes, and 2) improving storage and processing practices. Several high-yielding varieties of pulses suitable for commercial cultivation and consumption have been developed in different regions. Several chickpea genotypes developed at ICRISAT are listed with their cooking quality and nutritional quality parameters in Table 4. Newly developed genotypes are comparable with the controls, and some are superior with respect to certain characteristics : e. g., ICCV 2 in terms of utilizable protein, and ICCV 1 and ICCC 37 in terms of iron content. It has also been possible to develop pigeonpea genotypes with protein content on average nearly 20% higher than in a normal genotype (C 11) (Table 5). The values for utilizable protein were also considerably higher in the high-protein genotypes (Singh *et al.* 1990). There were no noticeable differences in other chemical constituents of high-protein genotypes (Table 5).

6. ANTINUTRITIONAL AND TOXIC FACTORS

Pulses contain a variety of antinutritional factors which directly or indirectly reduce nutritional quality. Protease (trypsin and chymotrypsin) inhibitors are the

Table 4 : Chemical composition and protein quality parameters of cooked whole seed of newly developed and control cultivars of Chickpea.

Genotype	Protein (%)	Starch %)	Soluble sugars (%)	Fat (%)	Ash (%)	Crude fiber (%)	Protein quality parameters TD[a]	BV[b]	NPU[c]	UP[d]	Calcium mg per 100 g sample	Iron
Desi												
ICCV 1	21.0	49.9	4.5	5.5	3.2	9.7	80.4	77.7	62.4	12.2	197.1	9.3
ICCC 37	20.6	55.4	6.0	6.1	3.1	8.1	85.1	76.2	64.7	12.6	176.4	9.6
ICCC 42	19.2	58.2	5.9	6.4	3.4	7.5	80.0	74.7	59.7	10.6	160.9	6.7
K 850	20.4	57.8	5.9	6.0	3.5	7.7	84.3	78.6	66.3	12.6	138.6	6.3
Annigeri	19.4	54.9	4.9	6.0	3.0	9.4	80.1	72.7	58.3	10.5	182.4	5.6
Kabuli												
ICCV 2	23.4	51.1	6.2	5.8	3.4	4.2	83.8	79.0	66.2	14.3	149.2	8.8
ICCV 3	18.3	59.2	6.9	6.8	3.2	3.6	82.9	89.6	74.3	12.7	129.0	7.9
ICCV 4	21.2	57.4	7.0	6.6	3.9	3.8	82.1	83.8	68.8	13.4	110.0	6.4
ICCV 5	19.5	59.1	6.8	6.7	3.5	3.7	85.9	83.7	72.0	13.1	113.4	5.9
ICCV 6	19.6	60.1	6.9	5.1	3.6	3.0	86.0	86.6	74.4	13.5	118.0	8.9
SE ±	0.12	0.25	0.08	0.14	0.03	0.14	0.19	2.10	2.00	0.38	3.59	0.29

[a]TD = true protein digestibility, [b]BV = biological value, [c]NPU = net protein utilization (TD x BV/100), [D]UP = utilizable protein.
Source : Singh *et al.* 1991.

Table 5 : Chemical composition and protein quality parameters of high and normal protein genotypes of pigeonpea.

Genotype	Protein (%)[a]	Starch (%)[b]	Soluble sugars (%)[b]	Fat (%)[a]	Ash (%)[a]	Crude fibre (%)	TD[b]	BV[b]	NPU[b]	UP[b]
HPL 8	28.7	54.3	4.3	2.6	4.9	1.4	83.7	67.0	56.1	15.5
HPL 40	31.1	55.6	5.1	2.5	5.1	1.1	82.9	65.3	54.1	16.7
C 11	24.8	58.7	4.8	2.9	4.9	1.2	84.3	66.7	56.2	13.5
ICPL 211	23.1	59.3	4.2	3.1	5.0	1.4	85.7	62.9	53.9	12.3
SE ±	0.90	0.30	0.06	0.02	0.03	0.03	2.14	1.68	1.06	0.25

[a] Raw dhal sample, [b] Cooked dhal sample, TD = true protein digestibility, BV= biological value, NPU = net protein utilization, UP = utilizable protein.

most common among these antinutritional factors. They have been extensively studies and their mode of action established (Singh 1988). Chickpea, pigeonpea, mungbean, urdbean, and lentils contain lower levels of these factors than do soybean and common beans. Trypsin inhibitor activity was reported to be in the following decreasing order : soybean, common bean, broad bean, pea, lentil, and chickpea (Singh 1988). This review also reported that both chickpea and pigonpea contained considerably higher levels of protease inhibitors than other commonly consumed Indian grain legumes, but much lower than the soybean. Levels of antinutritional factors of chickpea and pigeonpea are shown in Table 6.

Trypsin inhibitors are more resistant to changes on storage and this contributes to poor protein digestibility. Therefore, storage of pulses under adverse conditions should be avoided.

The ability of pulses particularly chickpea, to stimulate intestinal gas formation has hindered their utilization (Singh 1985). This flatulence is caused by sugars (galactose, raffinose, stachyose, and verbascose) in pulse seeds.

Polyphenols of legumes decrease protein digestibility, probably by making protein partially unavailable or by inhibiting digestive enzymes. Chickpea and pigeonpea contain considerable amounts of polyphenolic compounds (Table 6). Further, the protein quality in terms of digestibility and net protein utilization is adversely affected by the presence of high polyphenols in pigeonpea cultivars (Table 7). Polyphenol levels are not reduced by cooking unless the cooking broth is discarded. Phytolectins are toxic factors that interact with glycoprotein on the surface of red blood cells and cause agglutination. However, pulses generally have phytolectin activity below toxic levels e.g., chickpea (Singh 1988). Pulses also contain phytic acid that binds with metal ions, particularly divalent cations, such as calcium, zinc, and magnesium, and inhibits their absorption. Lathyrism, which is known to occur in humans, is a paralytic disease caused by excessive consumption of *Khesari* dhal, also called chickling vetch (*Lathyrus sativus*). However, the toxic factor involved (B-N-oxalyl-L aminoalanine) can be removed or destroyed by simple parboiling. Extensive genotypic variations exist for various antinutritional factors, and genotypes with reduced levels of such factors should be identified and used in breeding programs.

7. DEHULLING QUALITY

Post-harvest processing is a secondary approach to bring about grain quality improvement in pulses. Appropriate dehulling is probably more important for pulses than for any other food crops, mainly because the fibrous husk or seed

Table 6. Antinutritional factors and toxic substances in chickpea and pigeonpea seed.

Constituent	Chickpea			Pigeonpea		
	Number of genotypes tested	Range	Mean	Number of genotypes tested	Range	Mean
Protease inhibitors						
Trypsin (units/mg)	15	6.7-14.6	10.9	9	8.1-12.1	9.9
Chymotrypsin (units/mg)	15	5.7-9.4	7.1	9	2.1-3.6	3.0
Amylase inhibitor (units/g)	16	0-15.0	8.7	9	22.5-34.2	26.9
Oligosaccharides						
Raffinose	16	0.36-1.10	0.52	10	0.24-1.05	0.47
Stachyose	16	0.82-2.10	1.31	9	0.035-0.86	0.49
Stachyose + Verbascose	4	1.90-3.0	2.41	4	1.60-2.30	2.0
Polyphenols (mg/g)						
Total phenols	22	1.55-6.10	3.03	14	3.0-18.30	10.67
Tannins	5	Traces		10	0.0-0.2	0.03
Phytolectins (units/g)	1		400	1		400
Cyanogens (glycosides)	3	Traces		1	Traces	
Mycotoxins (ppb)	3	Traces-35	18	1	Traces	

Source : Singh 1988.

Table 7 : Biological evaluation of protein quality of pigeonpea cultivars differing in polyphenols and seed color.

Cultivar	Seed color	Protein [a] (%)	Polyphenols[a] (mg/g)	Crude fiber[a] (%)	Diet consumed[b] (g/rat)	TD[b] (%)	BV[b] (%)	NPU[b] (%)	UP[b] (%)
ICPL 87	Dark brown	22.2	14.7	7.7	43.0	75.6	57.1	43.1	9.7
ICPL 151	Red brown	19.3	13.3	8.7	42.6	78.8	58.4	46.0	9.0
ICPL 87067	Light gray	22.5	4.7	7.5	46.5	83.1	62.3	51.8	11.7
BDN 2	Light gray	21.4	4.8	8.6	47.5	84.0			
SE ±		0.11	0.16	0.08	0.22	1.03	1.46	1.37	0.29

[a]Based on two determinations of cooked whole-seed samples.
[b]Based on five determinations of cooked whole-seed samples.
TD = true protein digestibility, BV = biological value, NPU = net protein utilization (TD x BV/100), UP = utilizable protein (Protein x NPU/100).

coat contains high levels of antinutrients and also prevents the digestion of the seed. Most pulses are consumed only after dehusking. Although not common in many parts of the world, dehulling is the most popular method of processing in the Indian subcontinent. Both dry-and wet-dehulling methods are used throughout the country. The wet method involves soaking in water, sun drying, and dehulling, while the dry method involves oil, water application, sun drying, and dehulling. The wet method facilitates good dehusking and causes less breakage of the seeds/cotyledons, but may adversely affect cooking quality. The method is also labour intensive, usually taking 5-6 days, and only limited quantities can be processed at a time. The major disadvantages of the dry method are the high milling loss due to breakage and powdering, and the quantitative and qualitative losses that occur during dehulling.

Large-scale dehulling of pigeonpea (in a commerical dhal mill) gives dhal yields of 60%-85%, while small-scale dehulling (village-level *chakki*) yields between 50% and 80%. Dhal yields vary similarly for chickpea. No significant progress has been made in increasing dhal yield by developing suitable machinery/methods. In addition to giving low yields, dehulling also removes considerable amounts of calcium (about 20%) and iron (about 30%) as well as the nutritionally rich outer layers of the cotyledons (Table 8). Protein content is also significantly decreased, but dehulling does not adversely affect the amino acid balance.

8. COOKING QUALITY

Cooking quality, which is determined by cooking time and taste, flavor, color, texture, etc., of the cooked product is an important parameter. The traditional ways of cooking pulses include soaking, boiling and frying. Dhal and whole-seed cooking times of several genotypes of different pulses are shown in Table 9. Earlier, our results have also shown that for pigeonpea, early-maturing cultivars cook faster than medium-and late-maturing cultivars. In chickpea, kabuli types cook faster than desi types; this is one reason why they are preferred. As reported in Table 9, there are large varietal differences in the cooking time of different pulses, and efforts should be made to develop genotypes that cook faster, a most preferred characteristic from the consumer point of view.

Several physical, chemical, and structural properties influence cooking quality of the various physical characters, seed size, water absorption, dispersed solids, and texture (hardness) seem to be reliable indicators of cooking quality (Erskine *et al.* 1985; Singh 1987). Seed size is positively and significantly correlated with cooking time in chickpea (Williams and Singh 1987), and lentils (Erskine *et al.*

Table 8 : Effect of dehulling on the chemical compostition (g/100 g sample) of dhal and powder fractions of chickpea and pigeonpea.

	Dhal				Powder	
Dehulling time (min)	Protein %	Calcium	Iron (mg/100g)	Manganese	Calcium	Iron (mg/100g)
0	18.6[a]	43.0[a]	5.7	1.3	—	—
	21.4[b]	64.9[b]	5.7	1.8	—	—
2	18.0	39.5	5.0	1.2	85.0	12.0
	20.8	51.7	4.1	1.7	167.8	17.3
4	17.5	38.0	4.8	1.1	65.5	10.5
	20.3	51.1	4.0	1.5	116.8	11.9
8	17.5	35.5	4.3	1.0	45.0	8.5
	19.6	45.7	3.6	1.5	94.1	9.2
12	16.4	30.0	3.8	1.0	45.0	7.0
	19.6	45.1	2.8	1.3	90.4	8.5
SE ±	0.18	1.80	0.20	0.11	2.91	0.20
	0.17	2.83	0.19	0.14	2.00	0.31

[a]Chickpea, [b]Pigeonpea. All values are averages of two replicates and expressed on a moisture-free basis in g/100g.
- At 0-min dehulling time, there is no powder.

Table 9 : Cooking time in some pulses.

Legume	Number of genotypes	Component	Cooking time (min) Range	Mean
Chickpea	15	Dhal	26-50	35.0
	60	Whole seed	55-200	108.6
Pigeonpea	58	Dhal	20-68	37.3
	24	Whole seed	45-90	55.8
Green gram	60	Whole seed	29-55	39.0
Horse gram	83	Dhal	90-182.5	154.3
		Whole seed		
Lentils	24	Whole seed	29-45	33.2

Source : Singh 1987, Singh *et al.* 1991.

1985). Among chemical factors, calcium, magnesium, phytin, and pectin play an important role. Dhal cooking time is positively correlated with calcium, magnesium, pectin, and protein content in pulses. At microstructure level, the cell wall and middle lamella characteristics, and the presence of starch granules and protein bodies influence the cooking characteristics of pulses. The middle lamella, which cements the individual cell together, consists principally of calcium salts

of polymers of galacturonic acid. Heating of legumes up to 90°C had no major effect on the microstructure. But fracture occurred at 100°C in the middle lamella due to depolymerization, resulting in softening of cotyledons (Rockland and Jones 1974). At 100°C, starch granules also changed their shape due to complete gelatinization. Miller (1967) reported that during cooking of legumes, softening also occurred as a reaction between phytic acid and insoluble calcium/ magnesium pectate present in the cell walls to provide soluble sodium/potassium pectate. Storage conditions are important -storage at high temperature and high humidity renders pulses susceptible to a hardening phenomenon, also known as hard-to-cook defect. This reduces consumer acceptance and nutritive value.

Also, there were positive correlations between cooking time and seed size in chickpea, pigeonpea, and lentils; bolder seed require longer to cook.

9. QUICK-COOKING DHAL

The major drawback in efficient utilization of pulses is their long cooking time. Presoaking has been recommended to facilitate the cooking process. "Soaking solutions" containing sodium chloride, sodium carbonate, sodium bicarbonate, or sodium tripolyphosphate have been the basis of a number of practical quick-cooking legume formulations. The carbonate or bicarbonate acts as an alkaline agent and buffer, and also as a protein-dissociating, solubilizing or tenderizing agent. A mixture of sodium carbonate and sodium bicarbonate is particularly effective. In a very recent study, pretreatment of pigeonpea in water or soaking solution at 25°C reduced the cooking time substantially. A solution of sodium bicarbonate was found to be most effective in reducing the cooking time (Table 10) but it adversely affected the product quality.

Treatment with enzymes also reduced cooking time. Of the enzymes, pectinase was the most effective. The role of pectic substances in combination with divalent ions (calcium and magnesium) in increasing cooking time in grain legumes has been known for many years. It is most likely that pectinase could degrade the pectic substances and thereby reduce their ability to form complex compounds with calcium and magnesium. This would facilitate cell wall dissolution during the cooking process and thus reduce the cooking time (Paredes-Lopez *et al.* 1991). Considerable attention has been paid for developing quick-cooking dhal of pigeonpea. Similar efforts should be made to develop quick-cooking dhal of other pulses, particularly of chickpea, which requires longer time to cook than most other pulses.

Table 10 : Effect of different treatments on dhal cooking time of pigeonpea genotypes[a].

Treatment	Solution pH	Cooking time (min) C 11	BDN 1	Market sample
Water	7.0	26	25	25
NaCl (1.0%)	7.1	20	18	19
Na_2CO_3 (1.0%)	11.3	12	12	10
$NaHCO_3$ (1.0%)	8.6	15	12	15
$Na_5P_3O_{10}$ (1.0%)	9.1	20	20	18
Salt mix[b]	9.1	14	15	12
SE±	-	0.4	0.6	0.6

[a] mean of two independent determinations.
[b] Salt-mix contained NaCl, 2.5%, $Na_5P_3O_{10}$, 1.0%, Na_2CO_3, 0.25%, and $NaHCO_3$, 0.75%).

10. PROCESSED AND SNACK FOODS

Processed and snack foods based on pulses are popular in many countries. Sometimes, pulses are detexturized (made softer) and used in the preparation of snacks and biscuits. Freshly sprouted pulses are germinated to prepare malts and malted flours are gaining consumer acceptance. Porridge-type weaning foods can be prepared from boiled and mashed pulses, e.g., mungbeans. Noodles prepared from the isolated starch fractions of mungbean and pigeonpea are satisfactory in terms of both physicochemical properties and consumer acceptance. Ample opportunities exist to increase the use of pulses in the manufacture of value added food products. For example, pigeonpea has a good potential for making *tempeh*, a fermented product traditionally prepared from soybean.

Pulses are consumed in large quantities as snack foods, usually deep-fried. For example, *seviya*, a snack item usually made from chickpea flour is extremely popular in the Indian subcontinent. There is a potential niche market for chickpea genotypes that absorb less oil during frying especially, since such genotypes normally contain high protein levels and could appeal to urban health-conscious consumers.

11. CONCLUSION

Genotype and processing practice are the key factors that influence nutritional quality and overall utilization of pulse crops. Considerable genotypic variation exists in nutritional factors, cooking time/quality "processability", and could be used in pulse improvement programs. For example, genotypes with reduced

levels of antinutritional factors could be identified and used to develop suitable cultivars. Quick-cooking dhal, also called instant dhal, could be developed by combining suitable genotypes with pretreatments that improve dehulling quality and reduce cooking time. Pulses are consumed in various forms. The development of quality standard and suitable genotypes for specific consumer needs should be emphasized.

Chickpea is more nutritious than any other pulse, but requires longer time to cook and produces flatus if consumed in large quantities. Pigeonpea suffers from relatively poor protein quality and difficulties in dehulling. Mungbean, urdbean, and lentil pose no serious problem when consumed. Although several high-protein genotypes have been identified, sources of high methionine have yet to be identified. It is necessary to identify the nutritional potential (including toxic and other undesirable components) of related wild species which are useful as sources of insect and disease resistance. Another research priority is to study the biochemical changes in proteins and carbohydrates induced by cooking, and eventually improve protein digestibility and the availability of amino acids (these remain low even after cooking). Vitamin and mineral losses due to cooking are another important research area.

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DOMESTIC PROCESSING OF GRAIN LEGUMES FOR THEIR NUTRITIONAL IMPROVEMENT

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ABSTRACT

Of the 146 legume species available worldwide about 80 such species are eaten by human and only 14 of these have major economic importance. Legume grains are one of the world's main source of food supply, especially in developing countries, in terms of food energy as well as nutrients. Known to be excellent sources of protein, legumes are also rich in important minerals and vitamins. Inspite of good nutritional profile, legumes have several nutritional and processing problems such as presence of antinutrients, prolonged cooking time, hard to cook phenomenon and poor digestibility. In order to increase the utilization of legumes attempts are warranted to develop processing techniques, especially at domestic level, as a major part of legume grain produced is processed and consumed as household level.

Domestic processing techniques, used to convert legume grains into consumable forms, include soaking, sprouting, boiling, roasting, decortication, fermentation etc. These treatments are beneficial in improving flavour, texture, protein and starch digestibility and mineral availability and in reducing the antinutrients.

Various methods of domestic processing of food legume grains including soaking, ordinary and pressure cooking, sprouting and cooking of sprouts have been found to reduce the level of antinutrients, the digestibility of protein and carbohydrates. A combination of soaking (soaking water discarded) with sprouting of pressure cooking (over pressure cooking to be avoided) brings about most desirable changes in the pulses for their most effective utilization for human nutrition.

The varieties of legume grains can be compared on the basis of their content of seed coat, phytic acid, polyphenols and saponins for predicting the bioavailability of minerals including calcium, iron and zinc from these grains. The bioaviabalility of calcium, iron and zinc can be enhanced by the domestic methods of processing such as; roasting, dehulling and sprouting are the most effective. *In vitro* methods can be reliably developed and can replace time-consuming, expensive and tedious *in vivo* method of assessing the availability of minerals. The improvement in digestibility of proteins and carbohydrates and availability of minerals (Ca, Fe and Zn) mediates through significant reduction in the level of antinutrients namely, phyticacid, polyphenol and saponins during processing.

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Centuries old tested methods of processing of grain legumes at household level possess several inherent advantage which matter for nutritional status of the population. In context of present day food scarcity and limited per capita nutrient availability it becomes acutely important that selected domestic processing methods are recommended which if adopted by people will undoubtedly enhance the utilization of grain legumes and consequently increse the amount of assimilable nutrients from the restricted intake of dietary legumes.

1. INTRODUCTION

In India, people are mostly vegetarian in dietary habits and depend largely on cereals and pulses as their staple food. Food legumes include those species of the family Leguminosae that are consumed directly by human beings most commonly as mature dry seeds, but occasionally as immature green seeds or as green pods with the immature seeds enclosed. Food legumes utilised as dry seeds are often referred, to as pulses or grain legumes.

India is the largest producer of grain legumes in world and food legumes provide the high protein component of the diet of majority of population. Daily per capita consumption of food legumes in different states within India vary from as low as 16 g in Tamil Nadu to 55g in Madhya Pradesh. Although a large number of pulse crops are grown in India, the most important of those are chickpea, pigeonpea (accounting for nearly half of total acreage and 60% of the total production of pulse crops), pulses of the vigna group (urdbean, mungbean and mothbean), lentils, pea, lathyrus and cowpea.

Pulses are considered poor man`s meat or also protein tablets. Beside proteins, pulses are important sources of carbohydrates, fibre, certain minerals (Ca, Mg, Zn, Fe, K and P) and B-complex vitamins. Food legumes have exceptional potential for alleviating human malnutrition in developing countries by virtue of several inherent advantages.

I) Universally, they can grow vigorously under a wide range of environments and on relatively poor soils without supplemental nitrogen, which is particularly advantageous for consistent agriculture in remote areas.

II) Because of their relatively low water requirements, they offer the most important means of increasing food production, farmer`s income and nutrient contribution in the diet in India`s dry lands, which constitute more than 75% of total cropped area.

III) They have a high supplementation value for cereal protein. Combination of pulses with cereal rich diet is promising in updating the dietary protein

quality. As a combination, pulses provide sufficient lysine to make good the deficiency in cereals. Sulphur containing amino acids, deficient in pulses are abundantly provided by cereals. Resulting protein is far better than present in either of the grains.

Legumes are consumed by humans in many forms. The nutrient bio-availability from legumes depends upon nutrient content and factors such as postharvest handling, processing methods, presence or absence of anti-nutritional and/or toxic factors, and possible interaction of nutrients with other food components i.e. polyphenolic compounds, phytic acid, certain minerals etc.,

Storage of food legumes under unfavorable condition is known to cause certain undesirable changes such as hardening of seed coat which results in an increase in cooking time. Cooking time for legumes is a function of moisture content, chemical composition, storage temperature, time and relative humidity.

Before they are consumed, pulses are generally subjected to simple processes like dehulling as *dhal*, soaking, cooking and autoclaving, sprouting, fermentation, roasting etc. Most of these household practices, though primarily developed to satisfy the palate of the consumer confer certain nutritional advantages and improve the food value of these grains.

2. DOMESTIC PROCESSING AND NUTRITIVE VALUE OF LEGUMES

2.1 Soaking

Soaking is very important step in processing of legumes. It is used as a treatment prior to many processes such as cooking, sprouting, fermentation etc. During soaking legume comes in contact with water which causes leaching of water soluble nutrients from legumes to water. This process is enhanced by presence of broken seeds and split seed coat.

Soaking has been found to decrease the level of total soluble sugars, nonreducing sugars as well as starch in many legumes (Table 1). Depending upon period of soaking the extent of reduction in total soluble sugars, reducing sugars and nonreducing sugars observed in chickpea ranged from 16 to 40, 16 to 25 and 16 to 42%, respectively and that in urdbean varied from 22 to 27, 27 to 35 and 22 to 27%, respectively. (Jood et al, 1988). In mungbean after 18 hour soaking loss of total soluble sugar, reducing sugar and non-reducing sugars and starch were 30%, 36%, 29% and 11.10%, respectively (Kataria and Chauhan 1988). Similar losses in sugars have been reported in other legumes (Jood *et al 1986*, *Silva* and