BIO - AVAILABILITY OF MINERALS FROM PULSES

By

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"Bio-availability of minerals from pulses"** is a bonafide record of research work done by me during the course of research and that it has not been previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"Bio-availability of minerals from pulses"** is a bonafide record of research work done independently by **Mrs. Ambili. Appukuttan. A** under my guidance and supervision and that it has not formed the basis for the award of any degree, diploma, fellowship or associate ship to her.

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EXTERNAL EXAMINER

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Abbreviation

AICR	-	American Institute for Cancer Research
BBI	-	Bowman Brik Inhibitor
cm^2	-	centimetre square
^0C	-	degree centigrade
DOPA	-	Dihydroxy Phenyl Alanine
E	-	Extractability
EDTA	-	Ethelene Diamine Tetra Acetic acid
FAO	-	Food and Agricultural Organisation
FDA	-	Food and Drug Administration
$Fe(NO_3)_3$	-	Ferric Nitrate
$Fecl_3$	-	Ferric Chloride
g	-	Gram
HCl	-	Hydrochloric acid
$HCLO_4$	-	Perchloric acid
HNO_3	-	Nitric acid
h	-	Hours
ICRISAT	-	International Crop Research Institute for the Semi-A rid Tropic
Kcal	-	Kilo calorie
Kg	-	Kilo gram
KSCN	-	Potassium thiocyanate
mg	-	milligram
ml	-	milliliter

mm	-	millimeter
N	-	Normality
NaOH	-	Sodium hydroxide
NAS	-	National Association of Scholars
NIN	-	National Institute of Nutrition
Nm	-	nano meter
O	-	Ordinary cooking
OD	-	Optical Density
%	-	Percentage
P	-	Pressure cooking
PER	-	Protein Efficiency Ratio
PUFA	-	Poly Unsaturated Fatty Acid
T	-	Total
TCA	-	Trichloro Acetic acid
USA	-	United State of America

Introduction

1. Introduction

Bio-availability is the degree to which food nutrients are available for absorption and utilization in the body. Thus, bioavailability refers to the amount of a nutrient in a food that the body may ultimately use to perform specific physiological functions. Bioavailability of nutrients varies within foods and depends on the concentration of enhancers and inhibitors of absorption. However, bioavailability of specific nutrients is a corner stone to determine the amount of any given nutrient for optimal health (Traber, 2000). Hence, low bioavailability of nutrients from a diet is also a contributory factor that significantly affects the nutritional status and health of a population.

Indian diets comprise mostly of foods from plant origin. The staple food consists mainly of cereals and pulses. Legumes not only add variety to human diet but also serve as a cheap source of protein in developing countries like India, where majority of the populations is vegetarian (Srivastava and Srivastava, 2003). Historically pulses are the natural protein supplement to cereals since ages.

Legumes contain low concentration of fat, good amount of protein, moderate amount of fiber and a reasonable balanced range of all dietary essential minerals. However besides these nutrients, it is known to contain many antinutritional factors viz phytic acid, polyphenols, saponins and trypsin inhibitors which are known to limit the utilization of legumes for human nutrition. These antinutritional factors are

known to reduce the activity of digestive enzymes, reduce the availability of nutrients for absorption and damage to the gastrointestinal tract. In animals they are known to cause lowered feed efficiency and growth depression.

The main source of iron from a typical Indian diet is contributed by cereals and pulses. Both pulses and grains are fairly good source of iron (2-10mg/100g). The prevalence of iron deficiency anaemia therefore in the majority of Indians is paradoxical. Poor iron availability has been extensively reported as the prime factor in considering the aetiology of iron deficiency anaemia especially in India (Rao, 1994). This is due to the presence of significant amount of phytates and tannins in legumes which are potent inhibitors of mineral absorption.

In many populations zinc deficiency has been attributed to an impaired bioavailability of dietary zinc (Ferguson *et al*., 1993). Marginal zinc deficiency and suboptimal zinc status have been recognized in many groups of the population in both developing and industrialized countries (Lonnerdal, 2000). Deficiency of zinc is wide spread in infants and children in developing countries (Hurrell, 2003). It is well recognized that despite having a relatively high zinc content in cereal and pulse based diet, high phytic acid and tannin content result in low availability of zinc which can be inadequate for normal growth and development. Therefore it is possible that zinc deficiency may affect particularly the poorer segments of population who depend on cereals and legumes as the major source of protein and calories.

Phytic acid, tannin and fiber bind with the divalent cations and lowers the bioavailability of minerals. Hence it is imperative to reduce the content of these anti nutrients by any of the processing methods for effective utilization of legumes.

In Indian households simple processing and cooking methods followed for legumes include soaking, dehulling, ordinary cooking, pressure cooking and germination. These processing and cooking methods may affect the phytic acid, tannin and fiber content which may consequently improve the bioavailability of minerals.

HCl extractability of minerals in foods is an index of their bioavailability from foods (Chompreeda and Fields, 1984). Thus the solubility of minerals in foods, subject to in vitro gastric intestinal digestion is a useful indicator of mineral bioavilability (Kim and Zemel, 1986). Hence the objective of the present study is to find out the effect of various processing and cooking methods on the in vitro availability of calcium, iron, phosphorus, potassium and zinc from commonly consumed pulses. The study was mainly concerned with the effect of various domestic processing and cooking methods on phytic acid, tannin and fiber content and HCl extractability of minerals.

Review of Literature

2. REVIEW OF LITERATURE

The literature pertaining to the study "Bio-availability of minerals from pulses" are given under the following heads:

2.1. Pulses in Indian dietaries
2.2. Nutritional significance of pulses
2.3. Health benefits
2.4. Anti nutritional factors
2.5. Effect of processing and cooking on the bio-availability of nutrients in pulses

2.1 Pulses in Indian dietaries

India is the largest producer and consumer of pulses in the world and accounts for 33 and 22 per cent of the global area and production of pulses respectively (Singh *et al*., 1992). Among food legumes, pulses continue to occupy an important place in human nutrition particularly in the developing countries like India. Historically pulses are the natural protein supplements to cereals since ages in the Indian sub-continent. A judicious mixing of pulses and cereals to provide a good quality diet was in practice, long before food scientists and nutritionists understood the nutritional importance of this practice. Legume grains are processed and cooked in a variety of ways depending on taste and cultural preferences. In India, about 80 per cent of the pulses are consumed in the form of *dhal* or flour and the remaining 20 per cent as whole seed (Singh, 1994). Nearly 80 per cent of the proteins consumed by humans in the developing countries are supplied by plants and plant products. In this context pulses are cheaper sources of protein when compared to animal proteins in the developing countries (Singh *et al*., 1997).

Pulses are the essential adjuncts in the Indian dietary. India depends great pulses to meet its demands for proteins. Pulses are considered as the meat of

the vegetable world (Khader, 2001). Legumes are an important constituent of the diet in India where majority of the population are vegetarians (Sinha *et al*., 2002). Grain legumes occupy an important place in our diet and are becoming scarce either due to lowered production, productivity or high cost (Chimmad, 2005).

Bengal gram (*Cicer arietinum* L.) is the most important pulse crop in India from production and consumption point of view. Other names of this pulse are *Channa* and *Chickpea*. India accounts for over 70 per cent of the world's total production and consumption of *chickpea* (ICRISAT, 1993). *Dhal* and food items prepared from *besan* are the major forms of chickpea consumption in India. *'Phutana'* (roasted grains), *'pakoda'* (oil fried), '*kadi'* (boiled in butter milk), *'roti'* (chickpea flour in combination with wheat flour), '*dhokla'* (fermented product), and '*satu'* (roasted chickpea flour in combination with cereal flours) are other common pulse food preparations in India (Singh, 1999). About 5.5 million tones of this pulse is produced in India, out of which nearly 70-75 per cent is converted to flour popularly known as *besan* which forms the choice base for several traditional sweet and savoury preparations (Pratape and Narasimha, 2005).

Most of the Pigeonpea (*Cajanus cajan* L.) produced in India is consumed in the form of *dhal curry* in North India and *sambar* in South India. Green and immature seeds are also used as a vegetable in some states (Faris *et al*., 1987). Pigeonpea is the second most important pulse in the country and India accounts for nearly 90 per cent of the world's supply of pigeonpea (Singh, 1993).

Green gram (*Vigna radiata* L.) is other wise known as *mung bean*. Green gram whole or split is used in a variety of ways in Indian homes (Mannay and Shadaksharaswamy, 1987). About 85 per cent of *mung bean* production is consumed in several countries of Asia (Singh and Singh, 1992). In India it is consumed in the form of *dhal* and whole seed, as well as after boiling and frying. They are also used with sugar as a snack or a dessert. It is also used in preparing weaning foods with added sugar and cereals (Singh, 1999).

The Indian sub continent alone contributes to about 40 per cent of the world's lentil production (Khan *et al*., 1987). Lentil (*Lens esculenta*) is consumed in the form of soup, whole seed and *dhal*. It is an excellent source of protein and amino acids when used to compliment cereal proteins particularly wheat, with which it is most often eaten in developing countries (Bhatty, 1988). The low levels of anti nutritional factors together with a high protein level and a shorter cooking time than most other pulses make lentil very suitable for human consumption (Williams *et al*., 1993).

Black gram (*Vigna mungo* L.) also called *urd bean,* is mostly grown and consumed in the Indian sub continent. *Urd bean* is predominantly eaten in India as boiled, whole seed, fried *dhal* and breakfast food in the form of *idli* and *dosa*. Its dark black seed colour,is due to polyphenols and tannins in the seed coat, but not in the cotyledons (Singh, 1999).

Cowpea (*Vigna unguiculata*) like other legume seeds is a good source of energy, protein, B vitamins and minerals (Oke *et al*., 1995). Nigeria has been reported as the largest cowpea producing (over 2000 MT cowpea/year) country in the world (Singh *et al*., 2003). As the requirement of pulses is increasing with population increase, emphasis is being laid upon utilization of under utilized legumes like cowpea (Sinha *et al*., 2005).

Horse gram (*Dolichos biflorus*) is an under utilized pulse probably due to its limitations such as anti nutritional factors, prolonged cooking time and strong flavour (Rao and Sampath, 1979). Horse gram is otherwise known as *Kulthi,* is largely grown in South India (Srivastava, 1984). It is a minor pulse crop commonly grown by the farmers and mostly preferred by the processors in pulse milling industry as a source of protein on account of cheaper pulse grain (Nimkar, 2006).

2.2 Nutritional significance of pulses

Pulses improve the nutritional quality of predominantly cereal based diets of large segments of population, as cereal proteins are deficient in lysine (Deosthale, 1984). Legumes not only add variety to human diet but also serve as a cheap source of supplementary proteins for a large human population in developing countries like India, where majority of the population is vegetarian (Bishnoi, 1991).

Legumes play an important role in Indian diets as they are economical sources of proteins, calories, B complex vitamins, soluble and insoluble dietary fiber components, minerals and low in fat and sodium content (Singh, 1997; Aparna *et al*., 2000; Venter and Eyssen-E-Van, 2001 and Srivastava and Srivastava, 2003). Legumes are the primary source of dietary proteins for the people of Indian sub continent (Gokavi and Malleshi, 2000).

Pulses are useful components of a balanced diet (Paris, 2001). Besides being an inexpensive source of proteins, pulses provide dietary calories in the form of carbohydrates (Sinha *et al*., 2002). Starch accounts for the major proportion of carbohydrates in pulses (Srilakshmi, 2003). In India 15-30 per cent of overall daily protein need is contributed by pulses (Singh *et al*., 2004). While cereals constitute the major portion of the diet, pulses are the major sources for providing the bulk of body building proteins (Singh *et al*., 2006).

Chickpea (Bengal gram) is a good source of carbohydrates, proteins, minerals and trace elements and its protein quality is similar to or better than other legumes such as pigeonpea, black gram and green gram (Williams and Singh, 1987). Studies conducted by Chavan and Kadam (1989) revealed that in chickpea varieties starch content ranged from 59.2 to 64.0 per cent. Thorne (1989) reported that chickpea contains 30-40 per cent amylose and 60-70 per cent amylopectin in their starch granules compared to other carbohydrate foods such as cereals which contain 25-30 per cent

amylose and 70-75 per cent amylopectin. As reported by Srilakshmi (2003) protein in bengal gram contain higher amounts of arginine and sufficient amount of tyrosine.

Pigeonpea is a rich source of proteins, carbohydrates and some minerals. The protein content ranged between 17.9 and 24.3 per cent (Salunkhe *et al*., 1986) for whole grain samples and between 21.1 and 28.1 per cent for split seeds. Pigeonpea also contains about 58.7 per cent carbohydrate, 1.2 to 8.1 per cent crude fiber and 0.6-3.8 per cent lipids. Duhan *et al*. (2001) reported that pigeonpea contained low concentration of fat, moderate amount of fiber, good amount of proteins and a reasonable balanced range of all dietary essentials. It is a good source of minerals such as calcium, phosphorus, magnesium, iron, sulphur and a fair source of some essential amino acids, though deficient in methionine and tryptophan (Onimawo and Asugo, 2004).

Cowpea is a good source of energy, protein, B. vitamins (thiamine and riboflavin) and minerals (Ogbeide and Ogbeide, 1985 and Oke *et al*., 1995). It can serve as a good source of nutrients particularly energy and protein for the weanling. Experimental studies conducted by Ofuya (2005) in rats, revealed that the digestability of raw cowpea starch was about 99 per cent, a value unaffected by processing.

The protein content of black gram is 25-28 per cent which is rich in lysine (Reddy *et al*., 1982). Black gram dhal is a good source of protein (26%), B complex vitamins and minerals (3.3%) especially calcium, phosphorus and iron (Dahal *et al*., 2003). According to Pande *et al*. (2006) black gram is a good source of water soluble vitamins (especially B complex) and contains minerals and PUFA.

Horse gram is a pulse with high protein content and is readily available in India (Ray, 1968). It is a good source of protein and minerals especially calcium and phosphorus and is comparatively less costly than other pulses (Rao and Sampath, 1979). Horse gram is an important source of protein and has been identified as one of the potential food sources (NAS, 1979). Horse gram dhal is fairly good in protein quality. Methionine is the major limiting amino acid and threonine and tryptophan are the other minor limiting amino acids in horsegram (Khader and Rao, 1986).

Rajmah is high in cellulose and non celluloic polysaccharides like lignin and so has been reported to have hypoglycemic effects comparable to bengal gram and fenugreek seeds (Sharma, 1986). According to Gopalan (1989) it is a good source of protein (22.9%), energy (346 kcal) and minerals (3.29 g).

Soybean contains more protein than beef, more calcium than milk and more lecithin than egg. It is also rich in vitamins, minerals and amino acids (FAO, 1990). Greta *et al*. (1993) analysed the concentration of tocopherols in some cereals and pulses and among these, soybean was found to have the highest level of tocopherol. Soy lecithin has functional properties like an antioxidant (Liu, 1997). It has become one of the most desirable label friendly food ingredients, because its nutritional phospholipids constituents are classified as a nutraceutical food (Colbert, 1998).

Soy foods are one of the fastest growing categories in the food industry even as dairy to meat alternatives to various types of soy rich Western foods (Golbitz, 2000). Soybean also contains many minor substances which are biologically active, non nutritive components known as phytochemicals (Chandan, 2001). Soybean contains 13-25 per cent oil, 30-50 per cent protein and 14-24 per cent carbohydrates. The major fatty acids are linoleic acid (55%) followed by oleic acid (21%), palmitic acid (9%), stearic acid (6%) and other fatty acids (Tripathi and Misra, 2005).

Soy milk is used as a base in a variety of products including tofu, soy yoghurt and soy based cheese (Patil and Nawab, 2002). It has a great potential to supplement dairy milk and it is nutritionally comparable with mother's milk and cow's milk (Chauhan and Chauhan, 2007).

2.3 Health benefits of pulses

Legumes are unique foods because of their rich nutrient content, including starch, vegetable protein, dietary fiber, oligosaccharides, phytochemicals (especially the isoflavones in soy) and minerals (Mathur *et al*, 1973). Pulses have both therapeutic and

protective effects. Legumes are excellent foods to increase dietary fiber consumption and are important in meeting the major dietary recommendations to improve the nutritional status of undernourished as well as overnourished people and to reduce the risk for chronic diseases such as cardiovascular diseases, diabetes mellitus, cancer and osteoporosis (Venter and E-Van, 2001).

Cardiovascular diseases are a major medical and public health concern in all population groups (Wolmarans, 1997). Dietary interventions to reduce the risk of cardiovascular diseases include the consumption of certain types of fatty acids, dietary fiber, isoflavones and anti-oxidants. The low saturated fat content of soy and the presence of α – linolenic acid makes soy food a good choice for a healthy - heart diet (Messina, 1999). In a large study of almost ten thousand men and women in USA who ate pulses four or more times in a week showed a 22 per cent lowered risk of coronary heart diseases and up to a 11 per cent lowered risk of cardiovascular events than those who ate pulses less than once in a week (Bazzano *et.al*, 2001).

Dietary fiber has major protective effects against cardiovascular diseases (Van-Horn, 1997). In USA, the Food and Drug Administration (FDA) approved the use of 25 gram of soy protein per day to reduce the risk of heart disease (Gell and Anderson, 1994). Dried beans, peas or soybean can prevent cardiovascular diseases (Kushi *et.al*, 1999).

Pulses are potential for the prevention of colon, breast and other cancers. Pulses contain a rich variety of compounds, if consumed in sufficient quantities, may help to reduce tumor risk (Steinmetz and Potter, 1996 and Mathers, 2002).

Saponins present in pulses have anti cancer properties. The isoflavones in pulses are a weak form of estrogen and are thought to compete with the body's own estrogen at estrogen receptor site's, blocking the body's stronger version i.e. tumor growth (Shamsuddin, 1999).

Soyabean may reduce risk of prostrate cancer and post menopausal breast cancer. Isoflavones as being responsible for the hypothesized anti cancer effects of soy (Hurrell *et al.*, 1992; Messina *et al.*, 1994; Kennedy, 1995; and Messina, 1999). The neutral fiber isolated from black gram possesses anti-colon cancer properties (Indria and Kurup, 2003).

Jenkins *et al.*, (1980) reported that hypocholestrolemic action of legume food, is to be due to their carbohydrate. Mathur *et al.* (1973) and Leelama *et al.* (1978) have shown that this effect is due to their proteins. Soy fiber supplementation has a modest hypocholestrolemic effect in humans (Lo *et al.*, 1986; and Anderson *et al.*, 1990). Fiber in foods such as beans and soy altered cholesterol metabolism at gastrointestinal, hepatic and peripheral sites (Lo *et al.*, 1986; Anderson *et al.*, 1990; Gell and Anderson, 1994; and Venter, 1999). Soybeans, with or without their fiber decreased serum cholesterol concentration through their protein and isoflavone contents (Anderson *et al.*, 1995).

Bengal gram consumed over a period of several weeks reduced serum cholesterol by increasing faecal excretion of total bile acids (Srilakshmi, 2003).

Black gram possessed significant lipid lowering effect (Anderson and Major, 2002 and Indria and Kurup, 2003). Reductions in blood cholesterol level of 10 per cent or more were achieved within two or three weeks on test diet containing either canned beans (69-150g/day) or dry beans (75-200g/day) (Nestel *et al.*, 2004).

Pulses are foods with very low glycemic index and can contribute to improved blood glucose control. Pulses reduce the risk of developing diabetes because of their high fiber, low fat content and low glycemic indices. Pulses are slowly digested and produced low insulin responses (Vorster *et al.*, 1987 and Marshall *et al.*, 1991). Dry beans and soy food offer benefits in the prevention of diabetes (Vorster *et al.*, 1987).

The slow rate of starch digestion is generally considered the most important determinant of low glucose and insulin responses to legumes (Brand *et al.*, 1990).

Legumes are rich in soluble fiber , phytates and tannins, all of which inversely correlate with carbohydrate digestion and glycemic response (Jenkins *et al.*, 1991). In subjects with low glucose tolerance, dry beans, soy protein isolate and soy fiber improved glucose tolerance and insulin response (Verster, 1993). Studies conducted by Gell and Anderson,(1994) showed that a meal containing 200g of chickpea resulted in lower blood glucose and insulin levels in the first hours after the meal.

Diet with low glycemic index improves the prevention of coronary heart disease in diabetic and healthy subjects. In obese or overweight individual low glycemic index foods increase satiety and facilitate the control of food intake (Rizkalla et.al, 2002 and Anderson and Major, 2002). Indira and Kurup (2003) reported that black gram possessed a significant hypoglycemic effect in humans.

Guar gum, a gel forming galactomannan polysaccharide derived from cluster beans also influences glucose tolerance. This is due to viscosity, alteration in postprandial responses to insulin and various gut hormones (Srilakshmi, 2003).

Soy isoflavones are proposed to preserve bone mineral density. Human studies also supported the potential role of soy isoflavones in increasing bone mineral density in post menopausal woman (Messina, 1999).

Isoflavones are another group of phytochemicals in pulses, but soybean is the only nutritionally relevant source of isoflavones. Soy isoflavones also have antioxidant properties (Anderson *et al*., 1991). The primary isoflavones in soybean are genistein and daidzein and their respective β-glycosides (Setchell and Cassidy, 1999).

2.4 Antinutritional factors in pulses

Legumes are known to contain a number of antinutritional and toxic factors, some of which are thermoliable, while others are heat stable. The former include trypsin inhibitors, haemagglutinins, goiterogens, saponins, alkaloids, cyanogenic glycosides etc.

Under heat stable category comes the phenolic compounds such as tannins (Liener, 1962). In addition, pulses have also other antinutritional factors like urease, phytic acid, allergens and flatulents (Rackis, 1974).

Like other legumes presence of antinutritional factors is one of the main draw back limiting the nutritional and food qualities of cowpea (Singh *et al*., 2005). Soybean also contains antinutritional factors like trypsin inhibitors, haemagglutinins, and goiterogens (Alok *et al*., 2006). Horse gram is an underutilized pulse probably due to its limitations such as antinutritional factors like protease inhibitors, phenolic compounds and haemagglutinins (Pavithra *et al*., 2006).

Trypsin inhibitors are proteins that inhibit the activity of trypsin in the gut and interfere with digestibility of dietary proteins and reduce their utilization. Red kidney bean and soybean contain high amounts of trypsin inhibitors (Vakwons and Barner, 1963; Lepkovsky *et al*., 1971; Kakade *et al*., 1973). Raw soybean contains undesirable trypsin inhibitors which has high thermal resistance (Savage *et al*., 1995). Trypsin inhibitors from beans can interfere with protein digestion, cause pancreatic enlargement and induced pancreatic tumours (Kennedy, 1995).

Studies conducted by Ramamani *et al*. (1996) revealed that, in soybean trypsin inhibitor was the highest (56.3 ± 1.64 mg/g of pH) in Ankur variety and the value showed a steep reduction on roasting for 10-15 min.

Two types of soy trypsin inhibitors are present in soybean, kunitz inhibitor and Bowman Brik inhibitor (BBI). They are proteins, which can bind the digestive enzyme trypsin (Liu, 1999). Boiling dry beans generally reduce the trypsin inhibitor content by 80-90 per cent.

Antinutrients present in plant foods are a group of heat liable proteins or glycoproteins known as lectins or haemagglutinins. Red kidney bean is one of the richest sources of lectins (Naebbas and Oppenbeim, 1980). Haemagglutintins reduce the food

intake resulting in poor growth. The lectins interact with dipeptides, disaccharides and other enzymes involved in nutrient digestion and uptake (Srilakshmi, 2003). Goiterogens are substances which interfere with iodine uptake by thyroid gland. Thiocyanate, isothiocyanate and other derivatives are present in soybean, lentils and ground nuts (Srilakshmi, 2003).

Saponins are present as triterpene glycosides in significant amounts in legume grains (Oakenfull, 1981; Vorster and Venter, 1994) which impart bitter taste to the plant foods and cause physiological disturbances and toxicity in human system. Saponins form insoluble complexes with 3- β -hydroxysteroid and are known to form large, mixed micelles with bile acids and cholesterol (Milgate and Robert, 1995). Saponins produce lather or form when shaken with water. Saponins cause vomiting and nausea in humans (Koralkar and Rao, 1997).

Legumes predominate in terms of their cyanide producing potential. This causes human intoxication or cyanide poisoning by interfering with tissue respiration. On hydrolysis of this glucoside by the enzyme β-glucosidase, hydrogen cyanide is liberated. Cyanide content in pulses in the range of 10-20 mg/100 g is considered as safe (Liener, 1969).

Lathyrism is a nervous disease that is now known to result from an excessive consumption of the pulses Lathyrus sativus or kesari dhal. When it is eaten in small quantities lathyrus seeds are valuable as food, since it contains 28 per cent protein. But a compound, which may very well be the causative principle of human neurolathyrism, was identified as β–N-oxalyl α-β diaminopropionic acid (Haytowitz and Mathews, 1986).

Favism is a disease characterized by hemolytic anaemia that occurs in individuals who are deficient in glucose 6-phosphate dehydrogenase. In susceptible individuals the levels of glutathione in the erythrocytes is also reduced (Hsu *et al*., 1973). Three different compounds present in faba bean have been implicated on playing a causative role in the disease. Two of these are glycosides known as vicine and covicine

and the third is an amino acid derivative known as dihydroxy phenyl alanine (DOPA). Those are present in the cotyledons of the broad and faba beans (Srilakshmi, 2003).

Tannins are condensed polyphenolic compounds. They are present in high amounts in seed coat of most legumes. Tannins bind with iron irreversibly and interfere with iron absorption. Tannin interferes with digestive action of trypsin and α-amylase rendering the dietary protein and carbohydrate indigestible. Tannins also bind proteins and reduce their availability (Gallardo *et al*., 1974).

Red gram is known to contain many antinutritional factors including polyphenols which are generally located in the seed coat of pigmented cultivars of red gram and are known to reduce the activity of digestive enzymes (Singh, 1988).

Red kidney bean, black gram and soybean have higher amounts of polyphenolic compounds (Lynch *et al*., 1994). Vobra *et al*. (1996) reported that high levels of total tannins, namely condensed tannins, minimized the nutritional value of carob bean. Marakis *et al*., (1996) reported the tannin content in carob bean to be 1.4 - 13.3 per cent. Waldia *et al*., (1996) observed that the seed coat of chickpea (*Cicer arietinum* L.) is rich in polyphenols and other antinutrients that might have reduced the cooking quality.

Pigeonpea contain as high as one per cent of tannin, followed by black gram 0.86 per cent, green gram 0.6 per cent and chickpea 0.18 per cent (Grewal and Jood, 2006). Studies conducted by Parvathi and Kumar (2006) revealed that tannin content of raw rice bean was 0.017 mg and phytic acid was 149.62 mg/100 g which reduced significantly on sprouting and cooking.

The oligosaccharides in pulses remain undigested and unabsorbed in the digestive tract and pass into distal part of the intestine, to be metabolized by microflora with resultant products of gases particularly hydrogen and carbondioxide (Calloway and Murphy, 1968). Legumes are consumed by humans and animals and these are not

available for energy generation or tissue synthesis due to the absence of α-galactosidase in the intestine (Hellendoom, 1969).

Chickpea is shown to be more flatus forming than pigeonpea, green gram and black gram, i.e. 93 per cent, 73 per cent, 60 per cent and 82 per cent respectively (Rao *et al*., 1973). Iyengar (1976) reported that the rate of *in-vitro* α-amylosis of the raw legumes is highest in green gram and lowest in chickpea. Raffinose, stachyose and verbascose are the major oligosaccharides of the raffinose family of sugars, present in pulses (Rao and Belvadi, 1978; Batra and Dhindsa, 1989). Raffinose and stachyose are the most gas forming sugars in pulses. Sucrose is the hydrolytic product of raffinose oligosaccharides and it is non flatulent (Vasissgfa *et al*., 1991).

The seed coat of most legumes are toxic if eaten uncooked because of the presence of some antinutrients that inhibit trypsin, chymotrypsin and amylase and also the presence of flatulence causing oligosaccharide such as stachyose, raffinose and verbascose (Osagie and Eka, 1998). Soy flour is high in oligosaccharides raffinose and stachyose and beany flavour that may be objectionable to some consumers (Surarez *et al*., 1999).

Animal feeding trials indicate that high phytate food interfere with absorption of several minerals (Reddy *et al*., 1982). Phytic acid present as a constituent in many grains, reduce iron absorption by forming insoluble complex of ferric phytate which was soluble during germination (Annapurani and Murthy, 1984). Phytate is largely responsible for poor iron availability from soybeans, the phytate content in beans is 1-2 per cent (Hurrell *et al*., 1992; Messina, 1999).

Pulses contain antivitamin factors. Unheated soybean meal contains antivitamin D_3, raw kidney bean contains antivitamin E and soy flour contain antivitamin B_{12} factor (Stein, 1976). Metal binding constituents are also present in pulses, which can decrease the availability of certain trace minerals such as zinc, manganese, copper and iron (Noah *et al*., 1980). Antithiamine factor thiaminase is present in *mung bean*,

antiniacin factor present in sorghum and antipyridoxine factor present in linseed (Liener, 1980).

2.5 Effect of processing and cooking on the bioavailability of nutrients in pulses:

Bioavailability is defined as the degree to which the amount of an ingested nutrient is absorbed and available to the body. Bioavailabilities of different nutrients are affected by trypsin inhibitors, haemagglutinins, tannins and phytates in pulses. These can be destroyed by different cooking and processing methods. Food processing such as heat treatment, milling, fermentation or the action of enzymes, contributes to their enhanced or reduced availability of nutrients (Yetley and Glinsmann, 1983).

2.5.1 Soaking and germination:

Soaking is a preliminary step common to almost all methods of preparing legumes, prior to cooking. Soaking helps in the removal of seed coat to shorten the cooking time (Srilakshmi, 2003). Germination generally improves the nutritional quality of seeds and increase the vitamin content of certain pulses. Germination brings about many biochemical transformations in seeds, which intrinsically improve their overall acceptability for consumption. Germination is also a conventional process (Babu, 1976) and is beneficial in reducing some of the antinutritional factors in cereals and legumes (Deosthale, 1982; Baber *et al.,* 1988).

Soaking reduce phytic acid and oligosaccharides of raffinose family. When legumes are in contact with hot or cold water some leaching of water soluble nutrients from the legumes into the water will occur. Water used for soaking can be used in cooking to minmise their losses (de.Boland *et al.,* 1975). Paramjyothi and Mulimani (2001) observed that soaking red gram seeds for 6 hours, 12 hours and 18 hours resulted in a gradual decrease in polyphenols.

During germination starch is significantly hydrolysed by hydrolytic enzymes which degrade amylase and amylopectin by successive removal of low molecular weight compound from the non reducing chain ends (Subbulakshmi *et al*., 1976). Jaya (1978) observed that a marked reduction in the concentration of oligosaccharides and alterations in some of the properties of starches in chicpea and green gram during germination.

Germination of soybean is done in order to convert oligosaccharides to monosaccharides and then soy milk is prepared using this germinated soybean seeds (Hsu *et al*, 1980). Germination can be considered as a process for improving the carbohydrate digestability of chick pea and green gram (Jaya and Venkataraman, 1981). Sprouting essentially predigest the food by breaking down the concentrated starch into simpler carbohydrates and the protein into free amino acids (Paar and Ingle, 1988)

Legumes contain more of protein than cereal and protein starch interaction in legumes may equally contribute to their decreased glycemic responses and poor starch digestibility (Geervani and Theophilan, 1981). Because of this legume carbohydrates are known as slow release carbohydrates (Jenkins *et al*., 1980 and Jenkins *et al*., 1982).

Soaking treatment improve the *in vitro* protein digestability of cooked horse gram (Kadam *et al*., 1983). For horse gram and cowpea most treatments improved protein digestibility only frying reduced protein digestibility. Digestibility was highest for the germination and cooking treatment (Elfaki *et al*., 1985).

There observed a slight increase in total nitrogen content after germination for 5 days but greatest increase was reported in glutamic and aspartic acid (Chen and Thacker, 1978). Crude protein showed an increase as a result of germination (Hsu, *et.al*, 1980).

Onimawo and Asugo (2004) observed a decrease in crude protein content in pigeon pea after germination. Germination produced significant increase in the protein

content. Increased protein content during germination may be due to utilization of non protein moieties and rapid protein synthesis (Sinha *et al.*, 2007).

Vitamin C, which is particularly absent in dry legume seeds, increased in significant amounts after germination (De and Barai, 1949 and Prabavathi and Rao, 1979). Babu (1976) has found two to three fold higher values of folic acid in germinated than in the raw cow pea.

During germination ascorbic acid content increased 4 -20 folds (Chen *et al.*,1975) riboflavin increased by 2.5 - 4.5 folds (Vandersteap, 1981) and thiamin content increased 6 times (Fordham *et al.*, 1975) in pulses.

β carotene content of sprouted *mung bean* is two and a half times higher than the dry bean, and some beans have more than eight times more β carotene after being sprouted (Chen, 1975)

Mathur *et al.* (1973) demonstrated that even large amount of ascorbic acid have only a moderate effect on iron absorption from soy. Sprouting was faster at room temperature than high temperature and ascorbic acid values initially increased and then decreased with increasing temperature in all legumes (Dikshit, 1992).

Sharma and sehgal (1992) reported a continous rise in vitamin C, as the soaking and germination time progressed till 48 hours. Thiamin content in cowpea, green gram and black gram were found to increases slightly in soaked and germinated pulses.

Rajalakshmi and Patel (1969) reported that germination increased ionisable iron by 24 per cent in peas. Chen *et al.* (1975) and Hsu *et al.*,(1980) determined nutrient composition of bean and pea seeds and suggested that decrease in phytate content during germination may cause essential mineral availability.

Lolas and Markakis (1975) reported that phytic acid react with protein to form complex products of varying composition and this had an inhibitory effect on the peptic digestion of albumin and elastin. This effect is believed to be releated to form insoluble complexes with phosphorus and minerals like calcium and zinc in acid medium. Germination increased the availability of minerals by decreasing the complex formation.

The beneficial effect of germination is in the improved availability of iron in chickpea (Prabhavathi and Rao, 1979). Germination decreased the phytin phosphorus level in green gram and increased the availability of calcium and iron (Giri, 1983).

Total calcium, phosphorus and iron contents of pigeon pea decreased with the period of soaking and losses in the mineral content due to soaking may be attributed to leaching out of these minerals in soaking water (Kumar, *et al.*, 1978).

Rao and Parvathi (1986) observed that the proportion of ionisable iron increased significantly in legume seed when seed coats were removed. In germinated legume seeds, thiamin content decreased by 20-30 per cent, while ionisable iron nearly doubled. Decorticated seed samples which had low tannin and high ionisable iron, did not show any improvement at different stages of germination. The phytate content of the seeds decreased and ascorbic acid content increased during germination. A reduction in tannin content of whole seed during germination is responsible for the observed improvement in ionisable iron.

The per cent increase of absolute available iron after 48 hours of germination when compared to other pulses showed that, green gram had the highest per cent of increase of absolute available iron followed by peas, horse gram, field bean, soybean, cowpea and bengal gram had the least increase (Annapurani and Murthy,1984).

Ionisable iron content in chickpea increased on germination upto 72 hours. On removal of the seed coat,the ionisable iron is 14 per cent both in raw and germinated grains of chickpea.

Bioavailability of zinc was enhanced when weanling rats were fed marginal zinc concentration from germinated peas. Increased zinc bioavailability was attributed to (a) partial phytate hydrolysis by phytate synthesized de navo during germination and (b) activation of pea phytase in the gastro intestinal tract of the rat and hydrolysis of phytate before zinc absorption occurs (Beal, *et al.*, 1984).

Increase in the germination period significantly affected the extractability of calcium, phosphorus and iron. After 48 hours of germination the extractabilities of calcium and phosphorus were found to be maximum in pigeon pea seeds (Bishnoi and khetarpaul, 1995; 1996a, 1996b; 1997). Germination resulted in a significant loss of phytic acid which further enhanced the absorption of minerals like calcium, iron and phosphorus from pulses (Duhan *et al.*, 2001).

Germination altered the total dietary fiber in all legumes (Chitra *et al.*, 1996). Nagaprabha and Prakash (2007) reported that germination lowered the mineral content of green gram. King and Puswastein (1987) reported an increase in protein content on sprouting of legumes.

2.5.2 Dehulling:

Dehulling of legumes seeds and splitting the cotyledons are often carried out for better product profile and acceptability. Dehulling reduces cooking time and it shows a negligiable effect on the total protein content and amino acid composition. Dehulling removes tannins that lower protein digestibility (Bressani and Elfas, 1980).

In vitro studies have also shown that availability of iron is about two to four times more in *dhal* as compared to whole grain (Prabhavathi and Rao, 1979). Dehulling of cowpea resulted in significant reduction in fiber content and this may be due to the fact that the most of the fiber found in testa was removed during the process of milling (Akinyle and Akinlostu, 1991 and Sinha, et.al, 2007).

Akinyole and Akinlostu (1991) reported that soaking for 4 hours and dehulling increased the protein content by 5.7 and 2.7 per cent in cow pea cultivers.

2.5.3 Heat treatment and Cooking:

Germination and pressure cooking gave the highest carbohydrate digestibility in legumes (Elfaki *et al.,* 1985). A decrease in protein content after cooking was reported by Khalil *et al.,* (1986) in field pea, moth bean and pigeon pea.

Starch digestibility varied depending on the type of legumes, bengal gram exhibited a significant increase when cooked in acidic media, control sample of cowpea had low digestibility (36.8 per cent) but increased significantly when cooked in tartaric acid (67 per cent). Green gram showed a decreased starch digestibility in all cooking media where as horse gram showed an increase in acidic media (Jogyabathi *et al.*,2001).

Ordinary cooking of presoaked and unsoaked seeds of *moong bean* have an improved *in vitro* protein and starch digestibility (34-38 per cent and 31-62 per cent) (Jood *et al.*,1998). The *in vitro* starch and protein digestibility of pressure cooked samples of bengal gram were found to be higher (Khatoon and Prakash, 2004)

Bengal gram on autoclaving at 15Ibs pressure for 15 minutes showed an improvement in protein efficiency ratio from 1.2-2.4 (Hirwe and Magar, 1951). Esh and Som (1952) also reported a slight change in the PER of bengal gram on autoclaving for 30 minutes at 15 Ibs pressure.

Hirwe and Magar reported (1953) a slight increase in the PER on autoclaving green gram dhal at 15 Ibs for 30 minutes. Adolph *et al.,* (1955) reported a marked improvement in the PER of chick pea on cooking in water for one hour after soaking overnight.

Devadas *et al.*,(1964) observed a marked improvement in the PER of dhals autoclaved for a period of 15 minutes at 15 Ibs pressure. Autoclaving the green gram dhal beyond 10 minutes at 10 Ibs pressure decreased protein quality. Autoclaving at 10 Ibs upto 10 minutes resulted in a slight increase in the PER of bengal gram dhal. Dehusking resulted in a marked improvement in the PER of horse gram and bengal gram while there was only a slight improvement with green gram. The improvement obtained by autoclaving could be attributed to the denaturation of protein and inactivation of antinutritional factors such as protease inhibitors and phytohaemagglutinins (Liner, 1980). Processing improved protein quality of legumes in general. Supplementation with the limiting sulphur containing amino acids further enhanced the protein quality in the autoclaved legumes. Roasting also resulted in a considerable improvement in the PER of whole horse gram (Khader and Rao, 1986).

Domestic processing techniques like soaking, sprouting, roasting and pressure cooking destroyed the antinutritional factors and improved the protein quality and digestibility in legumes (Wu *et al.*, 1995 and Willim *et al.*, 1994). Rani and Hira (1993) reported that roasting and pressure cooking destroyed the antinutritional factors present in faba bean thereby improving protein quality and digestibility. The increase in weight gain on autoclaving the raw cowpea meal in both conventional and antibiotic treated rats was due to the inactivation of antinutritional factors and the denaturation of cowpea storage protein resulting in greater availability of cowpea protein (Oke *et al.*, 1996).

Soybean was more susceptible to methionine losses during open vessel boiling (Parihar, 1996). Though trypsin inhibitor is heat labile, but heat treatment insolubilizes the much valued protein and more importantly excessive heat treatment can cause loss of essential amino acids in soy proteins (Rios- Iriarate and Barner, 1996).

Available lysine and a good per cent age of *in vitro* digestibility of proteins were retained in the pressure cooked soybean flour where as these values were very low for roasted soybean. PER values of roasted soybean protein were considerably

lower (1.8 as against 2.8 for pressure cooked soybean) though inactivation of trypsin inhibitor was nearly the same (Ramamani *et al.*, 1996).

Studies conducted by Rammamani *et al.*, (1996) revealed that by roasting the dehulled soy splits, PER improved from negative to 1.8. Gupta (2004) reported that processed soybean contained very high per cent of good quality protein (45.87 per cent) with good digestibility.

Cooking in different media lowered protein digestibility in all legumes and significant reduction was seen in bengal gram cooked with soda, citric and tartaric acid, cow pea cooked with acids, green gram cooked with tartaric acid and horse gram cooked in all media (Jogyabathi *et al.*, 2001).

Markotia and Modyil (2003) reported lower values for PER and FER for raw *moth bean* due to high antinutritional factors present in it. Studies conducted by Gupta, (2004) observed that the PER and FER values were lower for groups of rats fed on raw faba bean compared to those fed on treated legumes, such as germinated, roasted and pressure cooked. The lower FER and PER values were due to the presence of antinutritional factors in raw faba bean which in turn decreased the protein digestibility.

Pressure cooking and solar cooking of chickpea caused an increase in crude fiber content and a decrease in fat, ash and carbohydrate content (Sotelo, *et al*., 1987; Kasthurba *et al*., 1990; Giami, 1993). Cooking altered the dietary fiber content of some legumes. Ordinary cooking and pressure cooking increased crude fiber content which may be due to loss of water soluble materials (Sinha *et al.*, 2007).

Studies reported by Raghunath and Belvady (1979a) have shown that cooking loss of riboflavin values ranged from 13 to 35 per cent in chickpea, pigeon pea, green gram and black gram. On the other hand cooking losses of vitamin B6 in these pulses were relatively low.

Cooking decreased the thiamine content in most of the legumes (Khatoon and Prakash, 2004). In faba bean thiamine and the available niacin content lost up to 35 and 42 per cent on cooking and riboflavin was not affected (Pradanov *et al*., 2004).

Germination increased the riboflavin, vitamin C and niacin content in cowpea, peas, red gram, while heat treatment decreased the water soluble vitamin content of germinated pulses (Pande *et al*., 2006).

Cooking, roasting and milling showed two to four fold increase in biologically available iron (Lee and Clydesdale, 1981). Studies conducted by NIN (1994) revealed that the total iron content in seven varieties of whole pulses ranged between 5.7 to 6.4 mg/ 100gm but the per cent ionisable iron varied widely from 34-35.6. The per cent ionisable iron in split pulses was found to be significantly higher. Per centage of total and absolute iron (mg/ 100g) content of dehulled and milled pulses increased whereas roasted and cooked bengal gram showed decrease of total iron and increase of absolute available iron.

Pressure cooking of soaked and dehulled seeds brought about maximum improvement in iron extractability (Duhan, *et al*. 2001). Soaking and dehulling could bring about maximum in HCl extractability of zinc. Minerals content like calcium, iron and zinc were found to be significantly low in all processed bengal gram products (Pradanov *et al*., 2004).

Materials and Methods

3. MATERIALS AND METHODS

The methods followed and the materials used in the investigation on "Bio-availability of minerals from pulses" are given under the following heads.

3.1 Collection of pulses
3.2 Processing and cooking of samples
3.3 Analysis of chemical constituents of the pulses
3.4 Statistical analysis

3.1. Collection of pulses

Commonly used pulses like green gram (*Phaseolus aureus* Roxb.), bengal gram (*Cier arietinum* Linn.) and horse gram (*Dolichos biflorus* Roxb.) were selected for the study and they were procured from the local market in one lot. Milled bengal gram dhal and green gram dhal was also purchased.

3.2. Processing and cooking of the samples

The three pulses selected were cleaned by removing foreign materials prior to processing and cooking treatments. Raw seeds were powdered (0.5mm sieve) and packed in air tight containers and were used as control. The processing and cooking treatments were done in triplicate samples and are detailed below

3.2.1. Methods of processing

3.2.1.1. Soaking

Two hundred grams of the pulses (whole seeds) were soaked in distilled water for 6 h and 12 h at room temperature. The seed to water ratio was 1:5(w/v). The soaked seeds were washed and rinsed with water.

3.2.1.2. Soaking and dehulling

Two hundred grams of whole seeds were soaked in distilled water for 6 and 12 h as done in 3.2.1.1. After soaking, the hulls were removed manually by rubbing with hands.

3.2.1.3. Germination

Soaked seeds (12h) were rolled in muslin cloth, sprinkled with distilled water and kept for germination in a dark place at room temperature for 24 h and 36 h.

3.2.1.4. Horse gram dhal was prepared manually by using a mortar and pestle.

3.2.2 Methods of cooking

Ordinary cooking and pressure cooking was the two methods of cooking adopted.

3.2.2.1. Ordinary cooking

The unsoaked, soaked (6 h and 12 h), soaked (6 h and 12 h) and dehulled seeds and the milled pulses were cooked in beakers. The amount of water used for ordinary cooking was three times the weight of the seeds. Cooking was done for 30 minutes, until they became soft as felt between the fingers. For germinated samples (24 h and 36 h) ordinary cooking was done for 10 min, 20min and 30min.

3.2.2.2. Pressure cooking

The unsoaked, soaked (6 h and 12 h), soaked (6 h and 12 h) and dehulled seeds and the milled pulses were subjected to pressure cooking at 1.5 kg/cm^2 for 5

min. Water used for pressure cooking was twice the weight of seeds. For germinated samples (24 h and 36 h) pressure cooking was done for 2 minutes and 5 minutes.

3.2.3. Preparation of processed and cooked samples

All the processed and cooked seeds were dried in a hot air oven kept at 60^0C to a constant weight and powdered (0.5 mm sieve). The powdered samples were packed in air tight containers for further chemical analysis.

The treatments are listed below

Ordinary cooking

T_1 - Control (Uncooked)
T_2 - Cooked without soaking
T_3- Soaked for 6 hours
T_4 - Soaked for 12 hours
T_5 - Soaked for 6 hours and dehulled
T_6 -Soaked for 12 hours and dehulled
T_7 - Milled (dhal)
$T_{8.1}$ - Germination for 24 hours, 10 min cooking
$T_{8.2}$ - Germination for 24 hours, 20 min cooking
$T_{8.3}$ - Germination for 24 hours, 30 min cooking
$T_{9.1}$ - Germination for 36 hours, 10 min cooking
$T_{9.2}$ -Germination for 36 hours, 20 min cooking
$T_{9.3}$ - Germination for 36 hours, 30 min cooking

Pressure cooking

PT_1 - Control (Uncooked)
PT_2 - Cooked without soaking

PT_3- Soaked for 6 hours
PT_4 - Soaked for 12 hours
PT_5 - Soaked for 6 hours and dehulled
PT_6 -Soaked for 12 hours and dehulled
PT_7 - Milled (dhal)
$PT_{8.1}$ - Germination for 24 hours, 2 min pressure cooking
$PT_{8.2}$ - Germination for 24 hours, 5 min pressure cooking
$PT_{9.1}$ - Germination for 36 hours, 2 min pressure cooking
$PT_{9.2}$ -Germination for 36 hours, 5 min pressure cooking

3. 3.Analysis of chemical constituents of the pulses

The samples were analyzed for the following constituents.

3.3.1. Phytic acid
3.3.2 Total phosphorus
3.3.3 Total calcium
3.3.4 Total iron
3.3.5 Total potassium
3.3.6 Total zinc
3.3.7 Crude fiber
3.3.8 Tannin
3.3.9 HCl extractability of calcium, iron, phosphorus, potassium and zinc.

3.3.1. Phytic acid

The phytic acid content was determined colorimetically as phytate phosphorus (Sadasivam and Manickam, 1992).

The powdered sample (0.5 g) was extracted in 50 ml of 3 per cent trichloroacetic acid (TCA) with mechanical agitation. The content was centrifuged and aliquot of 10 ml was taken in a test tube. To this, 4 ml $FeCl_3$ solution was added. Then

the content was heated for 30 minutes in water bath. To an unclear liquid 1 or 2 drops of 3 per cent sodium sulphate in 3 per cent TCA was added and heated. The liquid obtained was centrifuged and washed the precipitate twice by dispersing in 25 ml of 3 per cent TCA. The sample was heated in boiling water for 10 minutes and centrifuged. The precipitate so obtained was dispersed in few ml of water and added 3 ml of 1.5 N NaOH and mixed. Volume was made up to 30 ml with water and heated for 30 minutes in water bath. Then the above contents were filtered and precipitate obtained was dissolved in 40 ml hot 3.2 N HNO_3 and volume was made up to 100 ml. Five ml of the aliquot was pipette out to a 100 ml volumetric flask and diluted to approximately 70 ml with water. Added 20 ml 1.5 M KSCN and made up to 100 ml and reading were taken immediately at 480 nm.

A standard graph was prepared using serial dilution of standard Fe $(NO_3)_3$ solution. The phytic acid content as phytate phosphorus was estimated from the standard graph and expressed in mg 100 g^{-1}.Phytic acid content was derived from phytate phosphorus using the formula of Reddy *et al.*, (1982).

$$\textbf{Phytic acid, (mg)} = \frac{\textbf{Phytate phosphorus in mg} \times \textbf{100}}{\textbf{28.18}}$$

3.3.2. Total Phosphorus

The phosphorus content was analysed colorimetrically as suggested by Jackson (1973), which gives yellow colour with nitric acid vandate molybdate reagent.

To five ml of pre digested aliquot, 5 ml of nitric acid vandate molybdate reagent was added and made up to 50 ml with distilled water. After 10 minutes the OD was read at 420 nm.

A standard graph was prepared using serial dilution of standard phosphorus solution.

3.3.3. Total Calcium

The calcium content was estimated using titration method with EDTA as suggested by Page (1982).

Two gram of the powdered sample was predigested with 20 ml of 9:4 mixtures of nitric acid and perchloric acid and volume was made up to 100 ml. To 5 ml of diacid extract, 10 ml water, 10 drops of hydroxylamine hydrochloride, 10 ml triethanol amine 2.5 ml sodium hydroxide and 10 drops of calcone were added. Then it was titrated with 0.02 N EDTA till the appearance of permanent blue colours. Calcium content was expressed in mg 100 g^{-1} of the sample.

3.3.4. Total Iron

The iron content was analyzed colourimetrically using ferric iron, which gives a blood red colour with potassium thiocyanate (Raghuramulu *et al.*, 2003).

To an aliquot of 6.5ml diacid solution, 1 ml of 30 per cent sulphuric acid, 1 ml of 7 per cent potassium persulphate solution and 1.5 ml of 40 per cent potassium thiocynate solution were added. The intensity of the red colour was measured within twenty minutes at 540 nm. A standard graph was prepared using serial dilution of standard iron solution. The iron content of the sample was estimated from the standard graph and expressed in mg 100g^{-1}.

3.3.5. Total Potassium

The potassium content was estimated using flame photometer as suggested by Jackson (1973).

One ml of the digested solution was made up to 25 ml and read directly in flame photometer and potassium content was expressed in mg 100 g^{-1}.

3.3.6. Total Zinc

The zinc content was estimated using atomic absorption spectro photometer as suggested by (Lindsey and Norwell, 1969).

The diacid extract was made up to 100 ml and was read directly in atomic absorption spectro photometer and zinc content was expressed in mg 100 g^{-1}.

3.3.7. Crude fiber

The fiber content was estimated by acid alkali digestion method as suggested by Chopra and Kanwar (1978).

Two gram of dried and powdered sample was boiled with 200 ml of 1.25 per cent sulphuric acid for 30 minutes. It was filtered through a muslin cloth and washed with boiling water and again boiled with 200 ml of 1.25 per cent sodium hydroxide for 30 minutes. Again it was filtered through muslin cloth and washed with sulphuric acid, water and alcohol. The residue was transferred to a pre weighed ashing dish, dried, cooled and weighed. The residue was then ignited for 30 minutes in a muffle furnace at 600°C, cooled in a desicator and reweighed. The fiber content of the sample was calculated from the loss in weight on ignition and expressed in per centage.

3.3.8. Tannin

The tannin content was determined as tannic acid by colorimetric method using Folin Dennis reagent (Sadasivam and Manickam, 1992).

The powdered material (0.5 g) was transferred to a volumetric flask having 75 ml water. Then the contents were heated for 30 minutes and centrifuged.

Supernatant was collected and made up to 100 ml. One ml of the sample was taken in 100 ml volumetric flask having 75 ml water, and added 5 ml Folin Dennis reagent and 10 ml of sodium carbonate and made up to 100 ml. After 30 minutes the absorbance was read at 700 nm. The tannin content was expressed as per centage from the standard graph prepared using serial dilution of standard tannic acid.

3.3.9. HCl Extractability

For HCl extractability of minerals, the samples were extracted with 0.03 N hydrochloric acid by shaking the contents at 37^0 C for 3 hours. The clear extract obtained after filtration with Whatman No: 42 filter paper was oven dried at 100^0 C and wet acid digested. The amount of the HCl extractable calcium, phosphorus, iron, potassium and zinc in the digested samples were determined by the methods as described above for the estimation of total minerals. HCl extractability of each mineral was derived by using the following formula (Duhan *et al.*,2001)

$$\textbf{Mineral extractability, \%} = \frac{\textbf{Mineral extractability in 0.03N HCL}}{\textbf{Total minerals}} \times \textbf{100}$$

3.4. Statistical analysis

Statistical analysis was done by using Ducan's Multiple Rank test and find the correlation between phytic acid, tannin, crude fiber with total minerals and their extractability.

Results

4. RESULTS

4.1 Effect of processing and cooking methods on total minerals and mineral extractability in pulses

Selected pulses viz Bengal gram, green gram and horse gram were subjected to processing and cooking as explained in chapter 3 (3.2.1, 3.2.2 and 3.2.3). The data was statistically analyzed by using DMRT and correlation methods.

4.1.1 Effect of ordinary cooking of processed pulses on total mineral and mineral extractability

4.1.1.1. Bengal gram

The results of processing and ordinary cooking on total minerals and mineral extractability is given in Table 1. Total calcium was found to range from 54.19 to 200.82 mg/ 100g. The maximum being in control and the least in the milled sample. Less than 1 per cent loss in total calcium was found in T_2 (200.56mg/100g) and T_3 (199.92mg/100g), where as 1 per cent loss was observed in T_4 (197.98mg/100g). A loss of 2 per cent was seen in T_5 (197.29 mg/100g), T_6 (197.09 mg/100g), $T_{8.1}$ (196.95 mg/100g), $T_{8.2}$ (196.73 mg/100g), $T_{8.3}$ (196.56 mg/100g) and $T_{9.1}$ (195.97 mg/100g). Total calcium loss was found to be 3 per cent in $T_{9.2}$ (195.57 mg/100g) and $T_{9.3}$ (189.10 mg/100g). About 73 per cent loss in total calcium was observed in T_7 (54.19 mg/100g). A significant loss in calcium was observed only T_7 and $T_{9\ 3}$.

Extractability of calcium showed a significant increase in all processed samples compared to the control which showed 53.60 per cent extractability. About 3 to 26 per cent increase was observed in calcium extractability, the maximum in treatments $T_{9.1}$ (67.35%), $T_{9.2}$ (67.33%) and $T_{9.3}$ (67.32%) which showed no significant difference between them. Calcium extractability was found to increase by 18 per cent in

Table - 1 Effect of processing and ordinary cooking on total minerals and mineral extractability in bengal gram

Treatment	Calcium		Iron		phosphorus		Potassium		Zinc	
	T mg/100 g	E %	T mg/100 g	E %	T mg/100 g	E %	T mg/100 g	E %	T mg/100 g	E %
T_1	200.82 [a]	53.60 [h]	10.33 [b]	24.22 [i]	310.65 [b]	41.87 [l]	806.05 [a]	38.44 [i]	4.30[a]	52.50 [k]
T_2	200.56 [a] (-0.1)	55.05 [g] (+3)	10.22 [c] (-1)	24.46 [h] (+1)	309.74 [c] (-0.3)	42.19 [k] (+1)	805.95 [a] (-0.01)	41.02 [h] (+7)	4.00 [b] (-7)	53.84 [j] (+3)
T_3	199.92 [a] (-1)	59.36 [f] (+11)	10.01 [d] (-3)	25.90 [g] (+7)	309.41 [c] (-0.4)	43.49 [i] (+4)	805.45 [b] (-0.1)	42.85 [g] (+11)	3.90 [b] (-9)	55.13 [i] (+5)
T_4	197.98 [a] (-1.)	59.95 [e] (+12)	9.69 [e] (-6)	27.34 [f] (+13)	308.76 [d] (-1)	45.19 [h] (+8)	804.32 [c] (-0.2)	43.96 [f] (+14)	3.32 [c] (-22)	57.60 [h] (+10)
T_5	197.29 [a] (-1)	61.62 [d] (+15)	8.97 [f] (-13)	29.02 [e] (+20)	307.18 [e] (-1)	46.89 [g] (+12)	803.79 [d] (-0.3)	44.64 [e] (+16)	3.10 [cd] (-28)	61.27 [g] (+17)
T_6	197.09 [a] (-2)	62.40 [c] (+16)	8.49 [g] (-18)	30.62 [d] (+26)	306.70 [f] (-1.)	48.25 [f] (+15.)	803.27 [c] -(0.3)	45.69 [e] (+19)	2.79 [d] (-35)	62.78 [e] (+20)
T_7	54.19[c] (-73.)	47.97[i] (-11)	11.67[a] (+13)	21.42 [j] (-12)	328.19[a] (+6)	42.78[j] (+2)	719.68[h] (-11)	48.00[a] (+25)	2.40[e] (-44)	61.27[f] (+17)
$T_{8.1}$	196.95 [a] (-2)	63.46 [b] (+18)	7.80 [h] (-24)	32.62 [c] (+35)	306.07 [g] (-1)	49.33 [e] (+18)	802.94 [f] (-0.4)	45.83 [cd] (+19)	2.90 [d] (-33)	63.39 [d] (+21)
$T_{8.2}$	196.73 [a] (-2)	63.43 [b] (+18)	7.85 [h] (-24)	32.33 [b] (+33)	305.97 [g] (-2)	49.67 [d] (+19)	802.80 [f] (-0.4)	45.86 [cd] (+19)	2.90 [d] (-33)	63.44[d] (+21)
$T_{8.3}$	196.56 [a] (-2)	63.39 [b] (+18)	7.85 [h] (-24)	32.35 [b] (+34)	305.88 [g] (-2)	49.86 [d] (+19)	802.69 [f] (-0.4)	46.09 [c] (+20)	2.79 [d] (-35)	63.45 [d] (+21)
$T_{9.1}$	195.97 [a] (-2)	67.35 [a] (+26)	6.96 [i] (-33)	38.39 [a] (+57)	305.32 [h] (-2)	52.73 [c] (+26)	801.04 [g] (-0.6)	46.57 [b] (+21)	2.50 [e] (-42)	68.42 [c] (+30)
$T_{9.2}$	195.57 [a] (-3)	67.33 [a] (+25)	6.84 [j] (-34)	38.40 [a] (+59)	305.26 [h] (-2)	53.40 [b] (+28)	801.97 [g] (-0.5)	46.63 [b] (+21)	2.56 [e] (-40)	68.80 [b] (+31)
$T_{9.3}$	189.10 [b] (-6)	67.32[a] (+25)	6.77 [j] (-34)	38.41[a] (+59)	305.19 [h] (-2)	53.73 [a] (+28)	801.81 [g] (-0.5)	46.75 [b] (+22)	2.50 [e] (-42)	69.19 [a] (+32)

T- total , E-extractability

Figures in parenthesis indicate per cent decrease (-) or increase (+) over control values

Values with different superscript are significantly different assessed by DMRT

treatments $T_{8.1}$ (63.46%), $T_{8.2}$ (63.43%) and $T_{8.3}$ (63.39%) which was not significantly different. An increase in 15 and 16 per cent in extractability was observed in T_5 (61.62%) and T_6 (62.4%) respectively. In T_4 (59.95%) 12 per cent increase was observed whereas in T_3 (59.36%) the increases was 11 per cent and the variation between treatments were found to be significant. A three per cent increase was observed in calcium extractability in T_2 which also was found to be significant compared to the control. But for T_7 (47.97%) the iron extractability was significantly low.

Total iron showed a significant reduction in all treatments when compared to the control. The iron content varied from 6.77 to 10.33 mg/100g. The maximum being in T_1 and the least in $T_{9.3}$. A loss varying from 1 to 34 per cent was observed in total iron with respect to the treatments. Maximum loss of 34 per cent was observed in $T_{9.2}$ (6.84mg/100g) and $T_{9.3}$ (6.77mg/100g) which showed no significant variation between treatments. A significant loss of 33 per cent was observed in $T_{9.1}$ (6.96mg/100g). About 24 per cent loss in total iron was seen in $T_{8.1}$ (7.80mg/100g) which were not significantly different between treatments. A significant increase of 18 per cent in total iron was observed for treatments T_6 (8.49mg/100g), T_5 (8.97mg/100g), T_4 (9.69mg/100g), T_3 (10.01mg/100g) and T_2 (10.22mg/100g) respectively and the loss was found to be significant with respect to treatments.

A significant increase in iron extractability was found in all treatments except for T_7 compared to the control. About 1to 59 per cent increase was observed in the extractability. Maximum iron extractability was observed (59%) in $T_{9.3}$ (38.41%), $T_{9.2}$ (38.40%) and $T_{9.1}$ (38.39%) which showed no significant variation between treatments. No significant variation was observed between $T_{8.2}$ (32.33%) and $T_{8.3}$ (32.35%) even though the per cent increase was 33 and 34 per cent respectively. A 35 per cent increase in iron extractability was observed in $T_{8.1}$ (32.62%) which was significantly low was compared to T_{82} and T_{83}. A significant decrease (12%) in iron extractability was found in T_7 (21.42%).

With regard to total phosphorus, there was a significant loss in all treatments except for T_7 which showed a significant increase in total phosphorus when compared to T_1 (control). The phosphorus content of the treatments varied from 305.19 to 328.19mg/100g. The maximum in T_7 and the least in $T_{9.3}$. The per cent loss in total phosphorus varied from 0.3 to 2 per cent. Maximum loss of 2 per cent was seen in $T_{9.3}$ (305.19mg/100g), $T_{9.2}$ (305.26mg/100g), $T_{9.1}$ (305.32mg/100g), $T_{8.3}$ (305.88 mg/100g) and $T_{8.2}$ (305.97 mg/100g). The loss in total phosphorus content in $T_{9.1}$, $T_{9.2}$ and $T_{9.3}$ were not significantly different, but differed significantly with $T_{8.2}$ and $T_{8.3}$. $T_{8.1}$, $T_{8.2}$, and $T_{8.3}$ showed no significant variation between treatments. In T_7 (328.19 mg/100g) there was a significant increase in total phosphorus by 6 per cent. About 1 per cent loss in phosphorus content was observed in T_4 (308.76 mg/100g), T_5 (307.18 mg/100g) and T_6 (306.70 mg/100g) and the variation between these treatments observed was also significant. A loss of less than 1 per cent was observed in T_2 (309.74 mg/100g) and T_3 (309.41 mg/100g) which was also a significant loss but the variation between T_2 and T_3 was not significant. In T_4 (308.76 mg/100g), about 1 per cent loss was observed in total phosphorus content.

Extractability of phosphorus showed a significant increase in all treatments when compared to control (T_1). A significant increase of 1-28 per cent was observed in treatments. Maximum increase in extractability by 28 per cent was observed in $T_{9.3}$ (53.73%) and $T_{9.2}$ (53.40%) but significant variation was observed between these treatments. About 26 per cent increase was observed in $T_{9.1}$ (52.73%) but differed significantly with $T_{9.2}$ and $T_{9.3}$.

A significant increase by 19 per cent was observed in $T_{8.2}$ (49.67%) and $T_{8.3}$ (49.86%) but there was no significant variation between treatments. $T_{8.1}$ (49.33%) showed an increase by 18 per cent but was significantly different from $T_{8.2}$ and $T_{8.3}$. Phosphorus extractability was found to be 42.78 per cent in T_7 which showed a significant increase by 2 per cent. Extractability was 43.49 per cent, 45.19 per cent, 46.89 per cent and 48.25 per cent in T_3, T_4, T_5 and T_6 respectively which showed a significant increase by about 4 per cent, 8 per cent, 12 per cent and 15 per cent

respectively. An extractability of 41.87 per cent was shown by T_1 whereas in T_2 (42.19%) a 1 per cent increase was observed in extractability which was also significant.

A loss in total potassium content was observed in treatments compared to the control (T_1). The potassium content of different treatments varied from 719.68 to 806.05 mg/100g. The per cent loss was found to range from 0.01 to 11 per cent in treatments. There was no significant loss in potassium content of T_2 (805.95mg/100g) and T_3 (805.45mg/100g) when compared to T_1 (806.05 mg/100g). A significant loss of potassium was observed in T_4 (804.32 mg/100g), T_5 (803.79 mg/100g) and T_6 (803.27 mg/100g) but the difference between T_4 and T_6 was not significant. Maximum potassium loss was observed in T_7 (719.68 mg/100g) which showed about 11 per cent loss. A significant reduction in potassium content of $T_{8.1}$, $T_{8.2}$ and $T_{8.3}$ was noted but the differences between these treatments were not significant. The potassium content of $T_{9.1}$ (801.04 mg/100g), $T_{9.2}$ (801.97 mg/100g) and$T_{9.3}$ (801.81 mg/100g) was significantly low when compared to T_1 (806.05 mg/100g) but no significant variation was observed between $T_{9.1}$, $T_{9.2}$ and $T_{9.3}$ which showed about a loss of 1 per cent in total potassium.

Regarding extractability of potassium, there was a significant increase in all treatments when compared to control (T_1). The per cent increase was found to range from 7 to 25. Maximum potassium extractability was found in T_7 (48.00%) which showed 25 per cent increase when compared to T_1 (38.44%). A significant increase in extractability by 21 per cent and 22 per cent was observed for $T_{9.1}$ (46.57%), $T_{9.2}$ (46.63%) and $T_{9.3}$ (46.75%) but there was no significant difference between $T_{9.1}$, $T_{9.2}$ and $T_{9.3}$. Similarly there was a significant increase in potassium extractability in $T_{8.1}$ (45.83%), $T_{8.2}$ (45.86%) and $T_{8.3}$ (46.09%) which showed an increase by about 19 to 20 per cent but there was no significant variation between these treatments. The increased potassium extractability in T_5 (44.64%) and T_6 (45.69%) by about 16 per cent and 19 per cent when compared to T_1 (38.44%), showed no significant variation between treatments. A significant increase in potassium extractability was also observed in T_2 (41.02%) by 7 per cent, T_3 (42.85%) by 11 per cent and T_4 (43.96%) by 14 per cent when compared with T_1 (control).

Total zinc showed a significant loss in treatments when compared to the control (T_1) except for T_2 and T_3. Total zinc showed an increase in T_2 (4 mg/100g) and T_3 (3.90 mg/100g) when compared to control T_1 (4.30 mg/100g) but the increase was not significant. In all other treatments the loss in total zinc varied from 7- 42 per cent. The maximum loss of 44 per cent was in T_7 (2.40 mg/100g) when compared to T_1 (4.30mg/100g). The per cent loss of zinc in T_4 (3.32 mg/100g), T_5 (3.10 mg/100g) and T_6 (2.79 mg/100g) were not significant between treatments and no significant difference was observed between T_6 (2.79 mg/100g) and T_7 (2.40 mg/100g). Treatments such as $T_{8.1}$ (2.90 mg/100g) , $T_{8.2}$ (2.90 mg/100g) and $T_{8.3}$ (2.79 mg/100g) showed no significant difference between them but was significantly low when compared to T_1 (4.30 mg/100g) similarly treatments like $T_{9.1}$ (2.50 mg/100g), $T_{9.2}$ (2.56 mg/100g) and $T_{9.3}$ (2.50 mg/100g) did not show significant variation in the loss of zinc but significant loss was found when compared to control T_1 (4.30mg/100g).

Zinc extractability showed a significant increase in all treatments when compared to the control (T_1). The extractability was found to range from 52.50 per cent in T_1 (control) to 69.19 per cent in $T_{9.3}$ and the increase was found to be 32 per cent in $T_{9\ 3}$ when compared to the control. An increase of 3-20 per cent was observed in T_2 (53.84 mg/100g), T_3 (55.13 mg/100g), T_4 (57.60 mg/100g), T_5 (61.27 mg/100g), T_6 (62.78mg/100g) and T_7 (61.27 mg/100g) which showed significant variation between treatments and were significantly high when compared to T_1 (52.50 mg/100g). The significant increase in zinc extractability in $T_{8.1}$ (63.39%), $T_{8.2}$ (63.44%) and $T_{8.3}$ (63.45%) showed no variation between treatments with 21 per cent increase when compared to the control. But the significant increase in the extractability of $T_{9.1}$ (68.42%), $T_{9.2}$ (68.80%) and $T_{9.3}$ (69.19%) showed significant variation between treatments with an increase ranging between 30-32 per cent from that of control (52.50%).

4.1.1.2 Green gram

Effect of processing and ordinary cooking on total minerals and mineral extractability in green gram is presented in Table 2.

Table –2 Effect of processing and ordinary cooking on total mineral and mineral extractability in green gram

Treatment	Calcium		Iron		Phosphorus		Potassium		Zinc	
	T mg/100g	E %	T mg/100gm	E %	T mg/100gm	E %	T mg/100gm	E %	T mg/100gm	E %
T_1	122.75 [a]	20.01 [h]	7.06. [b]	49.15[k]	324.13 [b]	47.84 [l]	840.88 [b]	34.57 [e]	3.60 [a]	68.57 [k]
T_2	122.41 [b] (-0.3)	20.29 [g] (+2)	6.87. [bc] (-3)	50.43 [J] (+3)	323.89 [bc] (-0.1)	48.84 [J k] (+2)	840.53[b] (-0.04)	41.63 [d] (+20)	3.45 [ab] (-4)	69.44 [J] (+1)
T_3	122.53 [ab] (-0.2)	21.38 [f] (+7)	6.79. [c] (-4)	51.07[I] (+4)	323.81 [bc] (-0.1)	48.91[J] (+2)	841.20 [b] (-0.04)	41.37 [d] (+20)	3.37 [bc] (-6)	70.27 [I] (+2)
T_4	121.56 [c] (-1)	21.91 [e] (+10)	6.49. [d] (-8)	52.38 [g] (+7)	323.62 [bc] (-0.2)	50.16[I] (+5)	839.73 [cd] (-0.1)	42.16 [d] (+22)	3.42 [ab] (-5)	71.17 [h] (+4)
T_5	120.78 [d] (-2)	23.17 [d] (+16)	6.25 [e] (-11)	54.40 [f] (+11)	323.17[ef] (-0.3)	52.39 [h] (+10)	839.44 [de] (-0.2)	44.47 [c] (+29)	3.43 [a b] (-6)	73.52 [f] (+7)
T_6	120.09 [e] (-2)	24.32 [c] (+22)	5.96.[f] (-16)	64.40 [d] (+31)	323.38 [de] (-0.2)	52.94 [g] (+11)	839.24 [def] (-0.2)	45.22 [c] (+31)	3.39 [bc] (-6)	74.20 [e] (+8)
T_7	70.61 [I] (-43)	20.46[g] (+2)	9.72[a] (+38)	51.41[h] (+5)	398.83[a] (+23.)	48.64[k] (+2)	1132.71[a] (+35)	49.80[a] (+44)	2.21 [d] (-16)	73.17[g] (+7)
$T_{8\,1}$	119.26 [f] (-3)	26.78 [b] (+34)	5.65 [g] (-20)	63.71 [e] (+30)	321.99 [h] (-1)	53.37 [f] (+12)	838.80[efg] (-0.2)	47.34 [b] (+37)	3.1967 [cd] (-11)	74.68 [d] (+9)
$T_{8\,2}$	119.29 [f] (-3)	26.82 [b] (+34)	5.59 [g] (-21)	64.40 [d] (+31)	322.87 [fg] (-0.4)	53.76 [e] (+12)	838.64 [efg] (-0.3)	47.47 [b] (+37)	3.30b [cd] (-8)	74.88[d] (+9)
$T_{8\,3}$	119.15 [f] (-3)	26.85 [b] (+34)	5.54 [g] (-22)	64.86 [c] (+32)	322.74 [g] (-0.4)	55.07[d] (+15)	838.48 [fgh] (-0.3)	47.72 [ab] (+38)	3.20 [cd] (-11)	76.01 [a] (+11)
T_{91}	118.17 [g] (-4)	28.77 [a] (+44)	5.19[h] (-26)	69.42 [b] (+41)	321.94 [h] (-1)	55.28 [c] (+16)	838.09[h] (-0.3)	48.48[ab] (+40)	3.20 [cd] (-11)	75.31 [b] (+10)
$T_{9\,2}$	118.01 [gh] (-4)	28.81 [a] (+44)	5.13 [h] (-27)	70.17 [a] (+43)	321.58 [i] (-1)	55.62[b] (+16)	837.6 [hi] (-0.4)	48.60 [ab] (+41)	3.20 [cd] (-11)	75.62 [a] (+10)
$T_{9\,3}$	117.90 [h] (-4)	28.84 [a] (+44)	5.08 [h] (-28)	70.19 [a] (+43)	321.71 [h] (-1)	55.94[a] (+17)	837.49 [I] (-0.4)	48.78 [ab] (+41)	3.10 [d] (-14)	75.80 [a] (+11)

T- total, E-extractability

Figures in parenthesis indicate perc ent decrease (-) or increase (+) over control values

Values with different superscript are significantly different assessed by DMRT

Total calcium in green gram showed a reduction in all treatments when compared to the control. The calcium content varied from 70.61 to 122.75mg/100g, the maximum in T_1 and the least in T_7. A loss varying from 0.2 to 43 per cent was observed in total calcium with respect to treatments. Maximum loss of 43 per cent was observed in T_7 (70.61mg/100g). Less than 1 per cent loss in total calcium was observed in T_2 (122.41 mg/100g) and T_3 (122.53mg/100g). The reduction in calcium in T_2 was found to be significant when compared to control but there was no significant variation between T_2 and T_3. There was a significant reduction total calcium in T_4 (121.56 mg/100g), T_5 (120.78 mg/100g) and T_6 (120.09 mg/100g) when compared to control and also between the treatments (T_3, T_4, T_5 and T_6). A significant loss of about 3 per cent in total calcium was observed in $T_{8.1}$ (119.26 mg/100g), $T_{8.2}$ (119.29 mg/100g) and $T_{8.3}$ (119.15 mg/100g) but no significant variation was observed between these treatments. A significant loss of about 4 per cent was noted in $T_{9.1}$ (118.17 mg/100g), $T_{9.2}$ (118.01 mg/100g) and $T_{9.3}$ (117.90 mg/100g) when compared to control but the variation between $T_{9.2}$ and $T_{9.3}$ was not significant. Significant variation existed between $T_{9.1}$ and $T_{9.3}$.

Extractability of calcium showed a significant increase in all the processed green gram samples compared to the control which showed an extractability of 20.01 per cent. Calcium extractability showed an increase which ranged from 2 to 44 per cent. Maximum calcium extractability was found in $T_{9.3}$ (28.84%), $T_{9.2}$ (28.81%) and $T_{9.1}$ (28.77%) when compared to control but showed no significant variation between treatments. About 34 per cent increase in calcium extractability was observed in $T_{8.1}$ (26.78%), $T_{8.2}$ (26.82%) and $T_{8.3}$ (26.85%) compared to control but the variations between these treatments were significant. Extractability of calcium showed a significant increase by 1 per cent in T_2 (20.29%) and by 2 per cent in T_7 (20.46%) when compared to control but the variation between these treatments were not significant. Extractability increased by 7 per cent in T_3 (21.38%), 10 per cent in T_4 (21.91%), 16 per cent in T_5 (23.17%) and 22 per cent in T_6 (24.32%) and also showed significant variation between these treatments.

Total iron showed a significant reduction in processed green gram samples except for T_6 and T_7 when compared to control (7.06 mg/100g). T_6 showed a significant increase by about 16 per cent (5.96 mg/100g) and T_7 showed about 38 per cent increase (9.72 mg/100g) in total iron. In all other treatments reduction in the total iron varied from 3 to 28 per cent compared to control. The reduction in T_2 (6.87 mg/100g) was not significant when compared to control and also with T_3 (6.79 mg/100g). But a significant loss of total iron was observed in T_3 (6.79 mg/100g), T_4 (6.49 mg/100g) and T_5 (6.25 mg/100g) when compared to the control and also between the treatments. A significant loss of 20 per cent in $T_{8.1}$ (5.65 mg/100g), 21 per cent loss in $T_{8.2}$ (5.59 mg/100g) and 22 per cent loss in $T_{8.3}$ (5.54 mg/100g) was observed when compared to the control but no significant variation was observed between $T_{8.1}$, $T_{8.2}$ and $T_{8.3}$. A significant loss of about 26 per cent was noted in $T_{9.1}$ (5.19 mg/100g) and about 27 per cent in $T_{9.2}$ (5.13 mg/100g) and a maximum loss of about 28 per cent in $T_{9.3}$ (5.08 mg/100g) but there was no significant variation between $T_{9.1}$, $T_{9.2}$ and $T_{9.3}$.

Extractability of iron showed a significant increase in all processed samples when compared to the control T_1 (49.15%). An increase varying from 3 to 43 per cent was observed in different processed samples when compared to control. Maximum increase in iron extractability by 43 per cent was observed in $T_{9.3}$ (70.19%) and $T_{9.2}$ (70.17%) when compared to the iron extractability in control and there was no significant variation between these two treatments. About 41 per cent increase in iron extractability was observed in $T_{9.1}$ (69.42%) which was significantly different from $T_{9.2}$ and $T_{9\ 3}$. Iron extractability was significantly high in $T_{8.3}$ (64.86%), $T_{8.2}$ (64.40%) and $T_{8.1}$ (63.71%) and significant variation existed between these treatments, the highest extractability being in $T_{8.3}$ which showed about 32 per cent increase when compared to the control. Iron extractability showed an increase by 31 per cent in $T_{8.2}$ and also in T_6 (64.40%) which were comparable. Iron extractability was 51.41 per cent in T_7 which was significantly high when compared to the control. A significant increase by 3 per cent and 11 per cent was observed in the iron extractability of T_2 (50.43%), T_3 (51.07%), T_4 (52.38%) and T_5 (54.40%) when compared to the control and there was significant variation between these treatments, the highest extractability of 54.40 per cent in T_5.

There observed a reduction in total phosphorous content in processed green gram samples when compared to the control (324.13mg/100g) except in T_7 which showed a significant increase in phosphorous content by 23 per cent (398.83mg/100g). The loss in total phosphorous in T_2 (323.89 mg/100g) and T_3 (323.81 mg/100g) were not significant when compared to control and between the treatments but the loss in T_4 (326.2 mg/100g) was significantly high when compared to control but no significant variation was observed when compared with T_2, T_3 and T_4.T_5 (323.17 mg/100g) and T_6 (323.38 mg/100g) showed significant loss in total phosphorous but no significant variation between the treatments were observed. A significant loss in total phosphorous was observed in $T_{8.1}$ (321.99 mg/100g), $T_{8.2}$ (322.87 mg/100g) and $T_{8.3}$ (322.74 mg/100g) but there was no significant variation between $T_{8.2}$ and $T_{8.3}$. A significant loss in total phosphorous was also observed in $T_{9.1}$ (321.94 mg/100g), $T_{9.2}$ (321.58 mg/100g) and $T_{9.3}$ (321.71 mg/100g) but no significant variation was observed between $T_{9\,1}$ and $T_{9\,3}$.

The extractability of phosphorous in control was found to be 47.84 per cent which increased significantly to 48.84 per cent in T_2 and 48.91 per cent in T_3. There was no significant variation between T_2 and T_3. The extractability of phosphorous significantly increased to 50.16 per cent in T_4 52.39 per cent in T_5 and 52.94 per cent in T_6 and the difference between these treatments were found to be significant. Phosphorous extractability was found to be 48.64 per cent in T_7 which was significantly high when compared to control but it is comparable to T_2 (48.84%). There was a significant increase in phosphorous extractability in $T_{8.1}$ (53.37%), $T_{8.2}$ (53.76%) and $T_{8.3}$ (5.07%) and there observed a significant variation between these treatments. Extractability was found to be maximum in $T_{9.3}$ (55.94%) followed by $T_{9.2}$ (55.62%) and $T_{9.1}$ (55.28%) which showed significant variation between treatments .

There was a loss in potassium content in processed samples when compared to the control T_1 (840.88mg/100g) except for T_3 and T_7. The loss in potassium in T_2 (840.53mg/100g) was not significant when compared to the control T_1. There was an increase in total potassium in T_3 (841.20mg/100g) but that was not

significant when compared to the control. There was a significant loss of total potassium in T_4 (839.73mg/100g), T_5 (839.44mg/100g) and T_6 (839.24mg/100g) but the variation between these treatments were not significant. A significant increase in total Potassium was observed in T_7 (1132.71mg/100g) which showed an increase by 35 per cent when compared to the control. A significant loss was observed potassium in $T_{8.1}$ (838.80mg/100g), $T_{8.2}$ (838.64mg/100g) and $T_{8.3}$ (838.48mg/100g) but there was no significant difference between these treatments. Maximum loss in total potassium was observed in $T_{9.3}$ (837.49mg/100g) followed by $T_{9.2}$ (837.6mg/100g) which showed no significant difference.

Potassium extractability showed a significant increase with all the processing methods when compared to the control, T_1 which showed an extractability of 34.57 per cent. Increase in the potassium extractability varied between 20 to 44 per cent. Maximum increase of 44 per cent was in T_7 which showed an extractability of 49.8 per cent. Potassium extractability showed a significant increase in T_2 (41.63%) and T_3 (41.31%) compared to the control and the difference between these treatments were also significant. T_4 showed an extractability of 42 .16 per cent which was not significantly different from T_3. Extractability increased to 44.47 per cent in T_5 and to 45.22 per cent in T_6 but there was no significant difference between T_5 and T_6. About 37 and 38 per cent increase was observed in $T_{8.1}$ (47.34%), $T_{8.2}$ (47.47%) and $T_{8.3}$ (47.72%) compared to control but there was no significant variation between these treatments. Potassium extractability was found to be 48.78 per cent in $T_{9.3}$, 48.60 per cent in $T_{9.2}$ and 48.48 per cent in $T_{9.1}$ and there was no significant variation between these treatments.

There was a significant loss in total zinc content in processed and cooked samples when compared to the T_1 (3.60mg/100g). Maximum loss of zinc was observed in T_7 (2.21mg/100g) followed by $T_{9.3}$ (3.10mg/100g). The difference between the treatments was found to be significant. The loss of zinc in $T_{8.1}$ (3.20mg/100g), $T_{8.2}$ (3.30mg/100g), $T_{8.3}$ (3.20mg/100g), $T_{9.1}$ (3.20 mg/100g), $T_{9.2}$ (3.20 mg/100g) and $T_{9.3}$ (3.10 mg/100g) was not significant between treatments, but loss was significant when compared to the control (T_1). Similarly the loss in T_2 (3.45 mg/100g), T_3

Table – 3 Effect of processing and ordinary cooking on total minerals and mineral extractability in horse gram

Treatment	Calcium		Iron		Phosphorus		Potassium		Zinc	
	T mg/100g	E %	T mg/100g	E %	T mg/100g	E %	T mg/100g	E %	T mg/100g	E %
T_1	285.23 ^{a}	42.57 j	8.90 ^{ab}	49.67 ^{l}	309.43 ^{b}	38.76 ^{m}	700.12 ^{a}	40.61 j	2.80 ^{a}	42.87 ^{k}
T_2	285.06^{ab} (-0.1)	44.53 ^{i} (+5)	8.72 ^{abc} (-2)	50.31 ^{k} (+1)	309.29^{bc} (-0.1)	42.03 ^{k} (+8)	699.64 ^{b} (-0.07)	41.43 ^{i} (+2)	2.75 ^{a} (-2)	43.57 j (+2)
T_3	284.94 ^{b} (-0.1)	44.98 ^{h} (+6)	8.68^{abc} (-2)	51.96 ^{j} (+5)	309.11 ^{c} (-o.1)	43.67 ^{j} (+13)	699.81 ^{b} (-0.04)	42.76 ^{h} (+6)	2.75 ^{a} (-2)	44.44 ^{i} (+4)
T_4	284.25 ^{c} (-0.3)	45.73 ^{g} (+7)	8.21 ^{abc} (-8)	53.61^{i} (+8)	308.98^{cd} (-0.2)	44.19 ^{i} (+14)	699.13^{c} (-0.14)	43.29^{g} (+7)	2.75 ^{a} (-2)	45.18 ^{h} (+5)
T_5	283.74 ^{d} (-0.5)	46.53 ^{f} (+9)	7.98 ^{abc} (-10)	54.81 ^{h} (+10)	308.78 ^{d} (-0.2)	45.33 ^{h} (+17)	698.66^{d} (-0.2)	44.07 ^{f} (+9)	2.75 ^{a} (-2)	46.29 ^{g} (+8)
T_6	283.18 ^{e} (-0.7)	47.67 ^{e} (+12)	7.89 ^{abc} (-11)	56.07 ^{g} (+13)	307.22 ^{e} (-1)	47.19 ^{g} (+22)	698.56 ^{d} (-0.22)	45.32 ^{e} (+12)	2.75 ^{a} (-2)	46.91 ^{f} (+9)
T_7	64.89 ^{j} (-77)	38.52 ^{k} (-10)	9.02 ^{a} (+1)	44.35^{m} (-11)	321.16 ^{a} (+4)	40.47 ^{l} (+4)	684.66 ^{g} (-2)	39.06 ^{k} (-4)	2.60 ^{ab} (-8)	35.00 ^{l} (-18)
$T_{8.1}$	282.64 ^{f} (-1)	49.89 ^{d} (+17)	7.84^{abc} (-12)	63.93 ^{f} (+29)	306.87^{f} (-1)	47.59 ^{f} (+23)	698.28 ^{e} (-0.3)	47.72 ^{d} (+18)	2.50 ^{ab} (-11)	48.63 ^{e} (+13)
$T_{8.2}$	282.45 ^{f} (-1)	50.45 ^{c} (+19)	7.74 ^{abc} (-13)	64.59 ^{e} (+30)	306.72 ^{f} (-1)	47.92 ^{e} (+24)	698.19 ^{e} (-0.3)	47.85^{cd} (+18)	2.50 ^{ab} (-11)	48.86 ^{e} (+14)
$T_{8.3}$	282.18 ^{g} (-1)	50.30 ^{c} (+18)	7.69^{abc} (-14)	65.01 ^{d} (+31)	306.60 ^{f} (-1)	48.58^{d} (+25)	698.06 ^{e} (-0.3)	48.11 ^{c} (+19)	2.50^{ab} (-11)	49.20 ^{d} (+16)
$T_{9.1}$	281.20 ^{h} (-1)	51.56 ^{b} (+21)	7.39 ^{c} (-17)	69.01 ^{c} (+39)	306.02 ^{g} (-1)	50.32 ^{c} (+30)	697.50 ^{f} (-0.3)	49.15 ^{b} (+21)	2.50 ^{ab} (-11)	50.00 ^{c} (+17)
$T_{9.2}$	281.30 ^{h} (-1)	51.95 ^{a} (+22)	7.32 ^{c} (-18)	69.70 ^{b} (+40)	305.97 ^{g} (-1)	50.65^{b} (+31)	697.42 ^{f} (-0.4)	49.28^{ab} (+23)	2.40 ^{b} (-14)	50.42 ^{b} (+18)
$T_{9.3}$	280.90 ^{i} (-2)	51.97^{a} (+22)	6.59 ^{d} (-26)	70.23 ^{a} (+41)	305.97^{g} (-1)	51.33 ^{a} (+32)	697.32 ^{f} (-0.4)	49.53 ^{a} (+22)	2.40 ^{b} (-14)	50.83 ^{a} (+19)

T- total , E-extractability

Figures in parenthesis indicate per cent decrease (-) or increase (+) over control values

Values with different superscript are significantly different assessed by DMRT

(3.37 mg/100g), T_4 (3.42 mg/100g), T_5 (3.43 mg/100g) and T_6 (3.39 mg/100g) was not significant between treatments.

Zinc extractability showed a significant increase in all processed and cooked samples when compared to the control T_1 (68.57%). Maximum zinc extractability was found in $T_{8.3}$ (76.01%) which showed no significant difference with $T_{9.2}$ (75.62%) and 75.31 per cent in $T_{9.1}$ and the difference was not significant. There was no significant difference in the extractability of zinc between $T_{8.1}$ (74.68%) and $T_{8.2}$ (74.88%). The increase in the extractability of zinc in samples T_2 (69.44%), T_3 (70.27%), T_4 (71.17%), T_5 (73.52%), T_6 (74.20%) and T_7 (73.17%) were found to be significant [Fig .11(a); fig.11 (b)].

4.1.1.3 Horse gram

The results of processing and ordinary cooking on total minerals and mineral extractability in horse gram in presented in Table 3.

Total calcium in control (T_1) was 285.23mg/100g.T_2 showed a loss in total calcium (285.06mg/100g) but the reduction was not significant compared to the control. All the other processed and cooked horse gram samples showed a significant loss in total calcium. Maximum loss of calcium was observed in T_7 (64.89mg/100g). T_2 (285.06mg/100g) and T_3 (284.94mg/100g) where comparable without significant difference between treatments. A significant reduction in total calcium was observed in T_3 (284.94mg/100g), T_4 (284.25mg/100g), T_5 (283.74mg/100g) and T_6 (283.18mg/100g) compared to T_1 and also between treatments. There was no significant difference between $T_{8.1}$ (282.64mg/100g) and $T_{8.2}$ (282.45mg/100g) but $T_{8.3}$ (282.18mg/100g) showed a significant reduction. The reduction in $T_{9.1}$ (281.20mg/100g) and $T_{9.3}$ (281.30mg/100g) showed no significant difference between treatments but $T_{9.3}$ (280.90mg/100g) showed a significant reduction.

Calcium extractability in horse gram was found to be 42.57% in control T_1. Which significantly increased in all processed and cooked samples except in T_7. Maximum calcium extractability was found in $T_{9.3}$ (51.97%) which showed no significant difference with that of $T_{9.2}$ (51.95%). But $T_{9.1}$ (51.56%) showed a difference in calcium extractability. There was a significant increase in calcium extractability in $T_{8.1}$ (49.89%), $T_{8.2}$ (50.45%) and $T_{8.3}$ (50.30%) but the difference between $T_{8.2}$ and $T_{8.3}$ was not significant. Calcium extractability in T_7 (38.52%) which showed a significant reduction when compared to all the treatments. The difference observed in calcium extractability of T_2 (44.53%), T_3 (44.98%), T_4 (45.73%), T_5 (46.53%) and T_6 (47.67%) was found to be significant.

Total iron in horse gram was 8.90mg/100g in control (T_1). Total iron was significantly reduced in $T_{9.2}$ (7.32mg/100g) and $T_{9.3}$ (6.59mg/100g) compared to control and the differences observed between these treatments were also significant. T_7 (9.02mg/100g) showed an increase in total iron which was not significant when compared to control. In all other treatments even though there was a reduction in total iron, it was not significant.

Iron extractability 49.67% in T_1 which showed a significant increase in all processed and cooked samples except for T_7 (44.35%) which showed a significant reduction in iron extractability. Maximum iron extractability was found in $T_{9.3}$ (70.23%) followed by $T_{9.2}$ (69.70%) and $T_{9.1}$ (69.01%), but the difference between these treatments were found to be significant. The increase in iron extractability of $T_{8.1}$ (63.93%),$T_{8.2}$ (64.59%) and $T_{8.3}$ (65.01%) also showed significant difference a significant increase in iron extractability in T_2 (50.31%), T_3 (51.96%), T_4 (53.61%), T_5 (54.81%) and T_6 (56.07%) and the difference between these treatments were also found to be significant.

Total phosphorus decreased in all processed samples when compared to the control T_1 (309.43mg/100g) except for T_7 (321.16mg/100g) which showed a significant increase. The loss in total phosphorus was not significant in T_2

(309.29mg/100g) when compared to control. There was a significant loss in phosphorus in T_3 (309.11mg/100g) and T_4 (308.98mg/100g) when compared to control but the difference observed between T_2, T_3 and T_4 were not significant. The decrease in phosphorus in T_5 (308.78mg/100g) was not significant when compared to control but significant difference was observed with that of T_6 (307.22mg/100g). The loss of phosphorus was significant in $T_{8.1}$ (306.87mg/100g), $T_{8.2}$ (306.72mg/100g) and $T_{8.3}$ (306.60mg/100g) but there was no significant variation between these treatments .A significant loss of phosphorus was observed in $T_{9.1}$ (306.02mg/100g), $T_{9.2}$ (305.97mg/100g) and $T_{9.3}$ (305.97mg/100g) but the difference between $T_{9.2}$ and $T_{9.3}$ were not significant.

Phosphorus extractability increased significantly in all the processed samples when compared to the control T_1 (38.76%).The increase in phosphorus extractability was found to vary from 4-32 per cent with respect to control., the maximum extractability being in $T_{9.3}$ (51.33%) and the least increase in T_7 (40.47%).A significant difference was observed in phosphorus extractability between all the treatments.

A significant loss in total potassium was observed in all processed samples when compared to control T_1 (700.12mg/100g). There was no significant difference in total potassium of T_2 (699.64mg/100g) and T_3 (699.81mg/100g) but T_4 (699.13mg/100g) showed significant difference. There was no significant difference between T_5 (698.66mg/100g) and T_6 (698.56mg/100g) but T_7 (684.66mg/100g) was significantly different. The variation was not significant between $T_{8.1}$ (698.28mg/100g), $T_{8.2}$ (698.19mg/100g) and $T_{8.3}$ (698.06mg/100g).Similarly the difference observed between $T_{9.1}$ (697.50mg/100g), $T_{9.2}$ (697.42mg/100g) and $T_{9.3}$ (697.32mg/100g) was also not significant.

Potassium extractability showed a significant increase in all processed samples compared to the control T_1 (40.61%) except in T_7 (39.06%) which showed a significant reduction in extractability. An increase varying from 2-22 per cent was found in various processed samples, the maximum extractability

Table - 4 Effect of processing and pressure cooking on total minerals and mineral extractability in bengal gram

Treatment	Calcium		Iron		Phosphorus		Potassium		Zinc	
	T mg/100g	E %	T mg/100g	E %	T mg/100g	E %	T mg/100g	E %	T mg/100g	E %
T_1	200.82 [a]	53.60 [h]	10.33 [b]	24.22 [j]	310.65 [b]	41.87 [K]	806.05 [a]	38.44 [i]	4.30[a]	52.50 [k]
PT_2	200.14 [b] (-0.3)	56.54 [g] (+6)	10.16 [b] (-2)	24.60 [f] (+2)	309.95 [c] (-0.2)	43.38 [J] (+4)	805.99 [b] (-0.4)	41.66 [h] (+8)	4.10 [a] (-5)	53.95 [j] (+3)
PT_3	199.36 [c] (-1)	59.53 [f] (+11)	9.69[c] (-6)	26.83 [h] (+11)	309.35 [d] (-0.4)	44.20 [h] (+6)	805.04 [b] (-0.1)	43.35[g] (+13)	3.70 [b] (-14)	53.75[i] (+2)
PT_4	197.60 [d] (-2)	60.22 [e] (+12)	9.21 [d] (-11)	27.79 [g] (+15)	308.37 [e] (-0.7)	45.90 [g] (+10)	804.67 [c] (-0.2)	43.53[g] (+13)	3.39 [c] (-21)	58.22 [h] (+11)
PT_5	197.07 [e] (-2)	61.90 [d] (+16)	8.69 [e] (-16)	29.91 [f] (+24)	307.67 [f] (-1)	46.25 [f] (+11)	803.56 [d] (-0.2)	44.31 [f] (+15)	3.00 [d] (-30)	61.66 [g] (+17)
PT_6	196.78[i] (-2)	63.01 [c] (+18)	8.39 [e] (-19)	30.98[e] (+28)	306.49 [g] (-1)	48.61[e] (+16)	803.11 [e] (-0.4)	44.82 [e] (+17)	2.80 [e] (-35)	62.50 [f] (+19)
PT_7	54.01 [i] (-73)	49.12 [i] (-8)	11.40 [a] (+10)	22.80[k] (-6)	328.04 [a] (+6)	43.62 [i] (+4)	719.40[h] (-11)	48.23 [a] (+26)	2.90 [e] (-33)	63.15 [e] (+20)
$PT_{8.1}$	196.40 [g] (-2)	64.64 [b] (+21)	7.55 [f] (-27)	34.83 [d] (+44)	305.76 [h] (-2)	50.69[d] (+21)	802.56 [f] (-0.4)	46.22[d] (+20)	2.80 [e] (-35)	64.64 [d] (+23)
$PT_{8.2}$	196.21 [g] (-2)	64.57 [b] (+21)	7.42[f] (-28)	36.05[c] (+49)	305.67[h] (-2)	51.36 [c] (+23)	802.49 [f] (-0.4)	46.35 [d] (+21)	2.80 [e] (-35)	65.66 [c] (+25)
$PT_{9.1}$	196.37 [g] (-2)	67.58 [a] (+26)	6.99 [g] (-32)	39.09 [b] (+61)	305.08 [f] (2)	54.41 [b] (+30)	801.76 [g] (-1)	46.90 [c] (+22)	2.50[f] (-40)	69.60 [b] (+33)
$PT_{9.2}$	195.17 [h] (-3)	67.63 [a] (+26)	6.54 [h] (-37)	39.75 [a] (+64)	304.95 [f] (-2)	55.08 [a] (+32)	801.59 [g] (-1)	47.15 [b] (+23)	2.40 [f] (-44)	70.41 [a] (+34)

T- total, E-extractability

Figures in parenthesis indicate per cent decrease (-) or increase (+) over control values

Values with different superscript are significantly different assessed by DMRT

being in $T_{9\ 3}$(49.53%), $T_{9\ 2}$(49.28%) showed no significant difference. $T_{9\ 1}$(49.15%) was comparable with that of $T_{9.2}$. An increase of about 18 per cent was shown by $T_{8\ 1}$(47.72%) and $T_{8\ .2}$ (47.85%) which showed no variation between treatments. There was no significant variation between $T_{8.2}$ and $T_{8.3}$ (48.11%).A significant increase varying from 2-12 per cent was observed for treatments T_2 to T_6 and the difference observed in these treatments were also found to be significant.

There was a significant reduction in total zinc in treatments T_1, T_2, T_3, T_4, T_5 and T_6 (2.75 mg/100g) when compared to control T_1 (2.80mg/100g). A reduction in total zinc was observed in T_7 (2.60mg/100g), $T_{8.1}$ (2.50mg/100g), $T_{8.2}$ (2.50mg/100g), $T_{8.3}$ (2.50mg/100g) and $T_{9.1}$ (2.50mg/100g) but was not significant. A significant loss in total zinc was observed in $T_{9.2}$ (2.40mg/100g) and $T_{9.3}$ (2.40mg/100g) when compared to control but there was no difference between these treatments.

Zinc extractability increased significantly in all processed samples except in T_7 (35.00%) which showed a significant reduction when compared to the control T_1 (42.87%). A significant increase in the extractability of zinc was observed which varied from 2-19%.When compared to control maximum zinc extractability was found in $T_{9.3}$ (50.83%) followed by $T_{9.2}$ (50.42%) and $T_{9.1}$ (50.00%). The differences between these treatments were also found to be significant. The difference observed in zinc extractability of $T_{8.\ 1}$ (48.63%) and $T_{8.\ 2}$ (48.86%) was not significant where as $T_{8.3}$ (49.20%) showed higher zinc extractability. The difference observed in treatments T_2 (43.57%), T_3 (44.44%), T_4 (45.18%), T_5 (46.29%) and T_6 (46.91%) was also significant with regard to zinc extractability.

4.1.2 Effect of pressure cooking of processed pulses on total mineral and mineral extractability

4.1.2.1 Bengal gram

The result of processing and pressure cooking on total minerals and mineral extractability in bengal gram is given in table 4.

Total calcium was found to be maximum in control T_1 (200.82mg/100g). There was a significant reduction in total calcium in all processed samples after pressure cooking when compared to control. Maximum loss was found in PT_7 (54.01mg/100g). A significant loss was observed in PT_2 (200.14mg/100g), PT_3 (199.36mg/100g), PT_4 (197.60mg/100g) and PT_6 (196.78mg/100g) and the variation observed between these treatments were also significant. Even though significant loss in calcium was observed in $PT_{8.1}$ (196.40mg/100g), $PT_{8.2}$ (196.21mg/100g) and $PT_{9.1}$(196.37mg/100g) when compared to control the difference between these treatments were not significant. But the variation observed in $PT_{9.2}$ (195.17mg/100g) was significant.

Calcium extractability was found to increase significantly in all processed samples except when compared to control T_1 (53.60%) except for PT_7 (49.12%) which showed a significant reduction. Maximum extractability was for $PT_{9.2}$ (67.63%) and $PT_{9.1}$ (67.58%) which showed no significant difference. Calcium extractability was 64.64% in $PT_{8.1}$ and 64.57% in $PT_{8.2}$ which showed a significant variation. The significant increase in calcium extractability was found to vary by 6-18 per cent for PT_2 (56.64%), PT_3 (59.53%), PT_4 (60.22%), PT_5 (61.90%) and PT_6 (36.01%) which showed a significant variation between these treatments.

Total iron was found to be highest in control T_1 (10.33mg/100g) which reduced significantly in various processed and pressure cooked samples except for PT_7 (11.40mg/100g) which showed a significant increase when compared to control. PT_2 (10.16mg/100g) showed a reduction in total iron which was not significant when compared to T_1. There was a significant variation in PT_3 (9.69mg/100g), PT_4 (9.21mg/100g), PT_5 (8.69mg/100g) and PT_6 (8.39mg/100g) but the variation between PT_5 and PT_6 was not significant. There was no significant variation in the loss of total iron in $PT_{8.1}$ (7.55mg/100g) and $PT_{8.2}$ (7.42mg/100g) . Maximum loss in total iron (about 37 per cent) was observed in $PT_{9.2}$ (6.54mg/100g). The variations observed between these treatments were also significant.

There was a significant increase in iron extractability in all processed and pressure cooked samples when compared to the control T_1 (24.22%) except for PT_7 (22.80%) which showed about 6 per cent reduction in extractability when compared to T_1. Maximum increase in iron extractability was found in $PT_{9.2}$ (39.75%) followed by $PT_{9.1}$ (39.09%). The increase was found to be about 64% and 61% respectively when compared to control. A significant increase of about 44% and 49% was observed in $PT_{8.1}$(34.83%) and $PT_{8.2}$ (36.05%) respectively and the difference between these treatments were also significant. A significant increase in iron was observed inPT_2 (24.60%), PT_3 (26.83%), PT_4 (27.79%), PT_5 (29.91%) and PT6 (30.98%) and the difference observed between these treatments were also significant.

A significant loss of total phosphorus was observed in all processed and pressure cooked samples when compared to the control T_1 (310.65mg/100g) except for PT_7 (328.04mg/100g) which showed an increase in total phosphorus by about 6 per cent when compared to the control. Even though the loss in total phosphorus was less than about 1 per cent in PT_2 (309.95mg/100g), PT_3 (309.35mg/100g), PT_4 (308.37mg/100g), PT_5 (307.67mg/100g) and PT_6 (306.49mg/100g) the loss was found to be significant and the difference observed between these treatments were also significant. There was no significant difference in the loss of total phosphorus observed between $PT_{8.1}$ (305.76mg/100g) and $PT_{8.2}$ (305.67mg/100g) and also between $PT_{9.1}$ (305.08mg/100g) and $PT_{9.2}$ (304.95mg/100g).

Phosphorus extractability was found to increase significantly in all processed and pressure cooked samples compared to the control T_1 (41.87%). Maximum phosphorus extractability was observed in $PT_{9.2}$ (55.08%) followed by $PT_{9.1}$ (54.41%) which also showed a significant difference. $PT_{8.1}$ (50.69%) and $PT_{8.2}$ (51.36%) also showed an increase in phosphorus extractability by 21 and 23 per cent respectively compared to the control, and the variation observed was also significant. PT_7 (43.62%) which showed about 4 per cent increase in phosphorus extractability was also significantly higher than control. A significant increase varying from about 4-16 per cent

Table - 5 Effect of processing and pressure cooking on total minerals and mineral extractability in green gram

Treatment	Calcium		Iron		Phosphorus		Potassium		Zinc	
	T mg/100g	E %	T mg/100g	E %	T mg/100g	E %	T mg/100g	E %	T mg/100g	E %
T_1	122.75 [a]	20.01 [h]	7.06[b]	49.15 [c]	324.13 [b]	47.84 [j]	840.88 [b]	34.57 [e]	3.60 [a]	68.57 [k]
PT_2	122.14 [b] (-0.3)	20.56 [g] (+3)	6.79 [c] (-4)	51.07[c] (+4)	323.25 [c] (-0.3)	48.79[i] (+2)	840.19 [c] (–0.1)	42.22 [d] (+22)	3. 50 [ab] (-3)	69.71[j] (+2)
PT_3	120.97 [c] (-1)	21.72 [f] (+9)	6.69 [c] (-5)	50.52 [c] (+3)	323.56 [d] (-0.2)	49.14 [h] (+3)	840.03 [c] (-1)	44.03 [cd] (+27)	3.45 [ab] (-4)	70.27[i] (+3)
PT_4	121.17[c] (-1)	22.69 [e] **(+13)**	6.42[d] (-9)	52.95 [bc] (+8)	322.92 [e] (-0.7)	50.16 [g] (+5)	839.46 [d] (-0.13)	43.79[cd] (+27)	3.39 [bc] (-6)	71.42 [h] (+4)
PT_5	120.40 [d] (-2)	23.25 [d] (+16)	6.19 [d] (-12)	54.92 [bc] (+12)	322.19 [e] (-0.6)	50.99 [f] (+7)	839.10 [e] (-0.21)	44.07[cd] (+28)	3.42 [a b] (-5)	72.26 [g] (+5)
PT_6	119.41[e] (-3)	26.00[c] (+30)	5.82[e] (-18)	61.85[bc] (+25)	322.08 [e] (-0.6)	51.95 [e] (+9)	837.97[f] (-0.4)	45.38 [c] (+31)	3.40[bc] (-6)	72.90 [f] (+6)
PT_7	70.14 [h] (-43)	19.94[h] (-0.34)	9.48 [a] (+34)	51.68 [c] (+5)	398.33 [a] (+23)	48.95 [i] (+2)	1132.58[a] (+35)	50.69 [a] (+47)	2.10 [d] (-40)	73.33 [e] (+7)
$PT_{8.1}$	118.94 [f] (-3)	27.51 [b] (+36)	5.47 [f] (-23)	65.57 [b] (+33)	321.74[fg] (-0.7)	54.27 [d] (+13)	838.19 [f] (-0.32)	48.33[b] (+40)	3.30 [bc] (-8)	73.75 [d] (+8)
$PT_{8.2}$	118.76 [f] (-3)	27.78 [b] (+39)	5.47[f] (-23)	67.81 [a] (+38)	321.61[gh] (-0.8)	54.60[c] (+14)	838.0 [f] (-0.34)	48.83 [ab] (+41)	3.30[bc] (-8)	74.08 [c] (+8)
$PT_{9.1}$	117.72 [g] (-4)	29.72 [a] (+49)	5.08 [g] (-28)	68.36 [a] (+39)	321.38 [hi] (-1)	56.31 [b] (+18)	837.26 [g] (-0.43)	49.15 [ab] (+42)	3.20[c] (-11)	76.00 [a] (+11)
$PT_{9.2}$	117.56[g] **(-4)**	29.78 [a] (+49)	5.02 [g] (–29)	68.68 [a] (+40)	321.15 [i] (-1)	56.66 [a] (+18)	837.19 [g] (-0.44)	49.25[ab] (+43)	3.20 [c] (-11)	75.31 [b] (+10)

T- total, E-extractability

Figures in parenthesis indicate per cent decrease (-) or increase (+) over control values

Values with different superscript are significantly different assessed by DMRT

was observed in samples PT_2 (43.38%), PT_3 (44.20%), PT_4 (45.90%), PT_5 (46.25%) and PT_6 (48.61%) and there was a significant difference between these treatments.

There was a significant loss in total potassium in all processed and pressure cooked samples when compared to the control T_1 (806.05mg/100g). Maximum loss was observed in PT_7 (719.40mg/100g) i.e. about 11 per cent. A loss of about less than one per cent was observed in $PT_{9.1}$ (801.76mg/100g) and $PT_{9.2}$ (801.59mg/100g) which showed about 1 per cent loss in total potassium. The differences observed between these treatments were not significant. Similarly the difference observed between $PT_{8.1}$ (802.56mg/100g) and $PT_{8.2}$ (802.49mg/100g) was also not significant. All the other samples showed significant difference between treatments.

There was a significant increase in potassium extractability in all processed and pressure cooked samples. Maximum increase of about 26 per cent was observed in PT_7 (48.23%) when compared to the control T_1 (38.44%). An increase of about 20 and 21 per cent was observed in $PT_{8.1}$ (46.22%) and $PT_{8.2}$ (46.35%) which showed no significant difference between treatments. $PT_{9.1}$ (46.90%) and $PT_{9.2}$ (47.15%) showed a significant increase of about 22 and 23 per cent but the differences between treatments were also significant. A significant increase varying from about 8-17 per cent was observed in treatments PT_2 (41.66%), PT_3 (43.35%), PT_4 (43.53%), PT_5 (44.31%) and PT_6 (44.82%) and the difference observed between these treatments were also significant.

Total zinc decreased significantly in all processed and pressure cooked samples when compared to the control T_1 (4.30mg/100g). Maximum loss was observed in $PT_{9.2}$ (2.40mg/100g) followed by $PT_{9.1}$ (2.50mg/100g) .There was no significant difference between these treatments. A significant loss in total zinc showed no variation between PT_6, $PT_{8.1}$ and $PT_{8.2}$ (2.80mg/100g) and showed no significant variation with PT_7 (2.90mg/100g). Significant variation in total zinc was observed between PT_2 (4.10mg/100g), PT_3 (3.70mg/100g), PT_4 (3.39mg/100g) and PT_5 (3.00mg/100g).

Zinc extractability increased significantly in extractability in all processed and pressure cooked samples when compared to control T_1 (52.50%). Maximum

extractability was for $PT_{9.2}$ (70.41%) which showed about 34 per cent increase compared to control. The increase was about 33 per cent in $PT_{9.1}$ (69.60%) which was significantly different from $PT_{9.2}$. In all other samples the extractability showed a significant variation of about 2-25 per cent.

4.1.2.2. Green gram

The result of processing and pressure cooking on total minerals and mineral extractability in green gram is given in table 5.

Total calcium decreased significantly in all processed and pressure cooked green gram samples compared to the control T_1 (122.75mg/100g). Maximum loss in about 43 per cent in total calcium was found in PT_7 (70.14mg/100g). There was no significant difference between PT_3 (120.97mg/100g) and PT_4(121.17mg/100g), between $PT_{8.1}$ (118.94mg/100g) and $PT_{8.2}$ (118.76mg/100g) and between $PT_{9.1}$ (117.72mg/100g) and $PT_{9.2}$ (117.56mg/100g).

Calcium extractability showed a significant increase after processing and cooking except in PT_7 (19.94%) when compared to control T_1 (20.01%) but the difference was not significant. A maximum increase of about 49 per cent was observed in calcium extractability in $PT_{9.2}$ (29.78%) and $PT_{9.1}$ (29.72%). There was no significant difference between $PT_{8.1}$ (27.51%) and $PT_{8.2}$ (27.78%). All other samples showed significant variation in calcium extractability between treatments .

Total iron showed a significant reduction after processing and pressure cooking when compared to the control T_1 (7.06mg/100g) except in PT_7 (9.48mg/100g) which showed about 34 per cent increase in total iron in all other treatments reduction in total iron varied from 4 - 29 per cent compared to control. Maximum loss was observed in $PT_{9.2}$ (5.02mg/100g) followed by $PT_{9.1}$ (5.08mg/100g) which showed no significant difference between the treatments. There was no significant difference was observed in $PT_{8.1}$ (5.47mg/100g) and $PT_{8.2}$ (5.47mg/100g). There was no significant difference was observed in PT_5 (6.19mg/100g) and PT_4 (6.42mg/100g)

between the treatments. Similarly the difference observed between PT_3 (6.69mg/100g) and PT_2 (6.79mg/100g) was also significant.

Iron extractability was found to increase significantly in all processed and pressure cooked samples when compared to control T_1 (49.15%). Maximum iron extractability of about 40 per cent was found to be $PT_{9.2}$ (68.68%) followed by $PT_{9.1}$ (68.36%), $PT_{8.2}$ (67.81%) and $PT_{8.1}$ (65.57%) which showed no significant difference between treatments. There was no significant difference between treatments in PT_6 (61.85%), PT_5 (54.92%), PT_4 (52.95%). Similarly there was no significant difference was observed between PT_7 (51.68%), PT_3 (50.52%) and PT_2 (51.07%).

There was a reduction in total phosphorus content in all processed green gram samples when compared to control T_1 (324.13mg/100g) except in PT_7 (398.33mg/100g) which showed a significant increase in phosphorus content by 23 per cent. There was a significant difference was observed in PT_2 (323.25mg/100g) and PT_3 (323.56mg/100g) when compared to control. There was no significant difference observed between PT_4 (322.92mg/100g), PT_5 (322.19mg/100g) and PT_6 (322.08mg/100g). A significant loss was observed in $PT_{8.1}$ (321.74mg/100g), $PT_{8.2}$ (321.61mg/100g), $PT_{9.1}$ (321.38mg/100g) and $PT_{9.2}$ (321.15mg/100g) but there was a significant variation was observed between the treatments.

The extractability of phosphorus in control was found to be 47.84 per cent which increased significantly to 48.79 per cent in PT_2 and PT_3 (49.14%). There was a significant difference was observed between PT_2 and PT_3. There was a significant difference observed in all other treatments, but the phosphorus extractability increased. Maximum phosphorus extractability was observed in $PT_{9.1}$ (56.31%) and $PT_{9.2}$ (56.66%).

Total potassium showed s significant loss in all processed and pressure cooked green gram samples when compared to control T_1 (840.88mg/100g) except in PT_7 (1132.58mg/100g) which showed a significant increase of about 35 per cent in total potassium. Maximum loss was observed in $PT_{9.2}$ (837.19mg/100g) followed by

Table - 6 Effect of processing and pressure cooking on total minerals and mineral extractability in horse gram

Treatment	Calcium		Iron		Phosphorus		Potassium		Zinc	
	T mg/100g	E %	T mg/100g	E %	T mg/100g	E %	T mg/100g	E %	T mg/100g	E %
T_1	285.23 ^{a}	42.57 ^{i}	8.90 ^{ab}	49.67 ^{i}	309.43 ^{b}	38.76 ^{k}	700.12 ^{a}	40.61 ^{i}	2.80 ^{ab}	42.87 ^{j}
PT_2	284.96 ^{ab} (-0.1)	43.86 ^{h} (+3)	8.43 b^{c} (-5)	51.64^{h} (+4)	307.96^{bc} (-0.5)	42.21 ^{i} (+9)	699.60 ^{b} (-0.07)	42.16 ^{g} (+4)	2.75 ^{ab} (-2)	44.28 ^{i} (+3)
PT_3	284.66 ^{bc} (-0.2)	44.99 ^{g} (+6)	8.56 ^{bc} (-4)	52.44 ^{g} (+6)	307.90 ^{c} (-0.5)	43.85 ^{h} (+13)	699.43 ^{b} (-0.1)	43.66 ^{f} (+8)	2.70 ^{b} (-4)	45.18 ^{j} (+5)
PT_4	284.38 ^{c} (-0.3)	46.11 ^{f} (+8)	8.16^{d} (-8)	55.15 ^{f} (+11)	307.54 ^{d} (-0.6)	44.87 ^{g} (+16)	698.00 ^{c} (-0.3)	43.69 ^{e} (+8)	2.75 ^{ab} (-2)	45.55 ^{g} (+6)
PT_5	283.73 ^{d} (-1)	46.87^{e} (+10)	7.64 ^{e} (-14)	53.39^{e} (+7)	307.44^{d} (-0.7)	45.53 ^{f} (+17)	697.80 ^{cd} (-0.3)	44.41 ^{d} (+9)	2.70 ^{ab} (-4)	46.29 ^{f} (+8)
PT_6	283.64 ^{d} (-1)	48.05^{d} (+13)	7.69 ^{e} (-14)	57.27 ^{d} (+15)	307.08 ^{e} (-0.8)	46.24 ^{e} (+190	697.56 ^{d} (-0.4)	45.87 ^{c} (+13)	2.70 ^{ab} (-4)	47.44 ^{e} (+11)
PT_7	64.21 ^{g} (-77)	38.92 ^{j} (-9)	8.98 ^{a} (+0.9)	44.54 ^{j} (-10)	322.02 ^{a} (+4)	40.79 ^{j} (+5)	684.15 ^{g} (-20)	41.11 ^{h} (+1)	1.96 ^{a} (-30)	35.5^{k} (-17)
$PT_{8.1}$	282.18 ^{e} (-1)	50.30^{c} (+18)	7.32 ^{f} (-18)	58.72 ^{c} +18)	306.49 ^{f} (-1)	48.60 ^{d} (+25)	696.28 ^{f} (-1)	46.63 ^{b} (+15)	2.50 ^{c} (-10)	48.00 ^{e} (+12)
$PT_{8.2}$	280.66 ^{f} (-2)	50.70 ^{b} (+19)	7.09 ^{fg} (-20)	58.79 ^{c} (+18)	306.29 ^{f} (-1)	50.81^{c} (+39)	696.87 ^{e} (-1)	46.92 ^{b} (+16)	2.50 ^{c} (-10)	48.77 ^{c} (+14)
$PT_{9.1}$	280.76 ^{f} (-2)	52.32 ^{a} (+22)	6.96 ^{g} (-22)	60.34 ^{b} (+22)	305.86 ^{g} (-1)	51.33 ^{ab} (+32)	696.29 ^{f} (-1)	47.39 ^{a} (+17)	2.40 ^{c} (-14)	50.42 ^{b} (+18)
$PT_{9.2}$	280.45^{f} (-2)	52.35^{a} (+23)	6.73^{g} (-24)	60.78^{a} (+22)	305.60^{g} (-1)	52.13^{a} (+34)	696.13^{f} (-1)	47.54^{a} (+17)	2.40^{c} (-14)	50.81a (+19)

T- total, E-extractability

Figures in parenthesis indicate per cent decrease (-) or increase (+) over control values

Values with different superscript are significantly different assessed by DMRT

$PT_{9.1}$ (837.26mg/100g) which showed a significant difference between treatments. Significant variation were not observed in treatments PT_6 (837.97mg/100g), $PT_{8.1}$ (838.19mg/g) and $PT_{8.2}$ (838.00mg/100g) with regard to loss in total potassium. Similarly the difference observed between PT_2 (840.19%) and PT_3 (840.03%) was not significant.

Potassium extractability was found to increase significantly in green gram samples after processing and pressure cooking when compared to control T_1 (34.57%). A maximum increase in extractability of about 47 per cent was observed in PT_7 (50.69%). An increase of about 41 to 43 per cent was observed in $PT_{8.2}$ (48.83%), $PT_{9.1}$ (49.15%) and $PT_{9.2}$ (49.25%) respectively which showed no significant difference between treatments and also with PT_7. There was no significant difference in the variation observed in $PT_{8.1}$ (48.33%) when compared to $PT_{8.2,}$ $PT_{9.1}$ and $PT_{9.2}$. Similarly the increase in potassium extractability observed in PT_2 (42.22%), PT_3 (44.03%), PT_4 (43.79%) and PT_5 (44.07%) showed no significant variation between treatments. PT_6 (45.38%) was comparable to that of PT3, PT4 and PT_5.

Total zinc showed a significant loss in samples PT_4 (3.39mg/100g), PT_6 (3.40mg/100g), PT_7 (2.10mg/100g), $PT_{8.1}$ (3.30mg/100g), $PT_{8.2}$ (3.30mg/100g), $PT_{9.1}$ (3.20mg/100g) and $PT_{9.2}$ (3.20mg/100g) when compared to control T_1 (3.60mg/100g). The difference observed in the loss of total zinc in treatments PT_2 (3.50mg/100g), PT_3 (3.45mg/100g) and PT_5 (3.42mg/100g) were not significant between treatments and also with that of the control. Maximum loss of about 40 per cent was observed in PT_7 (2.10mg/100g). About 6 to 11per cent loss was observed in treatments PT_6 (3.40mg/100g), $PT_{8.1}$ (3.30mg/100g), $PT_{8.2}$ (3.30mg/100g), $PT_{9.1}$ (3.20mg/100g) and $PT_{9.2}$ (3.20mg/100g) which showed no significant variation between treatments.

Zinc extractability was found to increase significantly in all processed and pressure cooked samples when compared to control T_1 (68.57%). Maximum increase of total of about 7 per cent was observed in PT_7 (73.33%). Zinc extractability increased significantly in PT_2 (69.71%) and PT_3 (70.27%) and the variation observed between these two treatments were not significant. All other treatments showed

a significant variation in the increased zinc extractability of processed and pressure cooked samples of green gram.

4.1.2.3Horse gram

The result of processing and pressure cooking on total minerals and mineral extractability in horse gram is given in table 6.

Total calcium in control (T_1) was 285.23mg/100g. PT_2 showed a loss in total calcium (284.96mg/100g), but the reduction was not significant compared to control. All other horse gram samples showed a significant loss in total calcium compared to control. Maximum loss in calcium was observed in PT_7 (64.21mg/100g). The significant reduction in PT_2 (284.96mg/100g), PT_3 (284.66mg/100g) and PT_4 (284.38mg/100g) where comparable but there was no significant difference between these treatments. Total calcium in PT_5 (283.73mg/100g) and PT_6 (283.64mg/100g) where comparable without significant difference between treatments. There was a significant difference between $PT_{8.1}$ (282.18mg/100g) and $PT_{8.2}$ (280.66mg/100g) and $PT_{8.2}$ showed a significant reduction in calcium content. There was no significant difference in calcium content in $PT_{8.2}$, $PT_{9.1}$ (280.76mg/100g) and $PT_{9.2}$ (280.45mg/100g).

Calcium extractability in horse gram was found to be 42.57% in control T_1. All processed and pressure cooked samples showed a significant increase in calcium extractability except in PT_7 (38.92%) which showed a significant reduction in calcium extractability. Maximum calcium extractability was found in $PT_{9.2}$ (52.35%) which showed no significant difference with $PT_{9.1}$ (52.32%). There was a significant increase in calcium extractability in $PT_{8.1}$ (50.30%) and $PT_{8.2}$ (50.70%), $PT_{8.2}$ having higher extractability. The difference in calcium extractability in PT_2 (43.86%), PT_3 (44.99%), PT_4 (46.11%), PT_5 (46.87%) and PT_6 (48.05%) was found to be significant, showing a gradual increase from about 3 to13 per cent.

Total iron in horse gram was 8.90mg/100g in control T_1 . A loss in iron was observed in all horse gram samples except in $PT_{9.1}$ (6.96mg/100g) and

$PT_{9.2}$ (6.73mg/100g) compared to control. There was no significant difference between other treatments but there is a reduction in iron content. PT_7 (8.98mg/100g) showed an increase in iron content, which was not significant when compared to control.

Iron extractability was (49.67%) in control T_1. Which showed a significant increase in all processed and pressure cooked samples except for PT_7 (44.54%) which showed a significant reduction in iron extractability. Maximum iron extractability was found in $PT_{9.2}$ (60.78%) and $PT_{9.1}$ (60.34%) but the difference between these treatments were found to be significant. The increase in iron extractability of $PT_{8.1}$ (58.72%) and $PT_{8.2}$ (58.79%) there was no significant difference between treatments. There was a significant increase in iron extractability in PT_2 (51.64%), PT_3 (52.44%), PT_4 (55.15%), PT_5 (53.39%) and PT_6 (57.27%) and the difference between these treatments were also found to be significant.

Total phosphorus decreased in all processed and pressure cooked horse gram samples when compared to control T_1 (309.53mg/100g) except for PT_7 (322.02mg/100g) which showed a significant increase. The loss in total phosphorus was not significant in PT_2 (307.96mg/100g) when compared to control. There was a significant loss in phosphorus in PT_3 (307.90mg/100g), PT_4 (307.54mg/100g), PT_5 (307.44mg/100g) and PT_6 (307.08mg/100g) when compared to control but the difference observed between PT_2 and PT_3 and PT_4 and PT_5 were not significant. The decrease in PT_6 (307.08mg/10g) was not significant compared to control. The loss of phosphorus was significant in $PT_{8.1}$ (306.49mg/100g) and $PT_{8.2}$ (306.29mg/100g) but there was no significant difference between treatments. There was no significant difference between $PT_{9.1}$ (305.86mg/100g) and $PT_{9.2}$ (305.60mg/100g) but there was a slight reduction in phosphorus content.

Phosphorus extractability increased significantly in all processed and pressure cooked horse gram samples when compared to control T_1 (38.76%). The increase in phosphorus extractability was found to vary from 9 to 34 per cent with respect to control. The maximum extractability in $PT_{9.1}$ (51.33%) and $PT_{9.2}$

Table - 7 Effect of processing and ordinary cooking on phytic acid, total phosphorus, phytate phosphorus, nonphytate phosphorus and phosphorus extractability in bengal gram

Treatment	Phytic acid mg/100gm	Total phosphorus mg/100gm	Phytate phosphorus		Non Phytate phosphorus %	Phosphorus extractability %
			Total mg	% of total		
T_1	579.10 [a]	310.65 [b]	163.19 [a]	52.50 [a]	47.50 [g]	41.87 [i]
T_2	566.00 [b] (-2)	309.74 [c] (-.29)	159.50 [b] (-2)	51.49 [b] (-2)	48.50 [h] (+2)	42.19 [k] (+1)
T_3	548.90 [c] (-5)	309.41 [c] (-.39)	154.70 [c] (-5)	50.09 [c] (-5)	49.83 [g] (+5)	43.49 [c] (+4)
T_4	529.50 [e] (-9)	308.76 [d] (-.61)	151.10 [d] (-7)	48.40 [e] (-8)	51.60 [e] (+9)	45.19 [h] (+8)
T_5	536.20 [d] (-7)	307.18 [e] (-1)	149.20 [e] (-9)	49.20 [d] (-6)	50.80 [f] (+7)	46.89 [g] (+12)
T_6	522.70 [f] (-10)	306.70 [f] (-1)	147.27 [f] (-10)	48.10 [e] (-8)	51.90 [e] (+9)	48.25 [f] (+15)
T_7	497.66 [k] (-14)	328.19 [a] (-6)	141.00 [i] (-14)	42.60 [n] (-18)	57.40 [a] (+21)	42.78 [j] (+2)
$T_{8.1}$	514.55 [hg] (-11)	306.07 [g] (-2)	145.10 [g] (-11)	47.30 [f] (-10)	52.60 [d] (+11)	49.33 [e] (+18)
$T_{8.2}$	514.20 [h] (-11)	305.97 [g] (-2)	144.90 [g] (-11)	47.40 [f] (-10)	52.70 [d] (+11)	49.67 [d] (+19)
$T_{8.3}$	514.90 [g] (-11)	305.88 [g] (-2)	145.10 [g] (-11)	47.40 [f] (-10)	52.53 [d] (+11)	49.86 [d] (+19)
$T_{9.1}$	504.60 [ji] (-13)	305.32 [h] (-2)	145.20 [g] (-13)	46.50 [g] (-11)	53.50 [cd] (+13)	52.73 [c] (+26)
$T_{9.2}$	504.30 [j] (-13)	305.26 [h] (-2)	142.20 [h] (-13)	46.58 [g] (-11)	53.06 [cd] (+12)	53.40 [b] (+28)
$T_{9.3}$	504.19 [i] (-13)	305.19 [h] (-2)	142.20 [h] (-13)	46.60 [g] (-11)	53.73 [b] (+13)	53.73 [a] (+29)

T- total, E-extractability

Figures in parenthesis indicate per cent decrease (-) or increase (+) over control value

Values with different superscript are significantly different assessed by DMRT

(52.13%) and the least increase in PT_7 (40.79%). There was significant difference was observed in phosphorus extractability between all other treatments [Fig .23(a); fig.23 (b)].

A significant loss in total potassium observed in all processed and pressure cooked horse gram samples when compared to control T_1 (700.12mg/100g). There was no significant difference in total potassium content in PT_2 (699.60mg/100g) and PT_3 (699.43mg/100g). There was no significant difference between PT_4 (698.00mg/100g), PT_5 (697.80mg/100g) and T_6 (697.56mg/100g). There was a significant difference in PT_7 (684.15mg/100g) when compared to control. There was a significant difference between $PT_{8.1}$ (696.28mg/100g) and $PT_{8.2}$ (696.87mg/100g). There was no significant difference was observed in $PT_{9.1}$ (696.29mg/100g) and $PT_{9.2}$ (696.13mg/100g).

In all processed and pressure cooked horse gram samples showed an increase in potassium extractability per cent age when compared to control T_1 (40.61%) except in PT_7 (41.11%) which showed a significant reduction in extractability. The extractability per cent age in differently treated samples vary from 4 to 17 per cent. The maximum extractability was found to be in $PT_{9.1}$ (47.39%) and $PT_{9.2}$ (47.54%) but there was no significant difference between treatments, followed by $PT_{8.1}$ (46.63%) and $PT_{8.2}$ (46.92%). A significant increase was observed in all other treatments.

A significant loss in total zinc content in all processed and pressure cooked horse gram samples when compared to control T_1 (2.80mg/100g). There was no change in total zinc in PT_2 (2.80mg/100g) and PT_3 (2.70mg/100g) when compared to control. There was a slight change in zinc content in PT_4, PT_5 and PT_6 (2.80mg/100g), when compared to control. A significant reduction in zinc was observed in PT_7 (1.96mg/100g). A significant loss in total zinc was observed in $PT_{8.1}$ and $PT_{8.2}$ (2.50mg/100g) and $PT_{9.1}$ and $PT_{9.2}$ (2.40mg/100g).

Zinc extractability was increased significantly in all processed and pressure cooked horse gram samples when compared to control T_1 (42.87%) except in PT_7 (35.50%) which showed a significant reduction. A significant

Table - 8 Effect of processing and ordinary cooking on phytic acid, total phosphorus, phytate phosphorus, nonphytate Phosphorus and phosphorus extractability in green gram

Treatment	Phytic acid mg/100g	Total phosphorus mg/100gm	Phytate phosphorus		Non phytate phosphorus %	Phosphorus extractability %
			Total (mg)	% of total		
T_1	545.70 ^{b}	324.13 ^{b}	153.80 ^{b}	47.45 ^{b}	52.63 ^{b}	47.84 ^{L}
T_2	530.50 ^{c} (-3)	323.89 $^{b\,c}$ (-0.1)	147.20 ^{d} (-4)	46.15 ^{c} (-3)	53.85 ^{b} (+2)	48.84 $^{J\,K}$ (+2)
T_3	513.40 ^{d} (-6)	328.81 ^{bc} (-0.1)	144.68 ^{e} (-6)	44.68 ^{d} (-6)	55.32 ^{b} (+5)	48.91 ^{J} (+2)
T_4	597.70 ^{f} (-9)	323.62 ^{cd} (-0.2)	139.20 ^{f} (-9)	43.80 ^{e} (-8)	56.99 ^{b} (+8)	50.16 ^{I} (+5)
T_5	502.50 ^{e} (-8)	323.17 ^{ef} (-0.3)	149.60 ^{c} (-3)	43.70 ^{e} (-9)	56.17 ^{b} (+7)	52.39 ^{H} (+10)
T_6	493.90 ^{g} (-10)	323.38 ^{de} (-0.2)	137.42 ^{gf} (-11)	42.50 ^{f} (-10)	57.50 ^{b} (+9)	52.94 ^{g} (+11)
T_7	684.80 ^{a} (+25)	398.83 ^{a} (+23)	194.00 ^{a} (+26)	48.39 ^{a} (+2)	51.61 ^{b} (-2)	48.64 ^{k} (+2)
$T_{8.1}$	487.22 ^{h} (-10)	321.99 ^{h} (-0.7)	135.56 ^{gh} (-12)	41.92 ^{g} (-12)	58.08 ^{a} (+10)	53.37 ^{f} (+12)
$T_{8.2}$	480.80 ^{i} (-12)	322.87 ^{hg} (-0.4)	134.20 ^{hi} (-13)	41.56 ^{h} (-12)	58.44 ^{a} (+11)	53.76 ^{e} (+12)
$T_{8.3}$	480.40 ^{j} (-12)	322.74 ^{g} (-0.4)	135.53 ^{gh} (-12)	40.96 ^{i} (-14)	58.06 ^{a} (+10)	55.07 ^{d} (+15)
$T_{9.1}$	469.50 ^{l} (-14)	321.94 ^{g} (-0.8)	132.30 ^{ij} (-14)	41.09 ^{i} (-13)	58.91 ^{a} (+12)	55.28 ^{c} (+16)
$T_{9.2}$	468.70 ^{m} (-14)	321.58 ^{i} (-0.8)	132.11 ^{j} (-14)	42.02 ^{g} (-11)	58.47 ^{a} (+11)	55.62 ^{b} (+16)
$T_{9.3}$	469.78 ^{k} (-14)	321.71 $^{i\,h}$ (-0.8)	132.36 ^{ij} (-14)	41.15 ^{i} (-13)	58.85 ^{a} (+12)	55.94 ^{a} (+17)

T- total, E-extractability

Figures in parenthesis indicate per cent decrease (-) or increase (+) over control values

Values with different superscript are significantly different assessed by DMRT

increase in the extractability of zinc was observed which vary from 3 to 19 per cent. Maximum extractability was found in $PT_{9.2}$ (50.81%) and $PT_{9.1}$ (50.42%) followed by $PT_{8.2}$ (48.77%) and $PT_{8.1}$ (48.00%) and there was a significant difference between these treatments. The difference observed in treatments PT_2 (44.28%), PT_3 (45.18%), PT_4 (45.55%), PT_5 (46.29%) and PT_6 (47.44%) were also significant with regard to zinc extractability.

4.2 Effect of processing methods and cooking on phytic acid, total phosphorus, phytate phosphorus and extractability of phosphorus from selected pulses

4.2.1. Ordinary cooking

4.2.1.1. Bengal gram

The effect of various processing methods and ordinary cooking on phytic acid, total phosphorus, phytate phosphorus and extractability pf phosphorus in bengal gram is given in table 7.

As revealed there was a significant reduction in phytic acid in all processed and cooked bengal gram samples. When compared to the control T_1 (579.10 mg/100gm). Maximum loss in phytic acid about 14 per cent was observed in T_7 (497.66 mg/100gm). Phytic acid in $T_{9.1}$ (504.60mg/100gm) and $T_{9.2}$ (504.30mg/100gm) are comparable without significant difference. Treatments $T_{8.1}$ (514.55 mg/100gm) and $T_{8.3}$ (514.90mg/100gm) showed no significant variation in phytic acid, but $T_{8.2}$ (514.20 mg/100gm) showed less phytic acid compared to $T_{8.3}$, but was comparable to $T_{8.1}$. About 2 to 10 per cent loss in phytic acid was observed in treatments T_2 (566.00 mg/100gm), T_3 (548.9mg/100gm), T_4 (529.50mg/100gm), T_5 (536.20mg/100gm) and T_6 (522.70mg/100gm) and the variation observed between these treatments were also significant.

As revealed in table 7 of the total phosphorus 52.5 per cent was in the form of phytate phosphorus in control T1 (163.19mg/100gm) and hence the least

Table - 9 Effect of processing and ordinary cooking on phytic acid, total phosphorus, phytate phosphorus, nonphytate phosphorus and phosphorus extractability in horse gram

Treatment	Phytic acid mg/100g	Total phosphorus mg/100gm	Phytate phosphorus		Non phytate phosphorus %	Phosphorus extractability %
			Total (mg)	% of total		
T_1	424.75 ^{a}	309.43 ^{b}	119.70 ^{a}	38.67 ^{a}	61.33 ^{i}	38.76 ^{m}
T_2	409.86 ^{b} (-4)	309.29 ^{bc} (-0.1)	115.50 ^{b} (-4)	37.34 ^{b} (-3)	62.66 ^{h} (+2)	42.03 ^{k} (+8)
T_3	361.19 ^{i} (-15)	309.11 ^{c} (-0.1)	110.19 ^{c} (-8)	35.65 ^{c} (-8)	64.35 ^{g} (+5)	43.67 ^{j} (+13)
T_4	373.01 ^{d} (-12)	308.98 ^{cd} (-0.2)	105.10 ^{e} (-12)	34.01 ^{e} (-12)	65.99 ^{e} (+8)	44.19 ^{l} (+14)
T_5	380.76 ^{c} (-10)	308.78 ^{b} (-0.2)	107.30 ^{d} (-10)	34.74 ^{d} (-10)	65.26 ^{f} (+6)	45.33 ^{n} (+17)
T_6	366.19 ^{e} (-14)	307.22 ^{e} (-0.7)	103.40 ^{f} (-14)	33.66 ^{f} (-13)	66.34 ^{d} (+8)	47.19 ^{g} (+22)
T_7	319.73 ^{m} (-25)	321.16 ^{a} (-0.9)	90.10 ^{k} (-25)	28.05 ^{j} (-27)	71.95 ^{a} (+17)	40.47 ^{i} (+4)
$T_{8.1}$	360.89 ^{g} (-16)	306.87 f (-0.8)	101.60 ^{g} (-15)	32.73 ^{n} (-14)	67.23 ^{c} (+10)	47.59 ^{f} (+23)
$T_{8.2}$	356.28 ^{i} (-16)	306.72 ^{f} (-0.9)	100.40 ^{h} (-16)	33.10 ^{g} (-14)	67.353 ^{c} (+10)	47.92 ^{e} (+24)
$T_{8.3}$	360.54 ^{n} (-15)	306.60 ^{f} (-1)	101.70 ^{g} (-15)	33.49 ^{f} (-13)	66.51 ^{d} (+8)	48.58 ^{d} (+25)
$T_{9.1}$	349.53 ^{j} (-18)	306.02 ^{c} (-1)	8.40 ^{j} ^{f} (-18)	32.15 ^{i} (-17)	67.71 ^{b} (+10)	50.32 ^{c} (+30)
$T_{9.2}$	349.18 ^{k} (-18)	305.97 ^{g} (-1)	49.50 ^{i} (-19)	32.29 ^{i} (-20)	67.85 ^{b} (+11)	50.65 ^{b} (+31)
$T_{9.3}$	348.47 ^{i} (-18)	305.97 ^{g} (-1)	98.20 ^{j} (-17)	32.10 ^{i} (-17)	67.90 ^{b} (+11)	51.33 ^{a} (+32)

T- total, E-extractability

Figures in parenthesis indicate per cent decrease (-) or increase (+) over control values

Values with different superscript are significantly different assessed by DMRT

phosphorus extractability (41.87%). There was a significant reduction in phytate phosphorus during processing of bengal gram and a corresponding significant increase in phosphorus extractability. Maximum reduction in phytate phosphorus in T_7 (141.0mg/100gm) with maximum non phytate phosphorus (57.40%) with only about 21% increase in phosphorus extractability (42.78%). Maximum reduction observed in phytate phosphorus in $T_{9.3}$ (142.20mg/100gm) and $T_{9.2}$ (142.20mg/100gm) showed no significant variation. But phosphorus extractability was significantly high in $T_{9.3}$ (53.73 %) compared to $T_{9.2}$ (53.40%) due to the low total phosphorus in $T_{9.3}$ (305.19mg/100gm). There was no significant variation in the loss of phytate phosphorus in $T_{8.1}$ (145.10mg/100gm), $T_{8.2}$ (144.90mg/100gm), $T_{8.3}$ (145.10mg/100gm) and $T_{9.1}$ (145.20 mg/100gm) but when compared to total phosphorus the per cent age of phytate phosphorus was significantly low in $T_{9.1}$ (46.50%) with a corresponding significant increase in non phytate phosphorus (53.50%) and phosphorus extractability (52.73%). Phytate phosphorus showed a significant reduction in T_2 (51.49%), T_3 (50.09%), T_4 (48.40%), T_5 (49.20%) and T_6 (48.10%). Among these samples non phytate phosphorus was the highest in T_7 (51.90%) and showed significantly high in phosphorus extractability (48.25%).

4.2.1.2 Green gram

The effect of various processing methods and ordinary cooking on phytic acid, total phosphorus, phytate phosphorus and extractability of phosphorus in green gram is given in table 8.

There was a significant reduction in phytic acid content of all processed and ordinary cooked green gram samples when compared to control T_1 (545.70mg/100g). Maximum loss of phytic acid was found in $T_{9.2}$ (468.70mg/100g) followed by $T_{9.3}$ (469.78mg/100g). Phytate phosphorus was also significantly low in $T_{9.1}$ (132.30mg/100g) followed by $T_{9.3}$ (132.36mg/100g). $T_{9.3}$ has maximum nonphytate phosphorus (58.85%) and phosphorus extractability (55.94%) when compared to the control (52.63% and (47.84%).

Table – 10 Effect of processing and pressure cooking on phytic acid, total phosphorus, phytate phosphorus, non phytate Phosphorus and phosphorus extractability in bengal gram

Treatment	Phytic acid mg/100gm	Total Phosphorus mg/100gm	Phytate phosphorus		Non phytate phosphorus %	Phosphorus extractability %
			Total (mg)	% of total		
P T_1	579.10 [a]	310.65 [b]	163.19 [a]	52.50 [a]	47.50 [g]	41.87 k
P T_2	559.60 [b] (-3)	309.95 [c] (-0.2)	157.70 [b] (-3)	50.89 b (-3)	49.11 [f] (+3)	43.38 [j] (+4)
P T_3	540.45 [c] (-6)	309.35 [d] (-0.4)	152.30 [c] (-6)	48.90 [d] (-7)	51.10 e (+8)	44.20 [h] (+6)
P T_4	526.88 [e] (-9)	308.37 [e] (-0.7)	148.10 [e] 9-9)	49.02 [d] (-7)	50.99 [e] (+7)	45.90 [g] (+10)
P T_5	532.64 [d] (-8)	307.67 [f] (-1)	150.16 [d] (-8)	50.01 [c] (-5)	51.98 [d] (+9)	46.25 [f] (+11)
P T_6	519.87 [f] (-10)	306.49 [g] (-1)	146.50 [f] (-10)	47.79 [e] (-9)	52.21 [d] (+10)	48.61 [e] (+16)
P T_7	492.90 [k] (-15)	328.04 [a] (+6)	138.90 [k] (-5)	42.34 [n] (-19)	57.65 [a] (+21)	43.62 [f] (+4)
P $T_{8.1}$	509.58 [g] (–12)	305.76 [h] (-2)	143.60 [g] (-12)	46.95 [f] (-11)	52.97 [c] (+12)	50.69 [c] (+21)
P $T_{8.2}$	508.16 [h] (-12)	305.67 [h] (-2)	143.20 [h] (-12)	46.84 [f] (-11)	53.22 [c] (+12)	51.36 [c] (+23)
P $T_{9.1}$	501.77 [i] (-13)	305.08 [i] (-2)	141.40 [i] (-13)	46.34 [g] (-12)	53.66 [b] (+13)	54.41 [b] (+30)
P $T_{9.2}$	500.77 [j] (-14)	304.95 [i] (-2)	141.10 [j] (-14)	46.25 [g] (-12)	53.75 [b] (+13)	55.08 [a] (+32)

T- total, E-extractability

Figures in parenthesis indicate per cent decrease (-) or increase (+) over control values

Values with different superscript are significantly different assessed by DMRT

A significant reduction was observed in total phosphorus content in all processed samples except in T_7 (398.83mg/100g) which showed a significant increase in total phosphorus. There was a significant increase in phytate phosphorus (194.97mg/100g) and corresponding reduction in nonphytate phosphorus (51.61%) when compared to control.

There was no significant variation in the nonphytate content of $T_{8.1}$ (58.08%), $T_{8.2}$ (58.44%) and $T_{8.3}$ (58.06%) and also between $T_{9.1}$ (58.91%), $T_{9.2}$ (58.47%) and $T_{9.3}$ (58.85%). And there was no significant difference between T_2 (53.85%), T_3 (55.32%), T_4 (56.67%), T_5 (56.17%) and T_6 (57.50%).

4.2.1.3 Horse gram

The effect of various processing methods and ordinary cooking on phytic acid, total phosphorus, phytate phosphorus and extractability pf phosphorus in horse gram is given in table 9.

There was a significant reduction in phytic acid in all processed and ordinary cooked horse gram samples when compared to control T_1 (424.75mg/100g). Maximum loss in phytic acid about 18 per cent was observed in $T_{9.3}$ (348.47mg/100g). About 18 per cent reduction was observed in $T_{9.2}$ (349.18mg/100g) and $T_{9.1}$(349.53mg/100g).In treatments $T_{8.2}$ about 15 per cent reduction (356.28mg/100g)was observed but in $T_{8.1}$(360.89mg/100g) and $T_{8.3}$ (360.54mg/100g) about 15 per cent reduction . About 4-14 per cent reduction was observed in T_2 (409.86mg/100g), T_3 (361.19mg/100g), T_4 (373.01mg/100g), T_5 (380.76mg/100g) and T_6 (366.19mg/100g) and the variation observed between the treatments were also significant.

About 38.67% of the total phosphorus was in the form of phytate phosphorus in control T_1 (119.70%). There was a significant reduction in phytate phosphorus content and a corresponding increase in non phytate phosphorus and phosphorus extractability. Reduction in phytate phosphorus was observed in $T_{9.3}$

Table – 11 Effect of processing and pressure cooking on phytic acid, total phosphorus, phytate phosphorus, non phytate phosphorus and phosphorus extractability in green gram

Treatment	Phytic acid mg/100gm	Total Phosphorus mg/100gm	Phytate phosphorus		Non phytate phosphorus %	Phosphorus extractability %
			Total (mg)	% of total		
P T_1	545.70 ^{b}	324.13 ^{b}	153.80 ^{b}	47.45 ^{b}	52.63 ^{g}	47.84 ^{j}
P T_2	524.43 ^{c} (-4)	323.25 ^{b} (-0.3)	147.70 ^{c} (-4)	45.69 ^{c} (-3)	54.310 ^{f} (+3)	48.79 ^{i} (+2)
P T_3	504.90 ^{d} (-7)	323.56 ^{c} (-0.2)	142.30 ^{d} (-7)	42.97 ^{e} (-9)	56.69 ^{e} (+6)	49.14 ^{h} (+3)
P T_4	491.10 ^{i} (-10)	321.92 ^{ef} (-0.7)	138.10 ^{i} (-10)	42.76 ^{e} (-10)	57.24 ^{d} (+9)	50.16 ^{g} (+5)
P T_5	497.20 ^{e} (-9)	322.19 ^{e} (-0.6)	140.08 ^{e} (-9)	43.52 ^{d} (-8)	56.48 ^{e} (+7)	50.99 ^{f} (+7)
P T_6	484.40 ^{g} (-11)	322.08 ^{e} (-0.6)	136.50 ^{g} (-11)	42.38 ^{f} (-11)	57.62 ^{c} ((+9))	51.95 ^{e} (+9)
P T_7	677.70 ^{a} (+24)	398.30 ^{a} (+23)	190.80 ^{a} (+24)	47.95. ^{a} (+1)	52.11 ^{n} (-1)	48.95 ^{hi} (+2)
P $T_{8.1}$	474.43 ^{h} (-13)	321.74 ^{fg} (-0.7)	133.60 ^{h} (-13)	41.52 ^{g} (-7)	58.48 ^{b} (+11)	54.27 ^{d} (+13)
P $T_{8.2}$	472.60 ^{i} (-13)	321.61 ^{gh} (-0.7)	133.20 ^{i} (-13)	41.40 ^{g} (-13)	58.59 ^{b} (+11)	54.60 ^{c} (+14)
P $T_{9.1}$	466.31 ^{j} (-15)	321.38 ^{hi} (-0.8)	131.28 ^{j} (-15)	40.88 ^{h} (-14)	59.12 ^{a} (+12)	56.31 ^{b} (+18)
P $T_{9.2}$	465.19 ^{k} (-15)	321.15 ^{i} (-0.9)	131.09 ^{k} (-15)	40.82 ^{h} (-14)	59.18 ^{a} (+12)	56.66 ^{a} (+18)

T- total, E-extractability

Figures in parenthesis indicate per cent decrease (-) or increase (+) over control values

Values with different superscript are significantly different assessed by DMRT

Table - 12 Effect of processing and pressure cooking on phytic acid, total phosphorus, phytate phosphorus, non phytate Phosphorus and phosphorus extractability in horse gram

Treatment	Phytic acid mg/100g	Total phosphorus mg/100g	Phytate phosphorus		Non phytate phosphorus %	phosphorus extractability %
			Total mg/100gm	% of total		
T_1	424.75 [a]	309.53 [b]	199.70 [a]	38.67 [a]	61.33 [ab]	38.76 [a]
P T_2	402.76 [b] (-5)	307.96 [bc] (-1)	113.50 [b] (-5)	35.45 [b] (-8)	63.24 [ab] (+3)	42.21 [a] (+9)
P T_3	384.31 [c] (-10)	307.90 [c] (-1)	108.30 [c] (-10)	35.17 [b] (-9)	64.87 [a] (+6)	43.85 [a] (+13)
P T_4	369.42 [e] (-13)	307.54 [d] (-1)	104.10 [e] (-13)	33.84 [b] (-12)	66.16 [ab] (+9)	44.87 [a] (+16)
P T_5	376.50 [d] (-11)	307.44 [d] (-1)	106.09 [b] (-11)	34.5 [b] (-11)	65.49 [ab] (+7)	45.53 [a] (+17)
P T_6	364.08 [f] (-14)	307.08 [e] (-1)	102.60 [f] (-14)	33.41 [b] (-14)	55.58 [b] (+7)	46.24 [a] (+19)
P T_7	334.99 [k] (-21)	322.02 [a] (+4)	94.40 [j] (-21)	29.40 [b] (-24)	70.60 [a] (+15)	40.79 [a] (+5)
P $T_{8\,1}$	353.43 [g] (-17)	306.49 [f] (-1)	99.60 [g] (-16)	32.49 [b] (-16)	67.53 [a] (+10)	48.60 [a] (+25)
P $T_{8\,2}$	352.02 [h] (-17)	306.29 [f] (-1)	99.20 [h] (-17)	32.80 [b] (-15)	67.62 [a] (+10)	53.81 [a] (+39)
P T_{91}	345.63 [i] (-19)	305.86 [g] (-1)	97.40 [i] (-19)	31.84 [b] (-18)	68.16 [a] (+11)	51.33 [a] (+32)
P T_{92}	344.93 [j] (-19)	305.60 [g] (-1)	97.20 [j] (-19)	31.84 [b] (-18)	68.20 [a] (+11)	52.13 [a] (+35)

T- total, E-extractability
Figures in parenthesis indicate per cent decrease (-) or increase (+) over control values
Values with different superscript are significantly different assessed by DMRT

(98.20%) and with maximum non phytate phosphorus (67.90%) and phosphorus extractability (51.33%). There was no significant difference was observed in nonphytate in $T_{9.1}$ (67.71%), $T_{9.2}$ (67.85%) and $T_{9.3}$ (67.90%). Maximum non phytate phosphorus was observed in T_7 (71.95%).

4.2.2 Effect of processing and pressure cooking on phytic acid, total phosphorus, phytate phosphorus and extractability of phosphorus from selected pulses

4.2.2.1. Bengal gram

The effect of processing and pressure cooking on phytic acid, total phosphorus, phytate phosphorus and extractability of phosphorus in bengal gram is presented in table 10.

Phytic acid was found to reduce significantly in all processed and pressure cooked samples when compared to the control T1 (579.10mg/100gm). Maximum loss in phytic acid was found in PT_7 (492.90mg/100gm) and a significant increase of about 6 per cent was observed in total phosphorus (328.04mg/100gm). Phytate phosphorus was the least in PT_7 (42.34%) with maximum non phytate phosphorus (57.65%), but phosphorus extractability was found to be 43.62%. In germinated samples ($T_{8.1}$, $T_{8.2}$, $T_{9.1}$ and $T_{9.2}$) the variation observed in the phytic acid content was significant. There was no significant variation in the per cent age of phytate phosphorus (% of total) in $PT_{8.1}$ (46.95%) and $PT_{8.2}$ (46.84%) and between $PT_{9.1}$ (46.34%) and $PT_{9.2}$ (46.25%). Phytate phosphorus was minimum in PT_7 (42.34%) followed by $PT_{9.2}$ (46.25%).

Maximum phosphorus extractability was in $PT_{9\ 2}$ (55.08%) which was significantly high when compared to other processed samples.

Table - 13 Effect of processing and ordinary cooking on phytic acid and mineral extractability in bengal gram

Treatment	Phytic acid mg/100gm	Calcium extractability %	Iron extractability %	Phosphorus extractability %	Potassium extractability %	Zinc extractability %
T_1	579.10 [a]	53.60 [h]	24.22 [i]	41.87 [l]	38.44 [i]	52.50 [k]
T_2	566.00 [b] (-2)	55.05 [g] (+3)	24.46 [h] (+1)	42.19 [k] (+1)	41.02 [h] (+7)	53.84 [j] (+3)
T_3	548.90 [c] (-5)	59.36 [f] (+11)	25.90 [g] (+7)	43.49 [c] (+4)	42.85 [g] (+11)	55.13 [i] (+5)
T_4	529.50 [e] (-9)	59.95 [e] (+12)	27.34 [f] (+13)	45.19 [h] (+8)	43.96 [f] (+14)	57.60 [h] (+10)
T_5	536.20 [d] (-7)	61.62 [d] (+15)	29.02 [e] (+20)	46.89 [g] (+12)	44.64 [e] (+16)	61.27 [g] (+17)
T_6	522.70 [f] (-10)	62.40 [c] (+16)	30.62 [d] (+26)	48.25 [f] (+15.)	45.69 [e] (+19)	62.78 [e] (+20)
T_7	497.66 [k] (-14)	47.97[i] (-11)	21.42[j] (-12)	42.78j (+2)	48.00[a] (+25)	61.27[f] (+17)
$T_{8.1}$	514.55 [gh] (-11)	63.46 [b] (+18)	32.62 [c] (+35)	49.33 [e] (+18)	45.83 [cd] (+19)	63.39 [d] (+21)
$T_{8.2}$	514.20 [h] (-11)	63.43 [b] (+18)	32.33 [b] (+33)	49.67 d (+19)	45.86 [cd] (+19)	63.44[d] (+21)
$T_{8.3}$	514.90 [g] (-11)	63.39 [b] (+18)	32.35 [b] (+34)	49.86 [d] (+19)	46.09 [c] (+20)	63.45 [d] (+21)
$T_{9.1}$	504.60 [j] (-13)	67.35 [a] (+26)	38.39 a (+57)	52.73 c (+26)	46.57 [b] (+21)	68.42 [c] (+30)
$T_{9.2}$	504.30 [J] (-13)	67.33 [a] (+25)	38.40 [a] (+59)	53.40 [b] (+28)	46.63 b (+21)	68.80 [b] (+31)
$T_{9.3}$	504.19[i] (-13)	67.32[a] (+25)	38.41[a] (+59)	53.73 [a] (+28)	46.75 [b] (+22)	69.19 [a] (+32)
		.450 **	.591 **	.791 **	.981 **	.901 **

Figures in parenthesis indicate per cent decrease (-) or increase (+) over control value

Values with different superscript are significantly different assessed by DMRT

** Correlation significant at the 0.01level (2-tailed)

4.2.2.2 Green gram

The effect of processing and pressure cooking on phytic acid, total phosphorus, phytate phosphorus and extractability of phosphorus in green gram is presented in table 11.

There was a significant reduction in phytic acid content of all processed and pressure cooked green gram when compared to control T_1(545.70mg/100gm). Maximum loss of phytic acid was found in $PT_{9.2}$ (465.19mg/100gm) followed by $PT_{9.1}$ (466.31mg/100gm). Phytate phosphorus was also significantly low in $PT_{9.2}$ (131.09mg/100gm) and hence with maximum non phytate phosphorus (59.18%). Phosphorus extractability was also significantly high in $PT_{9.2}$ (56.66%) when compared to the control T_1 (47.84%).

Total phosphorus also showed a significant reduction in all processed samples except in PT_7 (398.30mg/100gm) which showed a significant increase. There was a significant reduction in phytate phosphorus and a corresponding increase in non phytate phosphorus. There was no significant variation in the nonphytate phosphorus content of $PT_{8.1}$ (58.48%) and $PT_{8.2}$ (58.59%) and also between $PT_{9.1}$ (59.12%) and $PT_{9.2}$ (59.18%). Phosphorus extractability showed significant variation between samples. PT_2(48.79%) and PT_3(49.14%) showed a significant increase of about 2-3 per cent and in all the other processed samples the increase was found to range from 5-18 per cent.

4.2.2.3 Horse gram

The effect of processing and pressure cooking on phytic acid, total phosphorus, phytate phosphorus and extractability of phosphorus in horse gram is presented in table 12.

There was a significant reduction in phytic acid all processed and pressure cooked samples when compared to control the T_1 (424.75mg/100gm).Maximum loss of phytic acid about 21 per cent was found in PT_7 (334.99mg/100gm). About 17-19 per cent

Table - 14 Effect of processing and ordinary cooking on phytic acid and mineral extractability in green gram

Treatment	Phytic acid mg/100gm	Calcium extractability %	Iron extractability %	Phosphorus extractability %	Potassium extractability %	Zinc extractability %
T_1	545.70 [b]	20.01 [h]	49.15[k]	47.84 [L]	34.57 [e]	68.57 [k]
T_2	530.50 [c] (-3)	20.29 [g] (+2)	50.43 [J] (+3)	48.84 [J K] (+2)	41.63 [a] (+20)	69.44 [J] (+1)
T_3	513.40 [d] (-6)	21.38 [f] (+7)	51.07[I] (+4)	48.91[J] (+2)	41.37 [d] (+20)	70.27 [I] (+2)
T_4	497.70 [I] (-9)	21.91 [e] (+10)	52.38 [g] (+7)	50.16[I] (+5)	42.16 [d] (+22)	71.17 [H] (+4)
T_5	502.50 [e] (-8)	23.17 [d] (+16)	54.40 [f] (+11)	52.39 [h] (+10)	44.47 [c] (+29)	73.52 [f] (+7)
T_6	493.90 [g] (-10)	24.32 [c] (+22)	64.40 [d] (+31)	52.94 [g] (+11)	45.22 [c] (+31)	74.20 [e] (+8)
T_7	684.77 [a] (+25)	20.46[g] (+2)	51.41[h] (+5)	48.64[k] (+2)	49.80[a] (+44)	73.17[g] (+7)
$T_{8.1}$	487.22 [h] (-10)	26.78 [b] (+34)	63.71 [e] (+30)	53.37 [f] (+12)	47.34 [b] (+37)	74.68 [d] (+9)
$T_{8.2}$	480.80 [I] (-12)	26.82 [b] (+34)	64.40 [d] (+31)	53.76 [e] (+12)	47.47 [b] (+37)	74.88[d] (+9)
$T_{8.3}$	480.40[J] (-12)	26.85 [h] (+34)	64.86 [c] (+32)	55.07[d] (+15)	47.72 [ab] (+38)	76.01 [a] (+11)
$T_{9.1}$	469.50 [I] (-14)	28.77 [g] (+44)	69.42 [b] (+41)	55.28 [c] (+16)	48.48[ab] (+40)	75.31 [a] (+10)
$T_{9.2}$	468.70 [m] (-14)	28.81 [a] (+44)	70.17 [a] (+43)	55.62[b] (+16)	48.60 [ab] (+41)	75.62 [b] (+10)
$T_{9.3}$	469.78 [k] (-14)	28.84 [a] (+44)	70.19 [a] (+43)	55.94[a] (+17)	48.78 [ab] (+41)	75.80 [b] (+11)
		.665 **	**.623****	**.680 ****	**.062**	**.388 ***

Figures in parenthesis indicate per cent decrease (-) or increase (+) over control value

Values with different superscript are significantly different assessed by DMRT

* Correlation significant at the 0.05level (2- tailed)

** Correlation significant at the 0.01level (2-tailed)

loss in phytic acid was observed in $PT_{8.1}$ (353.43mg/100g) and $PT_{8.2}$ (352.02mg/100g) and $PT_{9.1}$ (345.63mg/100g) and $PT_{9.2}$ (344.93mg/100g). In treatments PT_2 (402.76mg/100g), PT_3 (384.31mg/100g), PT4 (369.43mg/100g), PT_5 (376.50mg/100g) and PT_6 (364.08mg/100g) and about 5-14 per cent reduction was observed.

About 38.67% of total phosphorus was in the form of phytate phosphorus in control T_1(119.70%) and it also posses lowest phosphorus extractability(38.76%). There was a significant reduction was observed in phytate phosphorus during processing and corresponding increase in nonphytate phosphorus and phosphorus extractability. Maximum reduction in phytate phosphorus was observed PT_7 (94.40%) and also posses reduction in phosphorus extractability. Maximum nonphytate phosphorus was observed in PT_7 (70.60%). There was no significant difference was observed in nonphytate phosphorus in $PT_{8.1}$ (67.53%) and $PT_{8.2}$ (67.62%) and $PT_{9.1}$ (68.16%) and $PT_{9.2}$ (68.20%). There was no significant difference was observed in phosphorus extractability per cent.

4.3 Effect of processing cooking and methods on phytic acid and mineral extractability from selected pulses

4.3.1. Ordinary cooking

4.3.1.1. Bengal gram

As revealed in Table .13 calcium extractability in bengal gram is maximum in $T_{9.1}$ (67.33%) under ordinary cooking. While the phytic acid content was 504.60mg/100gm compared to control value of T_1 579.10mg/100gm.There observed a significant negative correlation between phytic acid content and calcium extractability except in T_7 ,which showed the least phytic acid content (497.66mg/100gm) among treatments but the least calcium extractability also(47.97%) as against 53.60% in control(T_1).

Table - 15 Effect of processing and ordinary cooking on phytic acid and mineral extractability in horse gram

Treatment	Phytic acid mg/100gm	Calcium extractability %	Iron extractability %	Phosphorus extractability %	Potassium extractability %	Zinc extractability %
T_1	424.75 [a]	42.57 j	49.67 [l]	38.76 [m]	40.61 j	42.87 [k]
T_2	409.86 [b] (-4)	44.53 [i] (+0.05)	50.31 [k] (+!)	42.03 [a] (+8)	41.43 [i] (+2)	43.57 j (+2)
T_3	361.19 [f] (-15)	44.98 [h] (+6)	51.96 [j] (+5)	43.67 [j] (+13)	42.76 [h] (+6)	44.44 [i] (+4)
T_4	373.01[d] (-12)	45.73 [g] (+7)	53.61[i] (+8)	44.19 [i] (+14)	43.29[g] (+7)	45.18 [h] (+5)
T_5	380.76 [c] (-10)	46.53 [f] (+9)	54.81 [h] (+10)	45.33 [h] (+17)	44.07 [f] (+9)	46.29 [g] (+8)
T_6	366.19 [e] (-14)	47.67 [e] (+12)	56.07 [g] (+13)	47.19 [g] (+22)	45.32 [e] (+12)	46.91 [f] (+9)
T_7	354.86 [m] (-16)	38.52 [k] (-10)	44.35[m] (-11)	40.47 [l] (+4)	39.06 [k] (-4)	35.00 [l] (-18)
$T_{8.1}$	360.89 [g] (-16)	49.89 [d] (+17)	63.93 [f] (+29)	47.59 [f] (+23)	47.72 [d] (+18)	48.63 [e] (+13)
$T_{8.2}$	356.28 [i] (-16)	50.45 [c] (+19)	64.59 [e] (+30)	47.92 [e] (+24)	47.85[dc] (+18)	48.86 [e] (+14)
$T_{8.3}$	360.54 [h] (-15)	50.30 [c] (+18)	65.01 [d] (+31)	48.58[d] (+25)	48.11 [c] (+19)	49.20 [d] (+16)
$T_{9.1}$	349.53 [j] (-18)	51.56 [b] (+21)	69.01 [c] (+39)	50.32 [c] (+30)	49.15 [b] (+21)	50.00 [c] (+17)
$T_{9.2}$	349.18 [k] (-18)	51.95 [a] (+22)	69.70 [b] (+40)	50.65[b] (+31)	49.28[ab] (+21)	50.42 [b] (+18)
$T_{9.3}$	348.47 [i] (-18)	51.97[a] (+22)	70.23 [a] (+41)	51.33 [a] (+32)	49.53 [a] (+22)	50.83 [a] (+19)
		.218	**.340 ***	**.489 ****	.366 *	**.040**

Figures in parenthesis indicate per cent decrease **(-)** or increase **(+)** over control value

Values with different superscript are significantly different assessed by DMRT

* Correlation significant at the 0.05level (2- tailed)

** Correlation significant at the 0.01level (2-tailed)

The same trend was observed with iron extractability also. In T_1 iron extractability was only 24.22% with maximum phytic acid content (579.10mg/100gm). There was a significant negative correlation between phytic acid content and iron extractability with processing and ordinary cooking of bengal gram except for T_7 which showed a positive correlation between phytic acid (497.66mg/100gm) and also a reduction in iron extractability (21.42%) as against 24.22% in T_1 (control).

Phosphorus extractability showed a significant negative correlation with phytic acid . Maximum phosphorus extractability was seen in $T_{9.3}$ (53.73%) where the phytic acid was significantly reduced to 504.19mg/100gm as against579.10mg/100gm in T_1(control). Phosphorus extractability was least (41.87%)in T_1 where the phytic acid content was maximum (579.10mg/100gm) . Phytic acid was least in T_7(497.66mg/100gm) but phosphorus extractability was only 42.78% but still higher than T_1 (41.87%).

Potassium extractability showed a significant negative correlation with phytic acid in all treatments. Maximum potassium extractability was in T_7(48%) which also showed the least phytic acid content (497.66mg/100gm).

Zinc extractability also had a significant negative correlation with phytic acid . Maximum reduction in phytic acid was observed in T_7 (497.66mg/100gm) which showed a significant increase in zinc extractability (61.27%) but maximum extractability (69.19%) was found in $T_{9.3}$

4.3.1.2 Green gram

As revealed in Table.14 there was a significant reduction in phytic acid content of green gram due to various processing and ordinary cooking methods ,except in T_7 which showed an increase in phytic acid (684.77mg/100gm) as against 545.70 mg/100gm in T_1(control).

Table - 16 Effect of processing and pressure cooking on phytic acid and mineral extractability in bengal gram

Treatment	Phytic acid mg/100gm	Calcium extractability %	Iron extractability %	Phosphorus extractability %	Potassium extractability %	Zinc extractability %
T_1	579.10 ^{a}	53.60 ^{h}	24.22 ^{j}	41.87 ^{K}	38.44 ^{i}	52.50 ^{k}
P T_2	559.60 ^{b} (-3)	56.54 ^{g} (+6)	24.60 ^{l} (+2)	43.38 ^{J} (+4)	41.66 ^{h} (+8)	53.95 ^{j} (+3)
P T_3	540.45 ^{c} (-6)	59.53 ^{f} (+11)	26.83 ^{h} (+11)	44.20 ^{h} (+6)	43.35^{g} (+13)	53.75 (+2)^{l}
P T_4	526.88 ^{e} (-9)	60.22 ^{e} (+12)	27.79 ^{g} (+15)	45.90 ^{g} (+10)	43.53^{g} (+13)	58.22 ^{h} (+11)
P T_5	532.64 ^{d} (-8)	61.90 ^{d} (+16)	29.91 ^{f} (+24)	46.25 ^{f} (+11)	44.31 ^{f} (+15)	61.66 ^{g} (+17)
P T_6	519.87 ^{f} (-10)	63.01 ^{c} (+18)	30.98^{c} (+28)	48.61^{e} (+16)	44.82 ^{e} (+17)	62.50 ^{f} (+19)
P T_7	492.90^{k} (-15)	49.12 ^{i} (-8)	22.80^{k} (-6)	43.62 ^{i} (+4.)	48.23 ^{a} (+26)	63.15 ^{e} (+20)
P $T_{8.1}$	509.58 ^{g} (--12)	64.64 ^{b} (+21)	34.83 ^{d} (+44)	50.69^{d} (+21)	46.22^{d} (+20)	64.64 ^{d} (+23)
P $T_{8.2}$	508.16 ^{h} (-12)	64.57 ^{b} (+21)	36.05^{c} (+49)	51.36 ^{c} (+23)	46.35 ^{d} (+21)	65.66 ^{c} (+25)
P $T_{9.1}$	501.77 ^{l} (-13)	67.58 ^{a} (+26)	39.09 ^{b} (+61)	54.41 ^{b} (+30)	46.90 ^{c} (+22)	69.60 ^{b} (+33)
P $T_{9.2}$	500.77 ^{J} (-14)	67.63 ^{a} (+26)	39.75 ^{a} (+64)	55.08 ^{a} (+32)	47.15 ^{d} (+23)	70.41 ^{a} (+34)
		.374 *	.589 **	.695 **	.986 **	.894 **

Figures in parenthesis indicate per cent decrease (-) or increase (+) over control value

Values with different superscript are significantly different assessed by DMRT

* Correlation significant at the 0.05level (2- tailed)

** Correlation significant at the 0.01level (2-tailed)

Table - 17 Effect of processing and pressure cooking on phytic acid and mineral extractability in green gram

Treatment	Phytic acid mg/100gm	Calcium extractability %	Iron extractability %	Phosphorus extractability %	Potassium extractability %	Zinc extractability %
T_1	545.70 ^{b}	20.01 ^{h}	49.15 ^{c}	47.84 ^{j}	34.57 ^{e}	68.57 ^{k}
P T_2	524.43^{c} (-4)	20.56 ^{g} (+3)	51.07^{c} (+4)	48.79^{f} (+2)	42.22 ^{d} (+22)	69.71 (+2)
P T_3	504.90 ^{d} (-7)	21.72 ^{f} (+9)	50.52 ^{c} (+3)	49.14 ^{h} (+3)	44.03 ^{cd} (+27)	70.27 (+3)^{l}
P T_4	491.10 ^{f} (-10)	22.69 ^{e} **(+13)**	52.95 ^{bc} (+8)	50.16 ^{g} (+5)	43.79^{cd} (+27)	71.42 ^{h} (+4)
P T_5	497.20^{e} (-9)	23.25 ^{d} (+16)	54.92 ^{bc} (+12)	50.99 ^{f} (+7)	44.07^{cd} (+28)	72.26 ^{g} (+5)
P T_6	484.40 ^{g} (-11)	26.00^{c} (+30)	61.85^{bc} (+25)	51.95 ^{e} (+9)	45.38 ^{c} (+31)	72.90 ^{f} (+6)
P T_7	677.07 ^{a} (+24)	19.94^{h} (-0.34)	51.68 ^{c} (+5)	48.95 ^{i} (+2)	50.69 ^{a} (+47)	73.33 ^{e} (+7)
P $T_{8.1}$	474.43 ^{n} (-13)	27.51 ^{b} (+36)	65.57 ^{b} (+33)	54.27 ^{d} (+13)	48.33^{b} (+40)	73.75 ^{d} (+8)
P $T_{8.2}$	472.60 ^{i} (-13)	27.78 ^{b} (+39)	67.81 ^{a} (+38)	54.60^{c} (+14)	48.83 ^{ab} (+41)	74.08 ^{c} (+8)
P $T_{9.1}$	466.31 ^{j} (-15)	29.72 ^{a} (+49)	68.36 ^{a} (+39)	56.31 ^{d} (+18)	49.15 ^{ab} (+42)	76.00 ^{a} (+11)
P $T_{9.2}$	465.19 ^{k} (-15)	29.78 ^{a} (+49)	68.68 ^{a} (+40)	56.66 ^{a} (+18)	49.25^{ab} (+43)	75.31 ^{b} (+10)
		.705 **	.385 *	.626 **	.020	.280

Figures in parenthesis indicate per cent decrease (-) or increase (+) over control value

Values with different superscript are significantly different assessed by DMRT

* Correlation significant at the 0.05level (2- tailed)

** Correlation significant at the 0.01level (2-tailed)

Table - 18 Effect of processing and pressure cooking on phytic acid and mineral extractability in horse gram

Treatment	Phytic acid mg/100gm	Calcium extractability %	Iron extractability %	Phosphorus extractability %	Potassium extractability %	Zinc extractability %
T_1	424.75 [a]	42.57 [i]	49.67 [i]	38.76 [a]	40.61 [a]	42.87 [j]
P T_2	402.76 [b] (-5)	43.86 [h] (+3)	51.64 [h] (+4)	42.21 [a] (+9)	42.16 [a] (+4)	44.28 [i] (+3)
P T_3	384.31 [c] (-10)	44.99 [g] (+6)	52.44 [g] (+6)	43.85 [a] (+13)	43.66 [a] (+8)	45.18 [j] (+5)
P T_4	369.42 [e] (-13)	46.11 [f] (+8)	55.15 [f] (+11)	44.87 [a] (+16)	43.69 [a] (+8)	45.55 [g] (+6)
P T_5	376.50 [d] (-11)	46.87[e] (+10)	53.39[e] (+7)	45.53 [a] (+17)	44.41 [a] (+9)	46.29 [f] (+8)
P T_6	364.08 [f] (-14)	48.05[d] (+13)	57.27 [d] (+15)	46.24 [a] (+190	45.87 [a] (+13)	47.44 [e] (+11)
P T_7	334.99 [k] (-21)	38.92 [j] (-9)	44.54 [j] (-10)	40.79 [a] (+5)	41.11 [a] (+1)	35.5[k] (-17)
P $T_{8.1}$	353.43 [g] (-17)	50.30[c] (+18)	58.72 [c] +18)	48.60 [a] (+25)	46.63 [a] (+15)	48.00 [e] (+12)
P $T_{8.2}$	352.02 [h] (-17)	50.70 [b] (+19)	58.79 [c] (+18)	53.81 [a] (+39)	46.92 [a] (+16)	48.77 [c] (+14)
P $T_{9.1}$	345.63 [i] (-19)	52.32 [a] (+22)	60.34 [b] (+22)	51.33 [a] (+32)	47.39 [a] (+17)	50.42 [b] (+18)
P $T_{9.2}$	344.93 [j] (-19)	52.35 (+23)	60.78 (+22)	52.13 (+34)	47.54 (+17)	50.81 (+19)
		.416*	.353 *	.114	.615 **	.166

Figures in parenthesis indicate per cent decrease **(-)** or increase **(+)** over control value

Values with different superscript are significantly different assessed by DMRT

* Correlation significant at the 0.05level (2- tailed)

** Correlation significant at the 0.01level (2-tailed)

Calcium extractability was found to have a significant negative correlation with phytic acid. Maximum calcium extractability of 28.84%was found in $T_{9.3,}$ and also observed a significant reduction in phytic acid (469.78mg/100gm) as against 545.70 mg/100gm in T_1 (control).

A significant increase in iron extractability was noted with different processing methods as against T_1 (control) . Maximum iron extractability was observed in $T_{9.3}$(70.19%) which also showed a significant reduction in phytic acid (469.78mg/100gm) as against T_1(545.70mg/100gm). There was a significant negative correlation between phytic acid and iron extractability with different processing methods except in T_7 which showed an increase in phytic acid (684.77mg/100gm) but also showed an increase in iron extractability (51.41%).

Phosphorus extractability was also found to have a significant negative correlation with phytic acid except in T_7. Phytic acid content increased to 684.77mg/100gm in T_7 which showed an increase in phosphorus extractability (48.64%) as against T_1 (47.84%).

There was a significant increase in potassium extractability due to different processing methods and ordinary cooking in green gram but the increase in potassium extractability was not correlated with the phytic acid content in the processed samples. Maximum potassium extractability was observed in T_7 (49.80%) but phytic acid was also maximum in T_7 (684.77mg/100gm).

Zinc extractability increased from 68.57% in T_1 to 76.01% in $T_{8.3}$. Zinc extractability showed a significant negative correlation with phytic acid.

4.3.1.3 Horse gram

As revealed in table15, there was a significant increase in calcium extractability in horse gram samples processed by different methods and cooked by

Table - 19 Effect of processing and ordinary cooking on tannin and mineral extractability in bengal gram

Treatment	Tannin mg/100 gm	Calcium extractability %	Iron extractability %	Phosphorus extractability %	Potassium extractability %	Zinc extractability %
T_1	203.16 [a]	53.60 [h]	24.22 [i]	41.87 [l]	38.44 [i]	52.50 [k]
T_2	201.98 [b] (-1)	55.05 [g] (+3)	24.46 [h] (+1)	42.19 [k] (+1)	41.02 [h] (+7)	53.84 [j] (+3)
T_3	198.57 [c] (-2)	59.36 [f] (+11)	25.90 [g] (+7)	43.49 [i] (+3.86)	42.85 [g] (+11)	55.13 [i] (+5)
T_4	198.11 [d] (-2)	59.95 [e] (+12)	27.34 [f] (+13)	45.19 [h] (+8)	43.96 [f] (+14)	57.60 [h] (+10)
T_5	178.78 [e] (-12)	61.62 [d] (+15)	29.02 [e] (+20)	46.89 [g] (+12)	44.64 [e] (+16)	61.27 [g] (+17)
T_6	171.79 [f] (-15)	62.40 [c] (+16)	30.62 [d] (+26)	48.25 [f] (+15.)	45.69 [e] (+19)	62.78 [e] (+20)
T_7	159.77 [i] (-21)	47.97 [i] (-11)	21.42 [j] (-12)	42.78 [j] (+2)	48.00 [a] (+25)	61.27 [i] (+17)
$T_{8.1}$	169.40 [g] (-17)	63.46 [b] (+18)	32.62 [c] (+35)	49.33 [e] (+18)	45.83 [cd] (+19)	63.39 [d] (+21)
$T_{8.2}$	169.31 [g] (-17)	63.43 [b] (+18)	32.33 [b] (+33)	49.67 [d] (+19)	45.86 [cd] (+19)	63.44 [d] (+21)
$T_{8.3}$	168.99 [h] (-17)	63.39 [b] (+18)	32.35 [b] (+34)	49.86 [d] (+19)	46.09 [c] (+20)	63.45 [d] (+21)
$T_{9.1}$	151.80 [j] (-25)	67.35 [a] (+26)	38.39 [a] (+57)	52.73 [c] (+26)	46.57 [b] (+21)	68.42 [c] (+30)
$T_{9.2}$	151.50 [k] (-25)	67.33 [a] (+25)	38.40 [a] (+59)	53.40 [b] (+28)	46.63 [b] (+21)	68.80 [b] (+31)
$T_{9.3}$	151.50 [k] (-25)	67.32 [a] (+25)	38.41 [a] (+59)	53.73 [a] (+28)	46.75 [b] (+22)	69.19 [a] (+32)
		.626**	.851**	.913 **	.881**	.989**

Figures in parenthesis indicate per cent decrease (-) or increase (+) over control values

Values with different superscript are significantly different assessed by DMRT

** Correlation significant at the 0.01 level (2-tailed)

ordinary cooking method such as boiling. Maximum calcium extractability was in $T_{9.3}$ (51.97%) which also showed the least phytic acid content (348.47mg/100gm). Even though there was a significant reduction in phytic acid content in T_7 (354.86mg/100gm) as against T_1 (424.75mg/100gm) calcium extractability was only 38.52% which was the least extractability shown. There was no significant correlation between phytic acid and calcium extractability.

There was a significant increase in iron extractability with a significant reduction in phytic acid due to processing and ordinary cooking . Iron extractability increased to 70.23% in $T_{9.3}$, which was only 49.67% in T_1.Phytic acid content was also the least in $T_{9.3}$ (348.47mg/100gm). Iron extractability was only 44.35% in T_7 as against 49.67% in T_1, but there was a significant reduction in the phytic acid content of T_7 (354.86mg/100g). In all other samples, there was a significant correlation between phytic acid and iron extractability.

Regarding phosphorus extractability there was a significant negative correlation between phytic acid. A significant increase in phosphorus extractability was noted in all processed samples with a significant reduction in phytic acid. Maximum phosphorus extractability was in $T_{9.3}$ (51.33%) with the maximum phytic acid content (348.47mg/100g).

Potassium extractability also showed an increase with a significant decrease in phytic acid content. Potassium extractability in T_1 (40.61%) was increased to 49.53% in $T_{9.3}$ but reduction in potassium extractability was observed in T_7 (39.06%) even with a reduction in phytic acid (354.86mg/100gm). In all other treatments there was a significant negative correlation between phytic acid and potassium extractability.

There was an increase in zinc extractability from 42.87 % (T1) to 50.83 %(T9.3). A significant reduction in phytic acid content was also noted in all

treatments, but there was no significant negative correlation with zinc extractability. Zinc extractability was found to be less in T_7 (35%) as against T_1 (42.87%).

4.3.2. Effect of processing and pressure cooking on phytic acid and mineral extractability from selected pulses

4.3.2.1. Bengal gram

Pressure cooking of bengal gram processed in different ways (Table .16) revealed that there was a significant reduction in phytic acid content in all treatments with pressure cooking and a significant increase in calcium extractability except in PT_7. In PT_7 calcium extractability was reduced to 49.12% as against 53.60% in T_1,but there was a significant reduction in phytic acid in PT_7(492.90mg/100gm) compared to T_1(579.10mg/100gm). In all other samples there was a significant negative correlation between phytic acid and calcium extractability.

The same trend was observed in iron extractability also. Iron extractability in PT_7 was 22.80% as against 24.22% in T_1, but phytic acid showed a significant reduction in PT_7 (492.90mg/100gm).In all other samples there was a significant negative correlation between phytic acid and iron extractability.

With regard to phosphorus .potassium and zinc extractability there was a significant negative correlation between extractability and phytic acid content in all the treatments. Maximum phosphorus and zinc extractability was in $PT_{9.2}$ (55.08 and 70.41% respectively), which also showed a significant reduction in phytic acid (500.77mg/100gm). But potassium extractability was maximum in PT_7 (48.23%) which also showed the least phytic acid (492.90mg/100gm). Phosphorus, potassium and zinc extractability showed a significant negative correlation with phytic acid.

Table - 20 Effect of processing and ordinary cooking on tannin and mineral extractability in green gram

Treatment	Tannin mg/100 gm	Calcium extractability %	Iron extractability %	Phosphorus extractability %	Potassium extractability %	Zinc extractability %
T_1	403.08[a]	20.01 [h]	49.15[k]	47.84 [l]	34.57 [e]	68.57 [k]
T_2	401.98[b] (-0.3)	20.29 [g] (+2)	50.43 [j] (+3)	48.84 [j k] (+2)	41.63 [d] (+20)	69.44 [j] (+1)
T_3	397.98 [c] (-1)	21.38 [f] (+7)	51.07[i] (+4)	48.91[j] (+2)	41.37 [d] (+20)	70.27 [i] (+2)
T_4	388.92[d] (-4)	21.91 [e] (+10)	52.38 [g] (+7)	50.16[i] (+5)	42.16 [d] (+22)	71.17 [h] (+4)
T_5	204.10[e] (-49)	23.17 [d] (+16)	54.40 [f] (+11)	52.39 [h] (+10)	44.47 [c] (+29)	73.52 [f] (+7)
T_6	200.10 [f] (-50)	24.32 [c] (+22)	64.40 [d] (+31)	52.94 [g] (+11)	45.22 [c] (+31)	74.20 [e] (+8)
T_7	146.30 [i] (-64)	20.46[g] (+2)	51.41[h] (+5)	48.64[k] (+2)	49.80[a] (+44)	73.17[g] (+7)
$T_{8.1}$	199.80 [g] (-50)	26.78 [b] (+34)	63.71 [e] (+30)	53.37 [f] (+12)	47.34 [b] (+37)	74.68 [d] (+9)
$T_{8.2}$	198.70 [h] (-51)	26.82 [b] (+34)	64.40 [d] (+31)	53.76 [e] (+12)	47.47 [b] (+37)	74.88[d] (+9)
$T_{8..3}$	198.60 [h] (-51)	26.85 [b] (+34)	64.86 [c] (+32)	55.07[d] (+15)	47.72 [ab] (+38)	76.01 [a] (+11)
$T_{9..1}$	144.80[j] (-64)	28.77 [a] (+44)	69.42 [b] (+41)	55.28 [c] (+16)	48.48[ab] (+40)	75.31 [b] (+10)
$T_{9..2}$	144.60[k] (-64)	28.81 [a] (+44)	70.17 [a] (+43)	55.62[b] (+16)	48.60 [ab] (+41)	75.62 [b] (+10)
$T_{9..3}$	144.41[l] (-64)	28.84 [a] (+44)	70.19 [a] (+43)	55.94[a] (+17)	48.78 [ab] (+41)	75.80 [b] (+11)
		.867**	**.627 ****	**.916 ****	**.839 ****	**.981 ****

Figures in parenthesis indicate per cent decrease (-) or increase (+) over control values

Values with different superscript are significantly different assessed by DMRT

** Correlation significant at the 0.01 level (2-tailed)

4.3.2.2. Green gram

As shown in Table .17 maximum reductions in phytic acid was observed in $PT_{9.2}$ (465.19mg/100gm) among all treatments after pressure cooking of green gram. Extractability of calcium, iron and phosphorus was also maximum in $PT_{9.2}$ (29.78, 68.68 and 56.66%respectively). Phytic acid was found to be maximum in PT_7 (677.07mg/100gm) and potassium extractability was also maximum in PT_7 (50.69%) as against T_1 (34.57%). Maximum zinc extractability was observed in $PT_{9.1}$ (76%).There was a significant negative correlation between phytic acid and extractability of calcium, iron and phosphorus .

4.3.2.3. Horse gram

As revealed in Table .18, there was a significant reduction in phytic acid in all treatments of horse gram after pressure cooking. PT_7 showed the least phytic acid (334.99mg/100gm). Maximum calcium, iron, potassium and zinc extractability was observed in $PT_{9.2}$ (52.35,60.78,47.54 and 50.81% respectively). In PT_7 the extractability of calcium (38.92%), iron (44.54%) and zinc (35.50%) was reduced significantly when compared to control. Maximum phosphorus extractability was observed in $PT_{8.2}$ (53.81%). There was a significant negative correlation between calcium, iron and potassium extractability with phytic acid.

4.4 Effect of processing methods and cooking on tannin and mineral extractability from selected pulses

4.4.1. Ordinary cooking

4.4.1.1. Bengal gram

As reveled in Table 19, tannin content in bengal gram varied from 203.16mg/100g in T_1(control) to 151.50mg/100gm in $T_{9.3}$ and $T_{9.2}$ after processing and ordinary cooking .Tannin was significantly high in T_1 and T_2 when compared to other treatments. Least tannin content was observed in $T_{9.2}$ and $T_{9.3}$ followed by $T_{9.1}$.T_7

Table - 21 Effect of processing and ordinary cooking on tannin and mineral extractability in horse gram

Treatment	Tannin mg/100 gm	Calcium extractability %	Iron extractability %	Phosphorus extractability %	Potassium extractability %	Zinc extractability %
T_1	149.15[a]	42.57 j	49.67[l]	38.76[m]	40.61 j	42.87[k]
T_2	149.02[ab] (-0.1)	44.53[i] (+0.05)	50.31[k] (+!)	42.03[k] (+8)	41.43[i] (+2)	43.57 j (+2)
T_3	148.92[b] (-0.1)	44.98[h] (+6)	51.96[j] (+5)	43.67[j] (+13)	42.76[h] (+6)	44.44[i] (+4)
T_4	148.83[b] (-0.2)	45.73[g] (+7)	53.61[i] (+8)	44.19[i] (+14)	43.29[g] (+7)	45.18[h] (+5)
T_5	141.56[c] (-5)	46.53[f] (+9)	54.81[h] (+10)	45.33[h] (+17)	44.07[f] (+9)	46.29[g] (+8)
T_6	140.64[d] (-6)	47.67[e] (+12)	56.07[g] (+13)	47.19[g] (+22)	45.32[e] (+12)	46.91[f] (+9)
T_7	138.16[f] (-6)	38.52[k] (-10)	44.35[m] (-11)	40.47[l] (+4)	39.06[k] (-4)	35.00[l] (-18)
$T_{8.1}$	139.90[e] (-6)	49.89[d] (+17)	63.93[f] (+29)	47.59[f] (+23)	47.72[d] (+18)	48.63[e] (+13)
$T_{8.2}$	139.90[e] (-6)	50.45[c] (+19)	64.59[e] (+30)	47.92[e] (+24)	47.85[dc] (+18)	48.86[e] (+14)
$T_{8.3}$	139.80[e] (-6)	50.30[c] (+18)	65.01[d] (+31)	48.58[d] (+25)	48.11[c] (+19)	49.20[d] (+16)
$T_{9.1}$	135.65[g] (-9)	51.56[b] (+21)	69.01[c] (+39)	50.32[c] (+30)	49.15[b] (+21)	50.00[c] (+17)
$T_{9.2}$	135.43[h] (-9)	51.95[a] (+22)	69.70[b] (+40)	50.65[b] (+31)	49.28[ab] (+21)	50.42[b] (+18)
$T_{9.3}$	135.11[i] (-9)	51.97[a] (+22)	70.23[a] (+41)	51.33[a] (+32)	49.53[a] (+22)	50.83[a] (+19)
		.708 **	**.629 ****	**.863 ****	**.825****	**.491****

Figures in parenthesis indicate per cent decrease (-) or increase (+) over control values

Values with different superscript are significantly different assessed by DMRT

** Correlation significant at the 0.01 level (2-tailed)

(159.77mg/100gm) also showed a significant reduction in tannin content compared to control.

Calcium extractability varied from 53.60% in T_1 to 67.35per cent in $T_{9.1}$.Calcium extractability was found to increase with a reduction in tannin content in all treatments except in T_7 which showed a decrease in extractability (47.97%) when compared to T_1(53.60%). A significant variation was observed in calcium extractability with respect to various treatments. Maximum calcium extractability was observed in $T_{9.1}$ (67.35%) which showed no significant variation with $T_{9.2}$ (67.33%) and $T_{9.3}$ (67.32%) . The least tannin content was also observed in $T_{9.1}$ (151.8mg/100g), $T_{9.2}$ and $T_{9.3}$ (151.50mg/100g).

Maximum iron extractability was observed in $T_{9.3}$ (38.41%) against T_1 (24.22%). There was no significant variation in iron extractability of $T_{9.1}$ (38.39mg/100g) and $T_{9.2}$ (38.40mg/100g) with that of $T_{9.3}$. Tannin content was also minimum in $T_{9.1}$, $T_{9.2}$and $T_{9.3}$ which showed no significant variation. There was also a significant decrease in iron extractability in T_7 (21.42%) even though there was a significant reduction in tannin content in T_7 (159.77mg/100g). In all other treatments there was a significant negative correlation between tannin content and iron extractability.

Phosphorus extractability was also maximum in $T_{9.3}$ (53.73%) where the tannin content was maximum (151.50mg/100g). There was no significant variation in phosphorus extractability in treatments $T_{9.1}$ and $T_{9.2}$with that of t and also there was no significant variation in tannin content of $T_{9.1}$, $T_{9.2}$ and $T_{9.3}$. There was a significant negative correlation between tannin content and phosphorus extractability of processed bengal gram samples after ordinary cooking.

Potassium extractability varied from 41.02% to 46.75% in different treatments as against 38.44% in T_1 (control).There was a significant variation in potassium extractability with respect to various treatments. Maximum potassium

Table - 22 Effect of processing and pressure cooking on tannin and mineral extractability in bengal gram

Treatment	Tannin mg/100 gm	Calcium extractability %	Iron extractability %	Phosphorus extractability %	Potassium extractability %	Zinc extractability %
T_1	203.16 ^{a}	53.60 ^{h}	24.22 ^{j}	41.87 ^{K}	38.44 ^{i}	52.50 ^{k}
P T_2	201.95 ^{b} (-1)	56.54 ^{g} (+6)	24.60 ^{i} (+2)	43.38 ^{J} (+4)	41.66 ^{h} (+8)	53.95 ^{i} (+3)
P T_3	198.05 ^{c} (-3)	59.53 ^{f} (+11)	26.83 ^{h} (+11)	44.20 ^{h} (+6)	43.35^{g} (+13)	53.75 (+2)^{i}
P T_4	197.46 ^{d} (-3)	60.22 ^{e} (+12)	27.79 ^{g} (+15)	45.90 ^{g} (+10)	43.53^{g} (+13)	58.22 ^{h} (+11)
P T_5	175.75^{e} (-13)	61.90 ^{d} (+16)	29.91 ^{f} (+24)	46.25 ^{f} (+11)	44.31 ^{f} (+15)	61.66 ^{g} (+17)
P T_6	170.42^{f} (-16)	63.01 ^{c} (+18)	30.98^{e} (+28)	48.61^{e} (+16)	44.82 ^{e} (+17)	62.50 ^{f} (+19)
P T_7	148.77^{j} (-27)	49.12 ^{i} (-8)	22.80^{k} (-6)	43.62 ^{i} (+4.18)	48.23 ^{a} (+26)	63.15 ^{e} (+20)
P $T_{8.1}$	168.88^{g} (-16)	64.64 ^{b} (+21)	34.83 ^{d} (+44)	50.69^{d} (+21)	46.22^{d} (+20)	64.64 ^{d} (+23)
P $T_{8.2}$	168.47^{h} (-17)	64.57 ^{b} (+21)	36.05^{c} (+49)	51.36 ^{c} (+23)	46.35 ^{d} (+21)	65.66 ^{c} (+25)
P $T_{9.1}$	150.12^{i} (-26)	67.58 ^{a} (+26)	39.09 ^{b} (+61)	54.41 ^{b} (+30)	46.90 ^{c} (+22)	69.60 ^{b} (+33)
P $T_{9.2}$	150.01^{i} (-26)	67.63 ^{a} (+26)	39.75 ^{a} (+64)	55.08 ^{a} (+32)	47.15 ^{a} (+23)	70.41 ^{a} (+34)
		.703 **	.858 **	.926 **	.819 **	.967 **

Figures in parenthesis indicate per cent decrease (-) or increase (+) over control values

Values with different superscript are significantly different assessed by DMRT

** Correlation significant at the 0.01level (2-tailed)

extractability was in $T_{9.3}$ (46.75%) which showed no significant variation with that of $T_{9.1}$ (46.57%) and $T_{9.2}$ (46.63%).There was a significant negative correlation between potassium extractability and tannin content.

Zinc extractability was also increased with a reduction in tannin content in processed bengal gram after ordinary cooking. Extractability increased from 53.84% in T_2 to 69.19% in $T_{9.3}$ as against 52.50% in T_1 (control).Maximum extractability of 69.19% was observed in $T_{9.3}$ with the least tannin content(151.50mg/100g).There was a significant negative correlation between tannin content and zinc extractability.

4.4.1.2 Green gram

In green gram (Table 20) there was a significant negative correlation between mineral extractability and tannin content. Among treatments, T_1(403.08mg/100g) had the highest tannin content which showed the least calcium extractability (20.01%). With various processing methods, tannin content reduced from 401.98mg/100g in T_2 to 144.41 mg/100g in $T_{9.3}$ which also showed maximum calcium extractability (28.84%).

Iron extractability increased from 50.43% in T_2 to 70.19% in $T_{9..3}$ which also showed the least tannin content (144.41mg/100g). There was a significant reduction in tannin content due to various processing methods with an increase in iron extractability. Increase in iron extractability showed a significant negative correlation with that of tannin in processed samples.

Phosphorus extractability was also increased from 48.84% in T_2 to 55.94% in $T_{9.3}$ as against 47.84% in T_1. There was a significant increase in phosphorus extractability due to various processing methods which showed total free amino acid, significant negative correlation with tannin content. Least tannin content was observed in $T_{9.3}$ (144.41mg/100g).

Table - 23 Effect of processing and pressure cooking on tannin and mineral extractability in green gram

Treatment	Tannin mg/100 gm	Calcium extractability %	Iron extractability %	Phosphorus extractability %	Potassium extractability %	Zinc extractability %
T_1	403.08[a]	20.01 [h]	49.15 [c]	47.84 [j]	34.57 [e]	68.57 [k]
P T_2	401.58[b] (-0.4)	20.56 [g] (+3)	51.07[c] (+4)	48.79[f] (+2)	42.22 [d] (+22)	69.71[j] (+2)
P T_3	397.40[c] (-1)	21.72 [f] (+9)	50.52 [c] (+3)	49.14 [h] (+3)	44.03 [cd] (+27)	70.27[i] (+3)[i]
P T_4	388.76[d] (-4)	22.69 [e] **(+13)**	52.95 [bc] (+8)	50.16 [g] (+5)	43.79[cd] (+27)	71.42 [h] (+4)
P T_5	203.83[e] (-49)	23.25 [d] (+16)	54.92 [bc] (+12)	50.99 [f] (+7)	44.07[cd] (+28)	72.26 [g] (+5)
P T_6	200.10[f] (-50)	26.00[c] (+30)	61.85[bc] (+25)	51.95 [e] (+9)	45.38 [c] (+31)	72.90 [f] (+6)
P T_7	145.78[i] (-64)	19.94[h] (-0.34)	51.68 [c] (+5)	48.95 [i] (+2)	50.69 [a] (+47)	73.33 [e] (+7)
P $T_{8.1}$	199.8[g] (-50)	27.51 [b] (+36)	65.57 [b] (+33)	54.27 [d] (+13)	48.33[b] (+40)	73.75 [d] (+8)
P $T_{8.2}$	198.6[h] (-51)	27.78 [b] (+39)	67.81 [a] (+38)	54.60[c] (+14)	48.83 [ab] (+41)	74.08 [c] (+8)
P $T_{9.1}$	144.51[j] (-64)	29.72 [a] (+49)	68.36 [a] (+39)	56.31 [d] (+18)	49.15 [ab] (+42)	76.00 [a] (+11)
P $T_{9.2}$	144.11[k] (-64)	29.78 [a] (+49)	68.68 [a] (+40)	56.66 [a] (+18)	49.25[ab] (+43)	75.31 [b] (+10)
		.923**	.917 **	.907 **	.840 **	.933 **

Figures in parenthesis indicate per cent decrease (-) or increase (+) over control values
Values with different superscript are significantly different assessed by DMRT
** Correlation significant at the 0.01level (2-tailed)

Table - 24 Effect of processing and pressure cooking on tannin and mineral extractability in horse gram

Treatment	Tannin mg/100 gm	Calcium extractability %	Iron extractability %	Phosphorus extractability %	Potassium extractability %	Zinc extractability %
T_1	149.15 [a]	42.57 [i]	49.67 [i]	38.76 [k]	40.61 [i]	42.87 [j]
P T_2	149.02 [ab] (-0.1)	43.86 [h] (+3)	51.64 [h] (+4)	42.21 [f] (+9)	42.16 [g] (+4)	44.28 [f] (+3)
P T_3	148.89 [bc] (-0.2)	44.99 [g] (+6)	52.44 [g] (+6)	43.85 [h] (+13)	43.66 [f] (+8)	45.18 [j] (+5)
P T_4	148.81 [c] (-0.2)	46.11 [f] (+8)	55.15 [f] (+11)	44.87 [g] (+16)	43.69 [e] (+8)	45.55 [g] (+6)
P T_5	141.43 [d] (-5)	46.87 [e] (+10)	53.39 [e] (+7)	45.53 [f] (+17)	44.41 [d] (+9)	46.29 [f] (+8)
P T_6	140.11 [e] (-6)	48.05 [d] (+13)	57.27 [d] (+15)	46.24 [e] (+19)	45.87 [c] (+13)	47.44 [e] (+11)
P T_7	137.94 [h] (-8)	38.92 [j] (-9)	44.54 [j] (-10)	40.79 [j] (+5)	41.11 [h] (+1)	35.5 [k] (-17)
P $T_{8.1}$	139.60 [f] (-6)	50.30 [c] (+18)	58.72 [c] +18)	48.60 [d] (+25)	46.63 [b] (+15)	48.00 [e] (+12)
P $T_{8.2}$	139.10 [g] (-7)	50.70 [b] (+19)	58.79 [c] (+18)	50.81 [c] (+39)	46.92 [b] (+16)	48.77 [c] (+14)
P $T_{9.1}$	135.43 [i] (-9)	52.32 [a] (+22)	60.34 [b] (+22)	51.33 [ab] (+32)	47.39 [a] (+17)	50.42 [b] (+18)
P $T_{9.2}$	135.01 [j] (-9)	52.35 [a] (+23)	60.78 [a] (+22)	52.13 [a] (+34)	47.54 [a] (+17)	50.81 [a] (+19)
		.747 **	.859 **	.879**	.845 **	.610**

Figures in parenthesis indicate per cent decrease (-) or increase (+) over control values

Values with different superscript are significantly different assessed by DMRT

** Correlation significant at the 0.01 level (2-tailed)

Maximum potassium extractability was found in T_7 (49.80%) which was significantly high as against T_1 (34.57%). In all the processing methods, there was a significant increase in potassium extractability which was found to have a significant negative correlation with that of tannin content.

Zinc extractability was also increased with a reduction in tannin content due to various processing methods. In control (T_1) zinc extractability was 68.57% with maximum tannin content (403.08mg/100gm). This is increased to
75.80% in $T_{9.3}$ which showed a significant reduction in tannin (144.41mg/100g). There was no significant variation in the zinc extractability of $T_{9.2}$ (75.62%) with that of $T_{9.3}$. There was a significant negative correlation between tannin content and zinc extractability.

4.4.1.3 Horse gram

As reveled in Table.21, tannin content of horse gram was 149.15mg/100g (T_1) which was significantly reduced to 135.11mg/100g in $T_{9.3}$. There was an increase in calcium extractability of horse gram. T_1 showed minimum calcium extractability (42.57mg/100gm), which significantly increased to 51.97% in $T_{9.3}$.Extractability, was 51.95% in $T_{9.2}$ which showed no significant variation with $T_{9.3}$. In T_7 with a significant reduction in tannin (138.16mg/100g) there was a significant reduction in calcium extractability also (38.52%). In all other processing methods, there was a significant negative correlation between calcium extractability and tannin content.

Iron extractability of T_1 (49.67%) was significantly increased to a maximum of 70.23% in $T_{9.3}$ which also showed the minimum tannin content (135.11mg/100g) after processing. There was a significant negative correlation between iron extractability and tannin content of processed samples of horse gram when cooked by ordinary method, except in T_7 which showed a reduction in iron extractability (38.52%) and tannin content (138.16mg/100g) with processing.

Table - 25 Effect of processing and ordinary cooking on crude fiber and mineral extractability in bengal gram

Treatment	Crude fiber g/100 gm	Calcium extractability %	Iron extractability %	Phosphorus extractability %	Potassium extractability %	Zinc extractability %
T_1	4.68 [a]	53.60 [h]	24.22 [i]	41.87 [l]	38.44 [i]	52.50 [k]
T_2	4.61[ab] (-1)	55.05 [g] (+3)	24.46 [h] (+1)	42.19 [k] (+1)	41.02 [h] (+7)	53.84 [j] (+3)
T_3	4.60 [abc] (-2)	59.36 [f] (+11)	25.90 [g] (+7)	43.49 [c] (+3.86)	42.85 [g] (+11)	55.13 [i] (+5)
T_4	4.60 [abc] (-2)	59.95 [e] (+12)	27.34 [f] (+13)	45.19 [h] (+8)	43.96 [f] (+14)	57.60 [h] (+10)
T_5	1.97[d] (-57)	61.62 [d] (+15)	29.02 [e] (+20)	46.89 [g] (+12)	44.64 [e] (+16)	61.27 [g] (+17)
T_6	1.95[d] (-58)	62.40 [c] (+16)	30.62 [d] (+26)	48.25 [f] (+15.)	45.69 [e] (+19)	62.78 [e] (+20)
T_7	0.90 [e] (-80)	47.97[l] (-11)	21.42[l] (-12)	42.78j (+2)	48.00[a] (+25)	61.27[f] (+17)
$T_{8.1}$	4.51 [bc] (-4)	63.46 [b] (+18)	32.62 [c] (+35)	49.33 [e] (+18)	45.83 [cd] (+19)	63.39 [d] (+21)
$T_{8.2}$	4.51 [bc] (-4)	63.43 [b] (+18)	32.33 [b] (+33)	49.67 [d] (+19)	45.86 [cd] (+19)	63.44[d] (+21)
$T_{8.3}$	4.48 [c] (-4)	63.39 [b] (+18)	32.35 [b] (+34)	49.86 [d] (+19)	46.09 [c] (+20)	63.45 [d] (+21)
$T_{9.1}$	4.53 [bc] (-3)	67.35 [a] (+26)	38.39 [a] (+57)	52.73 [c] (+26)	46.57 [b] (+21)	68.42 [c] (+30)
$T_{9.2}$	4.52 [bc] (-3)	67.33 [a] (+25)	38.40 [a] (+59)	53.40 [b] (+28)	46.63 [b] (+21)	68.80 [b] (+31)
$T_{9.3}$	4.51[bc] (-4)	67.32[a] (+25)	38.41[a] (+59)	53.73 [a] (+28)	46.75 [b] (+22)	69.19 [a] (+32)
		.762 **	.801 **	.986 **	.826**	.910**

Figures in parenthesis indicate per cent decrease (-) or increase (+) over control values
Values with different superscript are significantly different assessed by DMRT
** correlation significant at the 0.01level (2-tailed)

There was an increase in phosphorus extractability in all processed samples of horse gram with a significant reduction in tannin content . Maximum phosphorus extractability was found in $T_{9.3}$ (51.33%) with a significant reduction in tannin (135.11mg/100g). There was a significant negative correlation between phosphorus extractability and tannin content of processed and cooked horse gram samples.

An increase in potassium extractability was observed in all processed samples except in T_7 (39.06%) which showed a reduction in extractability when compared to control (40.61%). Maximum extractability was found in $T_{9.3}$ (49.53%) with least tannin content (135.11mg/100g). There was a significant negative correlation between tannin content and potassium extractability.

Regarding zinc extractability there was a significant increase with respect to various processing methods and a significant reduction in tannin content. But in T_7, with a significant reduction in tannin content (138.16mg/100g), there was a reduction in zinc extractability also (35.00%). Maximum zinc extractability was in $T_{9.3}$ (50.83%) with least tannin content (135.11mg/100g).

4.4.2. Effect of processing and pressure cooking methods on tannin and mineral extractability from selected pulses

4.4.2.1. Bengal gram

As revealed in Table.22, tannin content in bengal gram varied from 203.16mg/100g in T_1 (control) to 150.01mg/100g in $PT_{9.2}$ after processing and pressure cooking. Least tannin content was observed in PT_7 (148.77mg/100g) followed by $PT_{9.2}$ and $PT_{9.1}$ (150.01 and 150.12mg/100g).

Calcium extractability varied from 53.60% in T_1 to 67.63% in $PT_{9.2}$.Calcium extractability was found to increase with decrease in tannin content in all

Table - 26 Effect of processing and ordinary cooking on crude fiber and mineral extractability in green gram

Treatment	Crude fiber g/100 gm	Calcium extractability %	Iron extractability %	Phosphorus extractability %	Potassium extractability %	Zinc extractability %
T_1	4.17[a]	20.01 [h]	49.15[k]	47.84 [L]	34.57 [e]	68.57 [k]
T_2	4.13 [a] (-1)	20.29 [g] (+2)	50.43 [j] (+3)	48.84 [J K] (+2)	41.63 [a] (+20)	69.44 [j] (+1)
T_3	4.13 [a] (-1)	21.38 [f] (+7)	51.07[f] (+4)	48.91[J] (+2)	41.37 [d] (+20)	70.27 [i] (+2)
T_4	4.12 [a] (-1)	21.91 [e] (+10)	52.38 [g] (+7)	50.16[I] (+5)	42.16 [d] (+22)	71.17 [h] (+4)
T_5	1.95 [c] (-53)	23.17 [d] (+16)	54.40 [f] (+11)	52.39 [H] (+10)	44.47 [c] (+29)	73.52 [f] (+7)
T_6	1.94 [c] (-53)	24.32 [c] (+22)	64.40 [d] (+31)	52.94 [g] (+11)	45.22 [c] (+31)	74.20 [e] (+8)
T_7	0.70 [d] (-83)	20.46[g] (+2)	51.41[h] (+5)	48.64[k] (+2)	49.80[a] (+44)	73.17[g] (+7)
$T_{8.1}$	2.40 [b] (-42)	26.78 [b] (+34)	63.71 [e] (+30)	53.37 [f] (+12)	47.34 [b] (+37)	74.68 [d] (+9)
$T_{8.2}$	2.42 [b] (-42)	26.82 [b] (+34)	64.40 [d] (+31)	53.76 [e] (+12)	47.47 [b] (+37)	74.88[d] (+9)
$T_{8.3}$	2.45 [b] (-42)	26.85 [h] (+34)	64.86 [c] (+32)	55.07[d] (+15)	47.72 [ab] (+38)	76.01 [a] (+11)
$T_{9.1}$	2.43 [b] (-42)	28.77 [g] (+44)	69.42 [b] (+41)	55.28 [c] (+16)	48.48[ab] (+40)	75.31 [a] (+10)
$T_{9.2}$	2.41[b] (-42)	28.81 [a] (+44)	70.17 [a] (+43)	55.62[b] (+16)	48.60 [ab] (+41)	75.62 [b] (+10)
$T_{9.3}$	2. 40 [b] (-42)	28.84 [a] (+44)	70.19 [a] (+43)	55.94[a] (+17)	48.78 [ab] (+41)	75.80 [b] (+11)
		.862 **	**.687****	**.973****	**.895****	**.929****

Figures in parenthesis indicate per cent decrease (-) or increase (+) over control values

Values with different superscript are significantly different assessed by DMRT

** correlation significant at the 0.01level (2-tailed)

Table - 27 Effect of processing and ordinary cooking on crude fiber and mineral extractability in horse gram

Treatment	Crude fiber g/100 gm	Calcium extractability %	Iron extractability %	Phosphorus extractability %	Potassium extractability %	Zinc extractability %
T_1	4.21[a]	42.57 j	49.67[l]	38.76[m]	40.61 j	42.87[k]
T_2	4.18[ab] (-1)	44.53[i] (+0.05)	50.31[k] (+!)	42.03[a] (+8)	41.43[i] (+2)	43.57 j (+2)
T_3	4.18[ab] (-1)	44.98[h] (+6)	51.96[j] (+5)	43.67[j] (+13)	42.76[h] (+6)	44.44[i] (+4)
T_4	4.16[abc] (-1)	45.73[g] (+7)	53.61[i] (+8)	44.19[i] (+14)	43.29[g] (+7)	45.18[h] (+5)
T_5	1.99[e] (-52)	46.53[f] (+9)	54.81[h] (+10)	45.33[h] (+17)	44.07[f] (+9)	46.29[g] (+8)
T_6	1.97[e] (-53)	47.67[e] (+12)	56.07[g] (+13)	47.19[g] (+22)	45.32[e] (+12)	46.91[f] (+9)
T_7	1.42[f] (-66)	38.52[k] (-10)	44.35[m] (-11)	40.47[f] (+4)	39.06[k] (-4)	35.00[f] (-18)
$T_{8..1}$	3.98[cd] (-5)	49.89[d] (+17)	63.93[f] (+29)	47.59[f] (+23)	47.72[d] (+18)	48.63[e] (+13)
$T_{8.2}$	3.98[cd] (-5)	50.45[c] (+19)	64.59[e] (+30)	47.92[e] (+24)	47.85[dc] (+18)	48.86[e] (+14)
$T_{8.3}$	3.96[d] (-6)	50.30[c] (+18)	65.01[d] (+31)	48.58[d] (+25)	48.11[c] (+19)	49.20[d] (+16)
$T_{9.1}$	4.04[abc] (-4)	51.56[b] (+21)	69.01[c] (+39)	50.32[c] (+30)	49.15[b] (+21)	50.00[c] (+17)
$T_{9.2}$	4.01[abc] (-5)	51.95[a] (+22)	69.70[b] (+40)	50.65[b] (+31)	49.28[ab] (+21)	50.42[b] (+18)
$T_{9.3}$	4.00[abc] (-5)	51.97[a] (+22)	70.23[a] (+41)	51.33[a] (+32)	49.53[a] (+22)	50.83[a] (+19)
		.775 **	**.621 ****	**.846 ****	**.839 ****	**.505 ****

Figures in parenthesis indicate per cent decrease (-) or increase (+) over control values
Values with different superscript are significantly different assessed by DMRT
** correlation significant at the 0.01 level (2-tailed)

treatments except in PT_7, which showed a decrease (49.12%) when compared to control (53.60%).A significant difference was observed in calcium extractability with respect to various treatments. Maximum calcium extractability was observed in $PT_{9.2}$ (67.63%) followed by $PT_{9.1}$ (67.58%).

Maximum iron extractability was observed in $PT_{9.2}$ (39.75%) as against T_1 (24.22%).There was also a significant decrease in iron extractability in PT_7 (22.80%) even though there was a significant reduction in tannin content (148.77mg/100g).In all other treatments there was a significant negative correlation between iron extractability and tannin content.

Phosphorus extractability varied from 41.87% in T_1 (control) to 55.08% in $PT_{9.2}$. Phosphorus extractability was also maximum in $PT_{9.2}$ (55.08 %) where the tannin content was minimum (150.01mg/100g). There was a significant negative correlation between tannin content and phosphorus extractability of processed bengal gram samples after pressure cooking.

Potassium extractability was also maximum in $PT_{9.2}$ (47.15%) as against T_1 (38.44%) where the tannin content was minimum 150.01mg/100g compared to the control (203.16mg/100g). There was a significant negative correlation between potassium extractability and tannin content in all the treatments.

The same trend was observed in zinc extractability also. Maximum zinc extractability was observed in $PT_{9.2}$ (70.41%) where the tannin content was minimum (150.01mg/100g). There was a significant negative correlation between zinc extractability and tannin content in all the treatments.

4.4.2.2 Green gram

Pressure cooking of green gram, processed in different ways (table.23) revealed that there was a significant reduction in tannin content in all

Table - 28 Effect of processing and pressure cooking on crude fiber and mineral extractability in bengal gram

Treatment	Crude fiber g/100 gm	Calcium extractability %	Iron extractability %	Phosphorus extractability %	Potassium extractability %	Zinc extractability %
T_1	4.68 [a]	53.60 [h]	24.22 [j]	41.87 [K]	38.44 [i]	52.50 [k]
P T_2	4.60 [b] (-2)	56.54 [g] (+6)	24.60 [I] (+2)	43.38 [J] (+4)	41.66 [h] (+8)	53.95 [J] (+3)
P T_3	4.59 [b] (-2)	59.53 [f] (+11)	26.83 [h] (+11)	44.20 [h] (+6)	43.35 [g] (+13)	53.75 (+2) [I]
P T_4	4.59 [b] (-2)	60.22 [e] (+12)	27.79 [g] (+15)	45.90 [g] (+10)	43.53 [g] (+13)	58.22 [h] (+11)
P T_5	1.79 [d] (-62)	61.90 [d] (+16)	29.91 [f] (+24)	46.25 [f] (+11)	44.31 [f] (+15)	61.66 [g] (+17)
P T_6	1.75 [d] (-63)	63.01 [c] (+18)	30.98 [c] (+28)	48.61 [e] (+16)	44.82 [e] (+17)	62.50 [f] (+19)
P T_7	0.90 [e] (-80)	49.12 [f] (-8)	22.80 [k] (-6)	43.62 [f] (+4)	48.23 [a] (+26)	63.15 [e] (+20)
P $T_{8.1}$	4.40 [c] (-6)	64.64 [b] (+21)	34.83 [d] (+44)	50.69 [d] (+21)	46.22 [d] (+20)	64.64 [d] (+23)
P $T_{8.2}$	4.40 [c] (-6)	64.57 [b] (+21)	36.05 [c] (+49)	51.36 [c] (+23)	46.35 [d] (+21)	65.66 [c] (+25)
P $T_{9.1}$	4.51 [b] (-4)	67.58 [a] (+26)	39.09 [b] (+61)	54.41 [b] (+30)	46.90 [c] (+22)	69.60 [b] (+33)
P $T_{9.2}$	4.51 [b] (-4)	67.63 [a] (+26)	39.75 [a] (+64)	55.08 [a] (+32)	47.15 [d] (+23)	70.41 [a] (+34)
		.763 **	.842 **	.918 **	.818**	.941**

Figures in parenthesis indicate per cent decrease (-) or increase (+) over control values
Values with different superscript are significantly different assessed by DMRT
** Correlation significant at the 0.01 level (2-tailed)

treatments. Among treatments, minimum tannin content was observed in $PT_{9.2}$ (144.11mg/100g) and $PT_{9.1}$ (144.51mg/100g) followed by PT_7 (145.78mg/100g) .Calcium extractability varied from 20.01 per cent in T_1 to 29.78 % in $PT_{9.2}$. There was a significant reduction in calcium extractability in PT_7 (19.94%).There was a significant negative correlation between calcium extractability and tannin content in all other treatments

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Iron extractability increased from 49.15 per cent in T_1 to 68.68 per cent in $PT_{9.2}$ which showed the least tannin content (144.11mg/100g). Increase in iron extractability showed a significant negative correlation with that of tannin in processed samples.

Maximum phosphorus extractability was observed in $PT_{9.2}$ 56.66 per cent as against 47.84 per cent in T_1 control. There was a significant increase in phosphorus extractability due to various processing methods which showed a significant negative correlation with tannin content.

The same trend was observed in potassium and zinc extractability of pressure cooked green gram samples. Maximum potassium extractability was observed in $PT_{9.2}$ (49.25 %) and maximum zinc extractability was observed in $PT_{9.1}$ (76.00%). There was a significant negative correlation between tannin content and potassium and zinc extractability.

4.4.2.3 Horse gram

As revealed in Table 24, tannin content of horse gram is 149.15mg/100g (T_1) which was significantly reduced to 135.01mg/100g in $PT_{9.2}$. Calcium extractability was found to increase with a decrease in tannin content in all treatments except in PT_7 which showed a decrease (38.92%) when compared to T_1 (42.57%) . Maximum calcium extractability was observed in $PT_{9.2}$ 52.35% whichshowed

Table - 29 Effect of processing and pressure cooking on crude fiber and mineral extractability in green gram

Treatment	Crude fiber g/100 gm	Calcium extractability %	Iron extractability %	Phosphorus extractability %	Potassium extractability %	Zinc extractability %
T_1	4.17[a]	20.01[h]	49.15[c]	47.84[f]	34.57[e]	68.57[k]
P T_2	4.12[a] (-1)	20.56[g] (+3)	51.07[c] (+4)	48.79[f] (+2)	42.22[d] (+22)	69.71 (+2)
P T_3	4.10[a] (-2)	21.72[f] (+9)	50.52[c] (+3)	49.14[h] (+3)	44.03[cd] (+27)	70.27 (+3)[l]
P T_4	4.10[a] (-2)	22.69[e] **(+13)**	52.95[bc] (+8)	50.16[g] (+5)	43.79[cd] (+27)	71.42[h] (+4)
P T_5	1.90[c] (-54)	23.25[d] (+16)	54.92[bc] (+12)	50.99[f] (+7)	44.07[cd] (+28)	72.26[g] (+5)
P T_6	1.88[c] (-55)	26.00[c] (+30)	61.85[bc] (+25)	51.95[e] (+9)	45.38[c] (+31)	72.90[f] (+6)
P T_7	0.60[d] (-85)	19.94[h] (-0.34)	51.68[c] (+5)	48.95[f] (+2)	50.69[a] (+47)	73.33[e] (+7)
P $T_{8.1}$	2.42[b] (-42)	27.51[b] (+36)	65.57[b] (+33)	54.27[d] (+13)	48.33[b] (+40)	73.75[d] (+8)
P $T_{8.2}$	2.42[b] (-42)	27.78[b] (+39)	67.81[a] (+38)	54.60[c] (+14)	48.83[ab] (+41)	74.08[c] (+8)
P $T_{9.1}$	2.51[b] (-40)	29.72[a] (+49)	68.36[a] (+39)	56.31[d] (+18)	49.15[ab] (+42)	76.00[a] (+11)
P $T_{9.2}$	2.50[b] (-40)	29.78[a] (+49)	68.68[a] (+40)	56.66[a] (+18)	49.25[ab] (+43)	75.31[b] (+10)
		.890**	.919**	.905**	.876 **	.819 **

Figures in parenthesis indicate per cent decrease (-) or increase (+) over control values

Values with different superscript are significantly different assessed by DMRT

** Correlation significant at the 0.01 level (2-tailed)

Table – 30 Effect of processing and pressure cooking on crude fiber and mineral extractability in horse gram

Treatment	Crude fiber g/100 gm	Calcium extractability %	Iron extractability %	Phosphorus extractability %	Potassium extractability %	Zinc extractability %
T_1	4.21[a]	42.57[i]	49.67[i]	38.76[k]	40.61[i]	42.87[j]
P T_2	4.18[a] (-1)	43.86[h] (+3)	51.64[h] (+4)	42.21[f] (+9)	42.16[g] (+4)	44.28[i] (+3)
P T_3	4.17[a] (-1)	44.99[g] (+6)	52.44[g] (+6)	43.85[h] (+13)	43.66[f] (+8)	45.18[j] (+5)
P T_4	4.16[a] (-1)	46.11[f] (+8)	55.15[f] (+11)	44.87[g] (+16)	43.69[e] (+8)	45.55[g] (+6)
P T_5	1.94[c] (-54)	46.87[e] (+10)	53.39[e] (+7)	45.53[f] (+17)	44.41[d] (+9)	46.29[f] (+8)
P T_6	1.93[c] (-54)	48.05[d] (+13)	57.27[d] (+15)	46.24[e] (+190	45.87[c] (+13)	47.44[e] (+11)
P T_7	1.45[d] (-66)	38.92[j] (-9)	44.54[j] (-10)	40.79[j] (+5)	41.11[h] (+1)	35.5[k] (-17)
P $T_{8.1}$	3.97[b] (-6)	50.30[c] (+18)	58.72[c] +18)	48.60[d] (+25)	46.63[b] (+15)	48.00[e] (+12)
P $T_{8.2}$	3.96[b] (-6)	50.70[b] (+19)	58.79[c] (+18)	50.81[c] (+39)	46.92[b] (+16)	48.77[c] (+14)
P $T_{9.1}$	4.01[b] (-5)	52.32[a] (+22)	60.34[b] (+22)	51.33[ab] (+32)	47.39[a] (+17)	50.42[b] (+18)
P $T_{9.2}$	4.01[b] (-5)	52.35 (+23)	60.78 (+22)	52.13[a] (+34)	47.54[a] (+17)	50.81 (+19)
		.668 **	.728 **	.836 **	.889 **	.637 **

Figures in parenthesis indicate per cent decrease (-) or increase (+) over control values
Values with different superscript are significantly different assessed by DMRT
** Correlation significant at the 0.01 level (2-tailed)

no significant variation with $PT_{9.1}$ (52.32%). In all other treatments there was a significant negative correlation between tannin content and calcium extractability except in T_7.

Maximum iron, potassium and zinc extractability was observed in $PT_{9.2.}$ (60.78, 47.54 and 50.81% respectively). In $PT_7$the extractability of iron (44.54%) and zinc (35.5%) was reduced significantly when compared to $T_{1.}$ Maximum phosphorus extractability was observed in $PT_{8.2}$ (50.81%). There was a significant negative correlation between calcium, iron and zinc extractability with tannin content except in T_7.

4.5 Effect of processing methods and cooking on crude fiber and mineral extractability from selected pulses

4.5.1. Ordinary cooking

4.5.1.1. Bengal gram

As revealed in Table .25 there was a significant reduction in crude fiber content of bengal gram due to various processing and ordinary cooking methods. Maximum reduction in crude fiber was observed in T_7 (0.90g/100g) followed by T_6 (1.95g/100g) and T_5 (1.97g/100g).

calcium extractability in bengal gram was maximum in $T_{9.1}$ (67.35%) under ordinary cooking in which the crude fiber content was 4.53g/100gm compared to control value of (T_1) 4.68g/100gm. There observed a significant negative correlation between crude fiber content and calcium extractability except in T_7, which showed the least crude fiber content (0.90g/100gm) among treatments, but the least calcium extractability also (47.97%) as against 53.60% in control (T_1).

The same trend was observed with iron extractability also. In T_1 iron extractability was only 24.22% with maximum crude fiber content (4.68g/100gm). There was a significant negative correlation between crude fiber content

and iron extractability with processing and ordinary cooking of bengal gram except for T_7 which showed a positive correlation between crude fiber (0.90g/100gm) and iron extractability (21.42%) as against 24.22% in T_1(control).

Phosphorus extractability showed a significant negative correlation with crude fiber. Maximum phosphorus extractability was seen in $T_{9.3}$ (53.73%) where the crude fiber was significantly reduced to 4.51g/100gm as against 4.68g/100gm in T_1 (control). Phosphorus extractability was least (41.87%) in T_1 where the crude fiber content was maximum (4.68g/100gm). Crude fiber was least in T_7 (0.90g/100gm) but phosphorus extractability was only 42.78% but still higher than T_1 (41.87%).

Potassium extractability showed a significant negative correlation with crude fiber in all treatments. Maximum potassium extractability was in T_7 (48%) which also showed the least crude fiber content (0.90g/100gm).

Zinc extractability also had a significant negative correlation with crude fiber. Maximum reduction in crude fiber was observed in T_7 (0.90g/100gm) which showed a significant increase in zinc extractability (61.27%) but maximum extractability (69.19%) was found in $T_{9.3.}$

4.5.1.2 Green gram

As revealed in Table.26, there was a significant reduction in crude fiber content of green gram due to various processing and ordinary cooking methods. Lowest crude fiber content was observed in T_7 (0.70g/100g) as against T_1 (4.17g/100gm) followed by T_6 (1.94gm/100g) and T_5 (1.95g/100gm).

Calcium extractability was found to have a significant negative correlation with crude fiber. Maximum calcium extractability of 28.84% was

found in $T_{9.3,}$ in which there observed a significant reduction in crude fiber (2.40g/100gm) as against 4.17g/100gm in T_1 (control).

A significant increase in iron extractability was noted with different processing methods as against T_1 (control). Maximum iron extractability was observed in $T_{9.3}$ (70.19%) which also showed a significant reduction in crude fiber (2.40g/100gm) as against T_1 (4.17g/100gm). There was a significant negative correlation between crude fiber and iron extractability with different processing methods.

Phosphorus extractability was also found to have a significant negative correlation with crude fiber. Crude fiber content reduced to 0.70g/100gm in T_7 which showed an increase in phosphorus extractability (48.64%) as against T_1 (47.84%).

There was a significant increase in potassium extractability due to different processing methods and ordinary cooking in green gram. Maximum potassium extractability was observed in T_7 (49.80%) where crude fiber was also reduced to (0.70g/100gm).

Zinc extractability increased from 68.57% in T_1 to 76.01% in $T_{8.3}$. Zinc extractability showed a significant negative correlation with crude fiber content.

4.5.1.3 Horse gram

As revealed in table27, there was a significant increase in calcium extractability in horse gram samples processed by different methods and cooked by ordinary cooking method such as boiling. Maximum calcium extractability was in $T_{9.3}$ (51.97%). There was a significant reduction in crude fiber content in T_7 (1.42g/100gm) as against T_1 (4.21g/100gm) but calcium extractability was only 38.52% which was the least extractability among the treatments.

There was a significant increase in iron extractability with a significant reduction in crude fiber due to processing and ordinary cooking. Iron extractability increased to 70.23% in $T_{9.3}$ which was only 49.67% in T_1. Crude fiber content was also the least in T_7 (1.42g/100gm). Iron extractability was only 44.35% in T_7 as against 49.67% in T_1. There was a significant reduction in the crude fiber content of T_6 (1.97g/100g) and T_5 (1.99g/100gm). In all other samples, there was a significant correlation between crude fiber and iron extractability.

Regarding phosphorus extractability there was a significant negative correlation between crude fibers. A significant increase in phosphorus extractability was noted in all processed samples with a significant reduction in crude fiber. Maximum phosphorus extractability was in $T_{9.3}$ (51.33%).

Potassium extractability also showed an increase with a significant decrease in crude fiber content. Potassium extractability in T_1 (40.61%) was increased to 49.53% in $T_{9.3}$ but reduction in potassium extractability was observed in T_7 (39.06%) even with a reduction in crude fiber (1.42g/100gm). In all other treatments there was a significant negative correlation between crude fiber and potassium extractability.

There was an increase in zinc extractability from 42.87 %(T1) to 50.83 %($T_{9.3}$). A significant reduction in crude fiber content was also noted in all treatments. Zinc extractability was found to be less in T_7 (35%) as against T_1 (42.87%).

4.5.2. Effect of processing methods and pressure cooking on crude fiber and mineral extractability from selected pulses

4.5.2.1. Bengal gram

Pressure cooking of bengal gram, processed in different ways (Table .28) revealed that there was a significant reduction in crude fiber content in all

treatments with pressure cooking and a significant increase in calcium extractability except in PT_7. In PT_7, calcium extractability was reduced to 49.12% as against 53.60% in T_1, but there was a significant reduction in crude fiber in PT_7 (0.90g/100gm) compared to T_1 (4.68g/100gm). In all other samples there was a significant negative correlation between crude fiber and calcium extractability.

The same trend was observed in iron extractability also. Iron extractability in PT_7 was 22.80% as against 24.22% in T_1 but crude fiber showed a significant reduction in PT_7 (0.90g/100gm). In all other samples there was a significant negative correlation between crude fiber and iron extractability.

With regard to phosphorus .potassium and zinc extractability there was a significant negative correlation between extractability and crude fiber content in all the treatments. Maximum phosphorus and zinc extractability was in $PT_{9.2}$ (55.08 and 70.41% respectively), in which there was also a significant reduction in crude fiber (4.51g/100gm). But potassium extractability was maximum in PT_7 (48.23%) which also showed the least crude fiber (0.90g/100gm). Phosphorus, potassium and zinc extractability showed a significant negative correlation with crude fiber.

4.5.2.2. Green gram

As shown in Table.29, maximum reduction in crude fiber was observed in PT_7 (0.60g/100gm) among all treatments after pressure cooking of green gram. Extractability of calcium, iron and phosphorus was maximum in $PT_{9.2}$ (29.78, 68.68 and 56.66% respectively). Crude fiber was found to be minimum in PT_7 (0.60g/100gm) but potassium extractability was maximum in PT_7 (50.69%) as against T_1 (34.57%). Maximum zinc extractability was observed in $PT_{9.1}$ (76%). There was a significant negative correlation between crude fiber and extractability of iron, phosphorus and zinc.

4.5.2.3. Horse gram

As revealed in Table.30, there was a significant reduction in crude fiber in all treatments of horse gram after pressure cooking .PT_7 showed the least crude fiber (1.45g/100gm).Maximum calcium, iron, potassium and zinc extractability was observed in $PT_{9.2}$ (52.35, 60.78, 47.54 and 50.81% respectively). In PT_7 the extractability of calcium (38.92%), iron (44.54%) and zinc (35.50%) was reduced significantly when compared to control. Maximum phosphorus extractability was observed in $PT_{9.2}$ (52.13%). There was a significant negative correlation between iron phosphorus and zinc extractability with crude fiber.

Discussion

5. DISCUSSION

5.1. Effect of processing and cooking methods on total minerals and mineral extractability in pulses

Pulses represent dry grain legumes for human consumption. The content of iron and other minerals are generally high in legumes. However legumes also contain antinutritional factors which inhibit the absorption of essential dietary minerals.

In the present study, among the pulses horse gram showed the highest calcium (285.23 mg/100gm) followed by bengal gram (200.82 mg/100gm) and the least in green gram (122.75 mg/100gm). But maximum calcium extractability was in bengal gram (53.60%). During ordinary cooking there was not a significant increase in calcium extractability in bengal gram (55.05%) and horse gram (44.53%) but a significant increase in green gram (20.29%). After pressure cooking, a significant increase in calcium extractability was observed in bengal gram (56.54%), green gram (20.56%) and horse gram (43.86%) [Fig.1 (a), 1(b)].

Total iron content was maximum in bengal gram (10.33 mg/100gm) and the least in green gram (7.06 mg/100gm). There was a reduction in total iron content on both ordinary cooking and pressure cooking but a significant increase in iron extractability was observed in all pulses. About 4 per cent increase in iron extractability was seen in green gram and horse gram and about 2 per cent increase in bengal gram after pressure cooking.

Total phosphorus was highest in green gram (324.13 mg/100gm) and the least in horse gram (309.4 mg/100gm). Phosphorus extractability was also maximum in green gram (47.84%) and least in horse gram (38.76%). A significant reduction in total phosphorus was observed in bengal gram due to ordinary cooking and pressure cooking but the reduction in total phosphorus was not significant in horse gram. A significant increase in phosphorus extractability was noted in all pulses

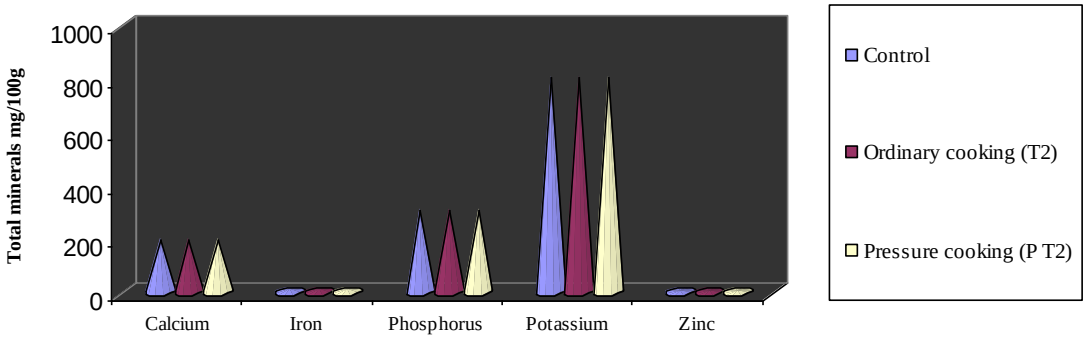

Fig.1(a) Effect of cooking methods on total minerals in bengal gram

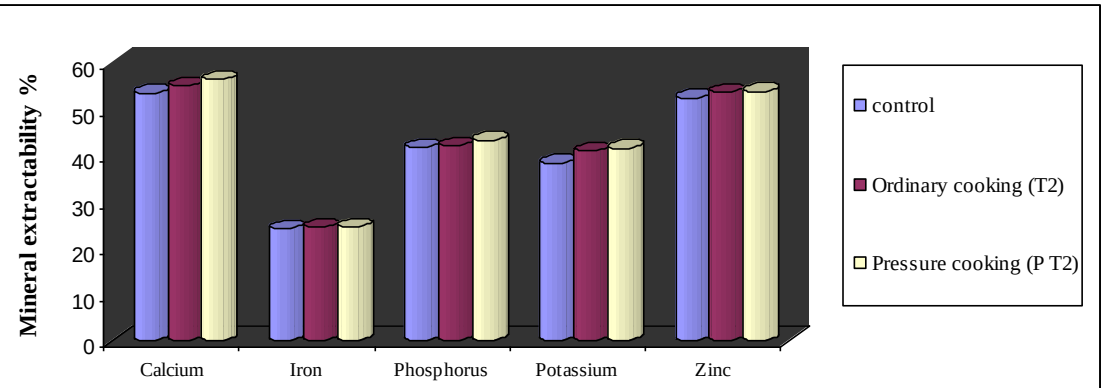

Fig.1(b) Effect of cooking methods on mineral extractability in bengal gram

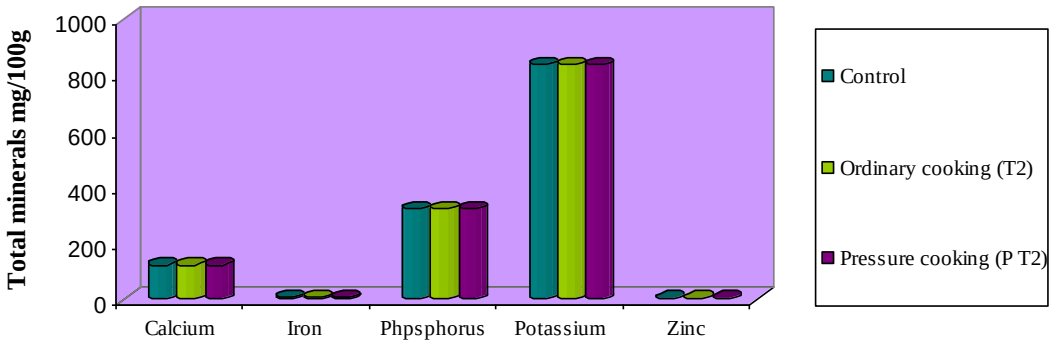

Fig.2(a) Effect of cooking methods on total minerals in green gram

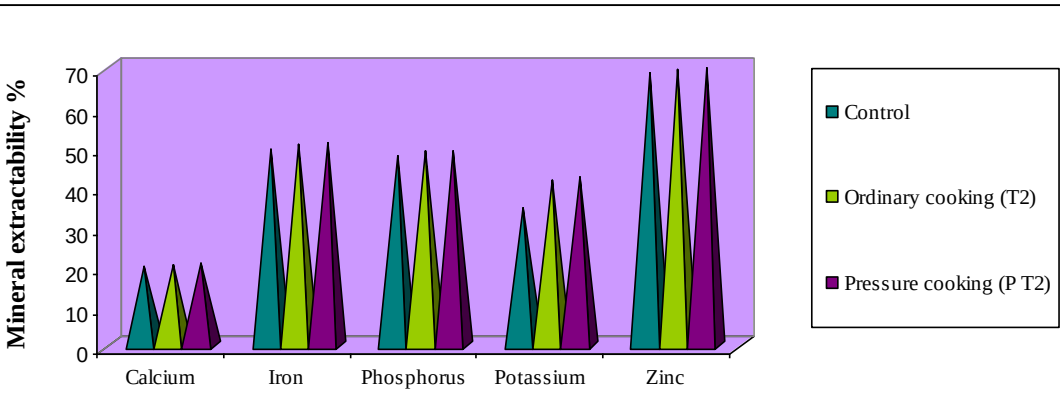

Fig.2(b) Effect of cooking methods on mineral extractability in green gram

due to cooking. Maximum phosphorus extractability was in pressure cooked green gram (48.79%) which showed a 2 per cent increase when compared to control. A 9 per cent increase was observed in pressure cooked horse gram after cooking [Fig.2 (a), 2(b)].

Total potassium was maximum in green gram (840.88 mg/100gm) and the least in horse gram (700.12 mg/100gm) but the horse gram showed the maximum potassium extractability (40.61%). Total potassium was found to decrease in all pulses due to cooking but this reduction was not significant in bengal gram (805.95 mg/100gm) and green gram (840.53 mg/100gm) in ordinary cooking, but a significant reduction in horse gram (699.64 mg/100gm). But after pressure cooking a significant reduction in total potassium was observed in all pulses.

There was a significant increase in potassium extractability in all pulses due to cooking especially after pressure cooking. Maximum potassium extractability was in green gram (42.22%) which showed a 22 per cent increase when compared to control. This was followed by an 8 per cent increase in bengal gram with an extractability of 41.66 per cent and a 4 per cent increase in horse gram with an extractability of 42.16 per cent.

Total zinc was highest in bengal gram (3.90 mg/100gm) and the least in horse gram (2.80 mg/100gm). There was a reduction in total zinc in bengal gram and green gram after cooking but not in horse gram. Extractability of zinc was highest in green gram (68.57%) and the least in horse gram (42.87%). After cooking by both methods a significant increase in zinc extractability was observed in all pulses. Maximum zinc extractability was in pressure cooked green gram (69.71%) followed by bengal gram (53.95%) [Fig.3 (a), 3(b)].

Antinutrients in pulses especially phytate reduce the bioavailability of divalent cations by the formation of insoluble phytates. However reduction in phytic acid as a result of cooking may explain higher HCl extractability of minerals from pulses.

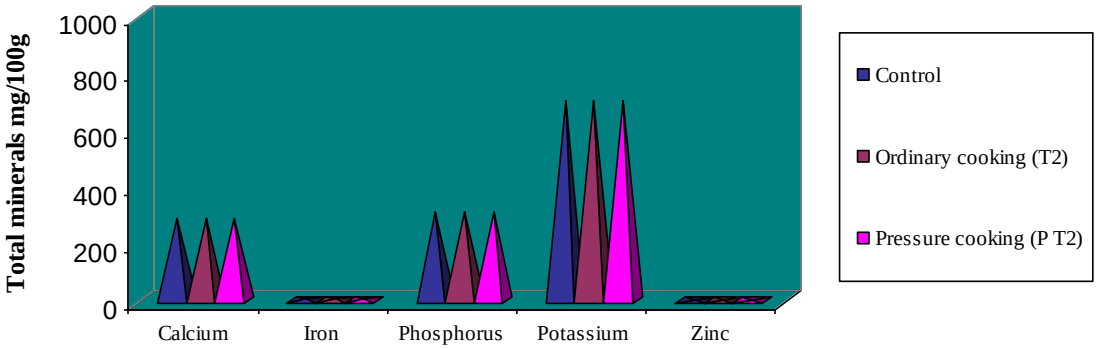

Fig.3(a) Effect of cooking methods on total minerals in horse gram

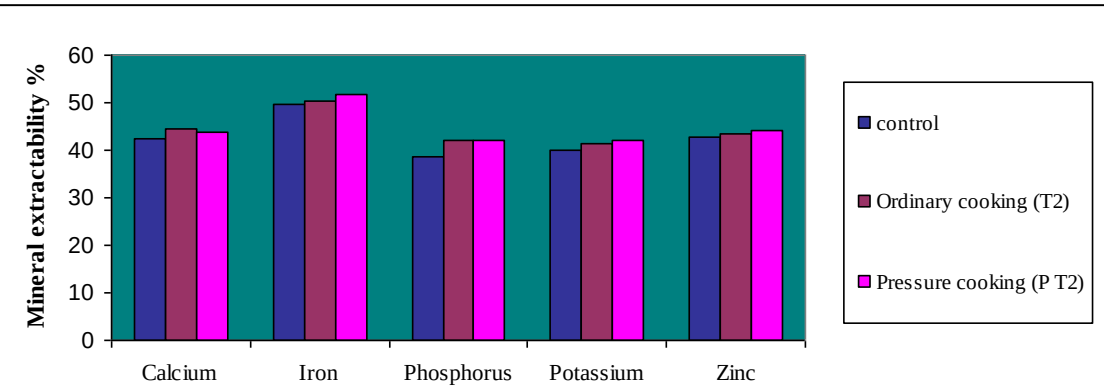

Fig.3(b) Effect of cooking methods on mineral extractability in horse gram

Various processing methods of pulses have been reported to lower the level of antinutrients especially phytic acid which is a powerful chelating agent for dietary essential minerals. Hence the effect of household processing methods on the availability of minerals was studied.

Soaking of pulses is one of the oldest methods of pretreatments of pulses before cooking. Soaking facilitates quicker cooking of pulses.

Soaking both 6 h and 12 h showed a reduction in total calcium content in all the pulses by conventional cooking method and by pressure cooking. The reduction observed was significant in all pressure cooked samples of pulses but under ordinary cooking, the reduction in total calcium observed in bengal gram due to soaking for 6 h (199.2 mg/100gm) and 12 h (197.98 mg/100gm) was not significant when compared to the control (200.82 mg/100gm). The loss of total calcium during soaking may be due to leaching of minerals from pulses to cooking water. With 12 h soaking and pressure cooking the loss in total calcium was more due to faster rates of leaching. But the rate of leaching of total calcium in bengal gram soaked for 6 h and 12 h when cooked under conventional method remained more or less constant without significant changes. This may be partly due to reabsorption of the divalent cations (calcium) from cooking water and partly due to reaction between divalent cation like Ca^{++} and Mg^{++},released from protein-carbohydrate complex during soaking with soluble phytate to from non diffusible calcium phytate compounds. But during pressure cooking these compounds are diffused to the cooking water thus showing a significant reduction in total calcium. Reddy *et al.* ,(1978) reported on black gram that after cooking black gram by conventional method, the loss of calcium was not much more after initial leaching when it was soaked. The present result on bengal gram coincide with the result of Reddy *et al., (*1978) on black gram [Fig.4 (a), 4(b)].

There was a significant increase in calcium extractability in all pulses due to soaking and cooking. 6 h soaking of bengal gram showed an increase of about 11 per cent in calcium extractability by both cooking methods. After 12 h soaking the increase was about 12 per cent. 6 h of soaking in green gram increased the calcium extractability by 7 per cent during ordinary cooking and by 9 per cent by pressure cooking. 12 hour soaking further increased this to 10 per cent and 13 per cent

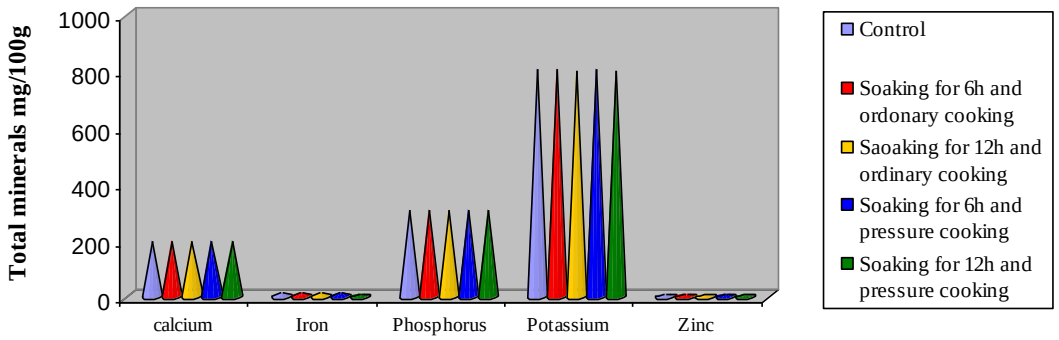

Fig.4(a) Effect of soaking and cooking methods on total minerals in bengal gram

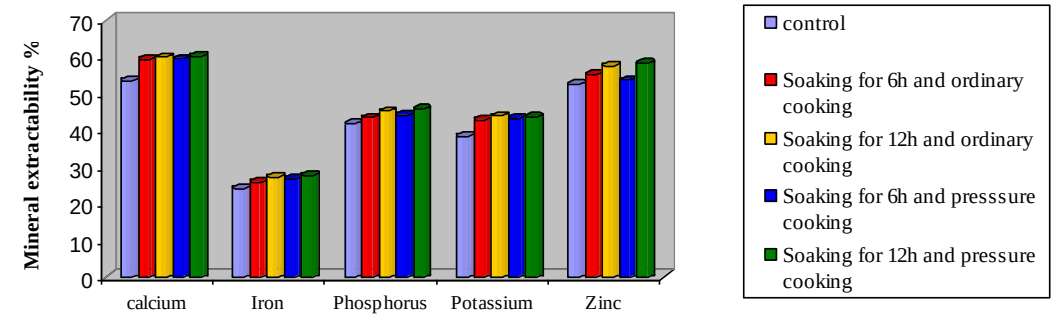

Fig.4(b) Effect of soaking and cooking methods on mineral extractability in bengal gram

respectively. In horse gram, 6 hour soaking showed a 6 per cent increase in calcium extractability by both methods of cooking but 12 h soaking showed a 7 per cent increase under ordinary cooking and about 8 per cent increase by pressure cooking. This is inline with the result of Duhan *et al.*, (2001) who found an increase in HCl extractability of calcium in pulses soaked for 6 h and as the period of soaking was increased from 6-12 h a successive improvement in calcium extractability.

A significant reduction in total iron was observed in soaked bengal gram and green gram in both cooking methods. The reduction in total iron in horse gram was not significant except in samples soaked for 12 h and pressure cooked.

About 3 and 6 per cent loss of total iron was observed in bengal gram soaked for 6 h by ordinary cooking and pressure cooking respectively. After 12 h of soaking this loss increased to 6 and 11 per cent respectively. Similarly maximum loss in iron was observed in 12 hour soaked green gram and horse gram after pressure cooking.

Extractability of iron in bengal gram soaked for 6 h and cooked by ordinary method was increased by 7 per cent and further to 11 per cent after pressure cooking [Fig.5(a), 5(b)]. This was increased to 13 per cent and 15 per cent respectively after 12 h soaking. A 4 per cent increase in iron extractability was found in green gram soaked for 6 h and cooked under conventional method but after pressure cooking the extractability showed only 3 per cent increase. After 12 h soaking iron extractability increased by 7 per cent and 8 per cent during ordinary cooking and pressure cooking respectively. For horse gram 11 per cent increase in iron extractability was observed in 12 hour soaked samples after pressure cooking.

The results are in good agreements with that of Lestienne *et al.*, (2005) who also observed a reduction in iron content of the soaked grains as compared to raw ones. Elmaki *et al.*, (2005) also revealed that as a result of soaking in water HCl extractability of iron increased significantly in three cultivars of white bean from the control value of 15.7 per cent, 11.7 per cent and 7.74 per cent to 32.0 per cent, 23.5 per cent and 19.2 per cent respectively. However significant increase in HCl extractability of iron was observed after cooking the seeds and it was increased to 47.3 per cent, 49.4 per cent and 45.3 per cent for the cultivars respectively. As a

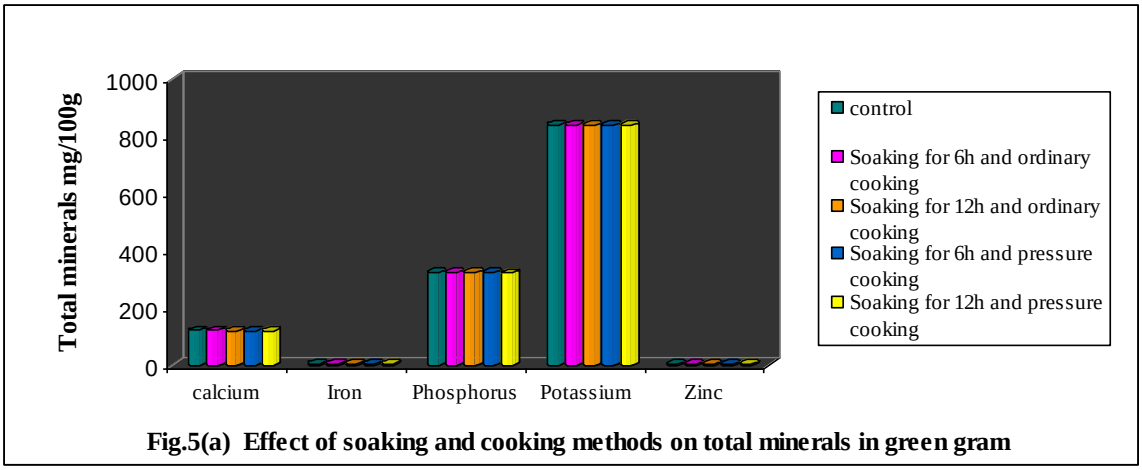

Fig.5(a) Effect of soaking and cooking methods on total minerals in green gram

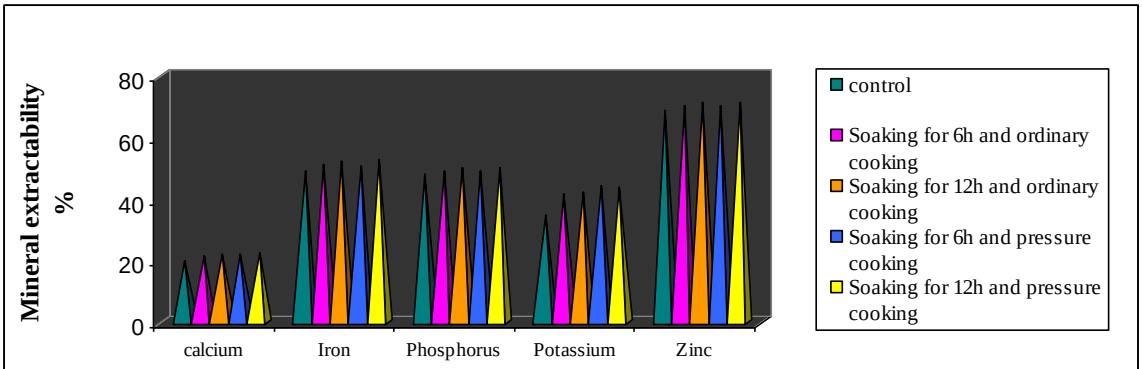

Fig.5(b) Effect of soaking and cooking methods on mineral extractability in green gram

divalent cation, iron is also generally present in association with phytic acid and this may be responsible for its lower extractability. However reduction in phytic acid as a result of soaking and cooking may explain higher HCl extractability of iron.

A significant reduction in total phosphorus was observed due to soaking and cooking in all the pulses except in green gram soaked for 6 h and cooked by ordinary method. Maximum reduction in total phosphorus was observed in soaking for 12 h and pressure cooking for all the three samples. A significant increase in phosphorus extractability was also observed in all the pulses. Soaking for 6 h and ordinary cooking increased phosphorus extractability of bengal gram by per cent, green gram by 25 per cent and horse gram by 13 per cent and when the soaking period was increased to 12 h the extractability also increased by 8 per cent, 5 per cent and 14 per cent respectively. In bengal gram maximum phosphorus extractability was 45.90 per cent which was in pressure cooked samples after 12 h of soaking. In green gram there was no difference in phosphorus extractability (50.16%) in samples soaked for 12 h and cooked by ordinary method and also in samples soaked for 12 h and pressure cooked. In horse gram, phosphorus extractability was increased to a maximum of 44.87 per cent in pressure cooked samples soaked for 12 h.

Duhan *et al.,* (2001) has also demonstrated the improvement in the HCl extractability of phosphorus in pigeon pea due to soaking followed by ordinary and pressure cooking. Cleavage of phosphorus from phytic acid may explain the increased HCl extractability of phosphorus in the soaked and cooked pulses. The reduction in phytate content of pulses during soaking can be attributed to leaching out of this antinutrient into soaking water under the influence of the concentration gradient. At higher temperature as in pressure cooking the initial rate of water inhibition and phytate leaching are high. The effect of phytate loss varies with crop species and different processing techniques.

There was no significant loss of total potassium in bengal gram and green gram when cooked by ordinary method after soaking for 6 h, but soaking for 12 h and ordinary cooking has resulted in a significant reduction in total potassium in bengal gram (804.32 mg/100gm), green gram (839.73 mg/100gm) and in horse gram (699.13 mg/100gm). Pressure cooking the pulses soaked for 6 and 12 h brought out a

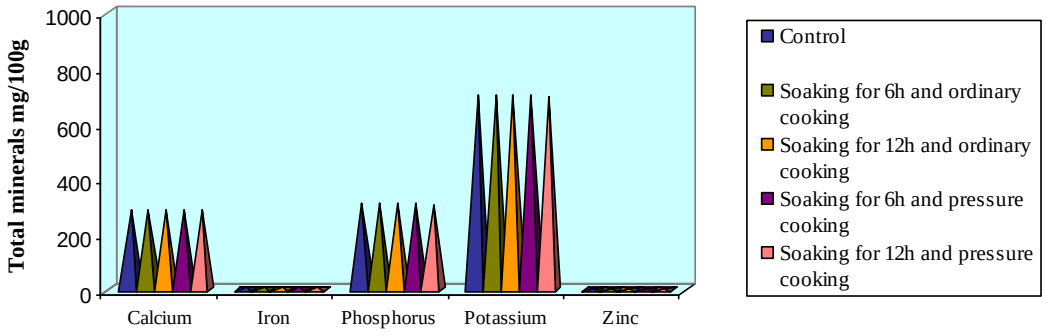

Fig.6(a) Effect of soaking and cooking methods on total minerals in horse gram

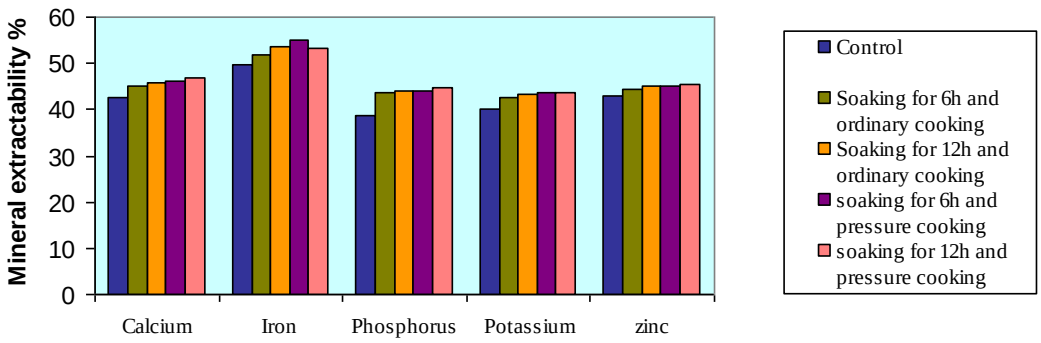

Fig.6(b) Effect of soaking and cooking methods on mineral extractability in horse gram

significant reduction in total potassium in all the pulses. HCl extractability of all the three pulses was improved by soaking and cooking. There was only 7 per cent increase in potassium extractability of bengal gram when cooked by ordinary method without soaking, but after soaking for 6 h this was increased to 11 per cent and reached to a maximum of 14 per cent when soaked for 12 h.

Unsoaked green gram when cooked by ordinary method increased the potassium extractability by 20 per cent, and even after 6 h soaking there was no change in this but after 12h of soaking extractability was increased to about 22 per cent [Fig.6 (a), 6(b)].

A 2 per cent increase in potassium extractability was noted in unsoaked and ordinary cooked horse gram but this was increased to 6 per cent after 6 h soaking and to 7 per cent after 12 h soaking. After pressure cooking potassium extractability was increased to 13 per cent in bengal gram, 27 per cent in green gram and 8 per cent in horse gram irrespective of the soaking period.

Total zinc was also reduced in bengal gram and green gram cooked after soaking. Unsoaked bengal gram when cooked by ordinary method showed a 7 per cent reduction in total zinc where as it was 9 per cent in 6 hour soaked and cooked samples. This was again increased to a loss of 22 per cent when soaked for 12 h. In green gram ordinary cooking of unsoaked pulses showed a 4 per cent reduction in total zinc which increased to a 6 per cent loss in 12 hour soaked pulses. In horse gram soaking and cooking had no effect on total zinc content which remained unchanged as in the control (2.80 mg/100gm). In bengal gram a 21 per cent reduction in total zinc was observed in samples which were pressure cooked after 12 h of soaking which was more or less same as that of the ordinary cooking method (22%). After pressure cooking the 12 hour soaked samples the loss was same (14%) as that of ordinary cooking after 12 hour soaking indicating no difference with cooking methods but only with soaking periods.

Cooking of unsoaked and soaked pulses caused a significant reduction in total zinc. It seems that soaking for 6h and 12h resulted in leaching of minerals which may be responsible for the mineral loss. The results are in agreement with

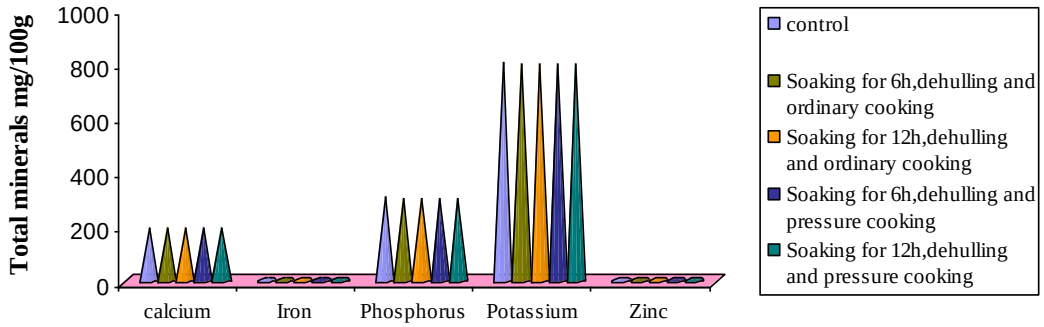

Fig.7(a) Effect of soaking,dehulling and cooking methods on total minerals in bengal gram

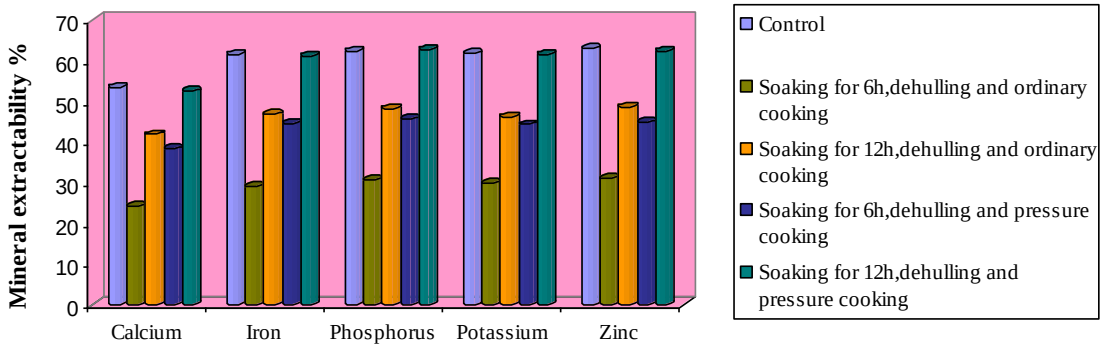

Fig.7(b) Effect of soaking,dehulling and cooking methods on mineral extractability in bengal gram

those reported earlier (Bishnoi and Khetarpaul, 1997; Duhan *et al*., 1989) Studies conducted by Duhan *et al*.,(2004) also revealed that on 6h soaking, the extractability of zinc and copper improved to the extent of 1-2 per cent and 1 per cent respectively. As the period of soaking increased, a significant increase in the extractability of zinc and copper was witnessed.

Cooking (both ordinary and pressure cooking) of pulses which are dehulled after soaking for 6h and 12h resulted in the loss of total minerals, but a significant increase in mineral extractability.

In the selected pulses there was a significant loss in total minerals when pulses were cooked after soaking and dehulling with some exceptions [Fig.7 (a), 7(b)]. In bengal gram loss in total calcium was not significant in dehulled pulses cooked by ordinary method, but significant loss was observed in the case of other minerals. Similarly in horse gram, reduction in total iron was not significant under ordinary cooking method. Total zinc also showed no significant reduction in horse gram soaked for 6h and 12h and cooked by two methods.

Significant increase in mineral extractability was observed after soaking and dehulling of pulses. In Bengal gram, an increase of 15 per cent and 16 per cent in calcium extractability was observed in samples soaked for 6h and 12h respectively after ordinary cooking, but after pressure cooking calcium extractability was increased to 16 and 18 per cent. The increase in calcium extractability by soaking and cooking was only 11-12 per cent in bengal gram.

Total iron decreased significantly, but HCl extractability of iron was increased by 20 per cent in dehulled bengal gram soaked for 6h and by 26 per cent in dehulled samples soaked for 6h and by 26 per cent in dehulled samples soaked for 12h after ordinary cooking. But after pressure cooking this was increased to 24 and 28 per cent respectively which showed an impact on pressure cooking on iron extractability. The iron extractability of soaked bengal gram (6h and 12h) by ordinary cooking was only 7 to 13 per cent respectively and in pressure cooking it was 11-15 per cent respectively.

There was a significant reduction in total phosphorus in dehulled bengal gram cooked by both methods after soaking for 6h and 12h. But the increase in HCl extractability of phosphorus which was 4 per cent in 6h soaking and ordinary cooking was increased to 12 per cent after dehulling. In the same way an increase by 15 per cent was observed in phosphorus extractability of soaked (12h) and dehulled bengal gram under ordinary cooking as against 8 per cent in bengal gram which was not dehulled after soaking (12h).

Soaked (6h) and dehulled bengal gram after pressure cooking showed an increase in phosphorus extractability by 11 per cent which was only 6 per cent in undehulled bengal gram. Pressure cooking of dehulled bengal gram after soaking (12h) increased the phosphorus extractability by 16 per cent as against 10 per cent in undehulled soaked (12h) bengal gram, showing the effect of dehulling and pressure cooking in increasing the phosphorus extractability.

Potassium extractability in bengal gram also increased during ordinary cooking of soaked (6h) and dehulled pulses by 16 per cent and 19 per cent after soaking for 12h, as against 11 per cent and 14 per cent in soaked and undehulled pulses. After pressure cooking of soaked and dehulled pulses, the potassium extractability was increased by 15 per cent (6h soaking) and 17 per cent (12h soaking) as against 13 per cent in undehulled pulses.

There was significant loss in total zinc in bengal gram after ordinary and pressure cooking. When soaked (6h) and dehulled pulses were cooked by ordinary methods the zinc extractability was increased by 17 per cent as against 5 per cent in undehulled pulses. After soaking for 12h, dehulled pulses showed an increase in zinc extractability by 20 per cent by ordinary cooking which was only 10 per cent in undehulled pulses. After pressure cooking of soaked (6h) and dehulled bengal gram, there was no difference in the increase in zinc extractability from that of ordinary cooking (17%) but the increase was only 2 per cent in pressure cooked samples which was only soaked (6h). After pressure cooking of soaked (12h) and dehulled bengal gram zinc extractability was increased by 19 per cent as against 20 per cent in ordinary cooking. But the increase in undehulled soaked (12h) bengal gram was only11per cent.

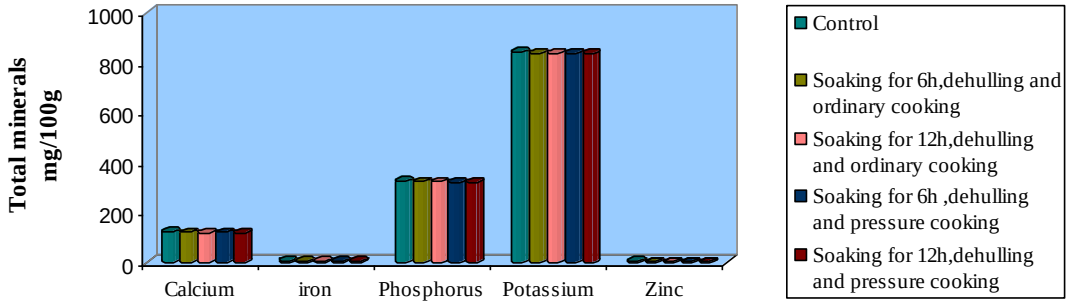

Fig. 8(a) Effect of soaking,dehulling and cooking methods on total minerals in green gram

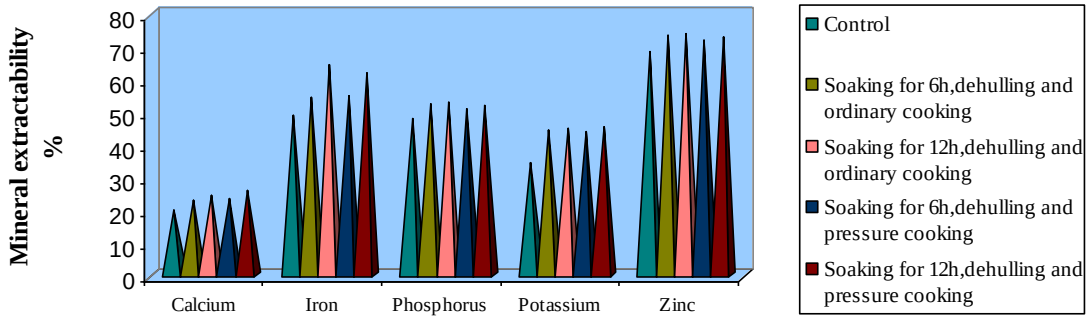

Fig. 8(b) Effect of soaking,dehulling and cooking methods on mineral extractability in green gram

In green gram also there was a significant reduction in total calcium after cooking (ordinary and pressure cooking) of soaked (6 and12 h) dehulled pulses [Fig.8 (a), 8(b)]. Under ordinary cooking of soaked (6h) and dehulled pulses, calcium extractability was increased by 16 per cent which was only 7 per cent in undehulled pulses. When soaking period was increased to 12h, calcium extractability was increased by 22 per cent. This was only 10 per cent in undehulled green gram. Under pressure cooking of soaked (6h) and dehulled pulses increase in calcium extractability showed no difference with that of ordinary cooking (16%), but this was only 9 per cent in undehulled pressure cooked pulses. When soaking period was increased to 12h, dehulled and pressure cooked samples showed an increase in calcium extractability by 30 per cent where as this was only 13 per cent in dehulled green gram.

In green gram there was a significant reduction in total iron. But HCl extractability of iron was increased by 11 per cent in soaked (6h) and dehulled samples after ordinary cooking as against 4 per cent in undehulled green gram. When soaking period was increased to 12h for ordinary cooking of dehulled samples, iron extractability was increased by 31 per cent as against 7 per cent in undehulled green gram. After pressure cooking of soaked (6h) and dehulled pulses, the increase in iron extractability was 12 per cent which was only 3 per cent in undehulled green gram. When soaking period was increased to 12h dehulled and pressure cooked samples showed an increase by 25 per cent which was lower than that in ordinary cooking but for undehulled green gram, this was only 8 per cent.

Total phosphorus also showed a significant reduction in green gram after cooking (ordinary and pressure cooking) of soaked (6h and 12h) and dehulled pulses. Phosphorus extractability showed a 10 per cent increase in soaked (6h) dehulled pulses after ordinary cooking as against 2 per cent in soaked (6h) and undehulled green gram. When soaking period was increased to 12h phosphorus extractability was increased by 11 per cent, which was only 5 per cent in undehulled green gram. Presure cooking of Soaked (6h) dehulled green gram showed only an increase of 7 per cent in phosphorus extractability but this was only 3 per cent in pressure cooked undehulled pulses. When soaking period was increased to 12h,

pressure cooked samples showed an increase in phosphorus extractability by 9 per cent which was lesser than ordinary cooking, but this was only 5 per cent in pressure cooked and soaked (12h) undehulled samples. This reveals the importance of soaking
period and dehulling and not the cooking method to increase the phosphorus extractability in green gram.

There was a significant reduction in total potassium in soaked (6h and 12h) and dehulled green gram after cooking (ordinary and pressure cooking). There was significant increase in potassium extractability by 29 per cent in soaked (6h) and dehulled green gram cooked by ordinary method, which was only 20 per cent in undehulled pulses. When the soaking period was increased potassium extractability also showed an increase by 31 per cent as against 22 per cent in undehulled samples. After pressure cooking of soaked (6h) and dehullled samples potassium extractability showed an increase by 28 per cent, which was 27 per cent in undehulled green gram. When soaking was extended to 12h, increase in potassium extractability showed no difference from that of ordinary cooking (31%) but this was only 27 per cent in undehulled green gram.

HCl extractability of zinc showed a significant increase by 7 per cent in soaked (6h) and dehulled green gram after ordinary cooking as against 2 per cent in undehulled green gram. When soaked for 12h, zinc extractability increased by 8 per cent which was 4 per cent in undehulled green gram. Pressure cooking increased the HCl extractability of zinc by 5 per cent in soaked (6h) and dehulled green gram as against 3 per cent in undehulled samples. When soaked for 12h and dehulled zinc extractability was increased by 6 per cent, which was only 4 per cent in undehulled and pressure cooked green gram.

In horse gram there was a significant reduction in total calcium, phosphorus and potassium due to cooking (ordinary and pressure cooking) of soaked (6h and 12h) and dehulled pulses. Total iron showed a significant reduction only in soaked (6h and 12 h) and dehulled horse gram after pressure cooking and no significant reduction with ordinary cooking. Total zinc also showed no significant reduction in all the processing and cooking methods.

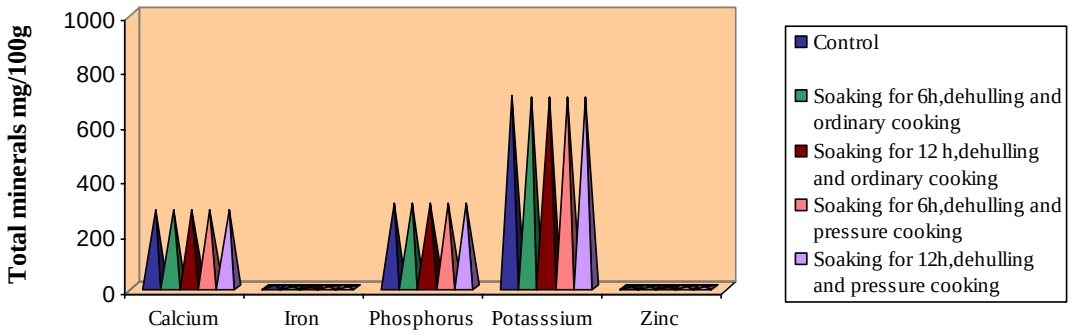

Fig.9(a) Effect of soaking,dehulling and cooking methods on total minerals in horse gram

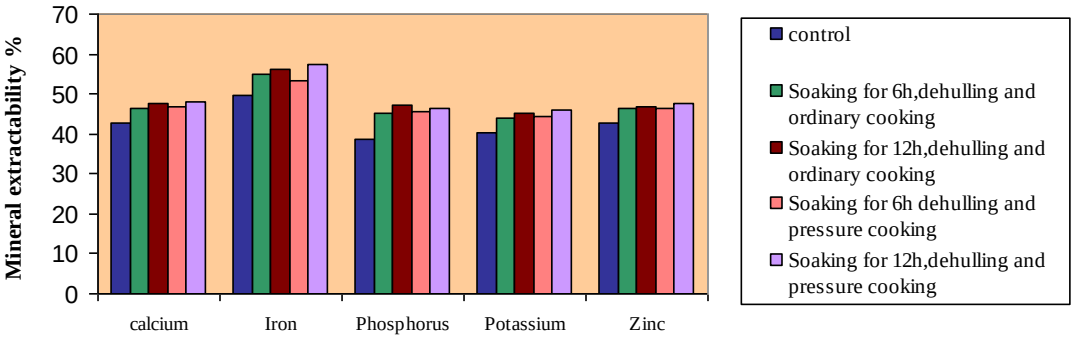

Fig. 9(b) Effect of soaking,dehulling and cooking methods on mineral extractability in horse gram

HCl extractability of calcium was found to increase by 9 per cent in soaked (6h) and dehulled horse gram after ordinary cooking which was only increased by 6 per cent in undehulled pulses. When soaked for 12h, calcium extractability was increased to 12 per cent whereas this was only 7 per cent in undehulled horse gram. After pressure cooking of soaked (6h) and dehulled horse gram calcium extractability was increased by 10 per cent as against 6 per cent in undehulled horse gram. A maximum of 13 per cent increase was observed in calcium extractability in dehulled horse gram soaked for 12h and pressure cooked where as this was 8 per cent in undehulled horse gram [Fig.9 (a), 9(b)].

Iron extractability in horse gram showed an increase by 10 per cent in ordinary cooked samples after soaking (6h) and dehulling, which was only 5per cent in undehulled horse gram. When soaked for 12h and dehulled iron extractability showed an increase by 13 per cent as against 8 per cent in undehulled horse gram. After pressure cooking of horse gram by soaking (6h) and dehulling iron extractability showed an increase of 7 per cent as against 6 per cent in undehulled horse gram. When soaked for 12h and dehulled, iron extractability was increased to a maximum of 15 per cent after pressure cooking which was only 11 per cent in undehulled horse gram.

Total phosphorus showed a significant reduction by cooking (ordinary and pressure cooking) of soaked (6 and12h) and dehulled horse gram. Phosphorus extractability showed an increase by 17 per cent in soaked (6h) and dehulled horse gram after cooking by ordinary method. This was only 13 per cent in undehulled horse gram. When soaked for 12h phosphorus extractability was increased by 22 per cent which was 14 per cent in undehulled horse gram. When pressure cooked, dehulled horse gram soaked for 6h showed an increase in phosphorus extractability by 17 per cent which was 13 per cent in undehulled horse gram. When soaked for 12h, pressure cooked and dehulled horse gram phosphorus extractability showed an increase of 19 per cent as against 16 per cent in undehulled sample.

Total potassium was significantly reduced in cooked (ordinary and pressure cooked horse gram after soaking (6h and 12h) and dehulling. HCl extractability of potassium was increased by 9 per cent in ordinary cooked horse gram

which was soaked (6h) and dehulled, but when soaked for 12h this was again increased by 12 per cent. But in undehulled horse gram this was only 6 and 7 per cent respectively. After pressure cooking of horse gram which was soaked for 6h and dehulled, potassium extractability showed an increase by 9 per cent, but on soaking for 12h the increase in potassium extractability was 13 per cent. But in undehulled horse gram for both soaking periods the increase was only 8 per cent.

Total zinc in horse gram showed no significant reduction when the soaked (6h and 12h) and dehulled samples were cooked (ordinary and pressure cooked). Zinc extractability showed an increase by 8 per cent when soaked (6h) and dehulled pulses were cooked by ordinary method but increased to 9 per cent when soaked for 12h but the increase in zinc extractability was only 4 and 5 per cent respectively. After pressure cooking of soaked (6h) and dehulled horse gram, zinc extractability showed the same increase (8%) as that in ordinary cooking, but increased to 11 per cent when soaked for 12h and pressure cooked after dehulling. However this was only 5 and 6 per cent in undehulled pressure cooked horse gram sample.

The present results are in close consistence with the results of Duhan *et al.,* (2002) who also reported a significant decline of total calcium on water soaking. In the present study all the minerals followed a trend similar to that obtained for calcium after soaking and dehulling except for horse gram which showed no significant reduction in total zinc upon soaking and dehulling.

In all the pulses studied, loss in total minerals was found to be more with an increase in the period of soaking. Dehulling of soaked seeds further caused a significant reduction in total minerals. The loss in the mineral content on soaking may be attributed to leaching out of these minerals into the soaking water (Kumar *et al.,* 1978). Dehulling is a contributing factor towards loss of total mineral content as minerals present in the hulls might have been lost during dehulling.

Cooking of unsoaked, soaked and soaked dehulled pulses caused a significant decrease in total minerals. It seems that both processing and cooking methods were responsible for mineral loss. The results are in agreement with thos

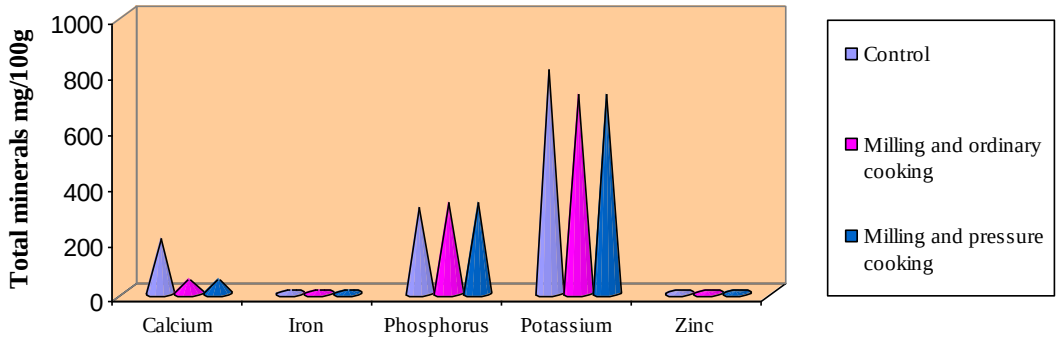

Fig.10(a) Effect of milling and cooking methods on total minerals in bengal gram

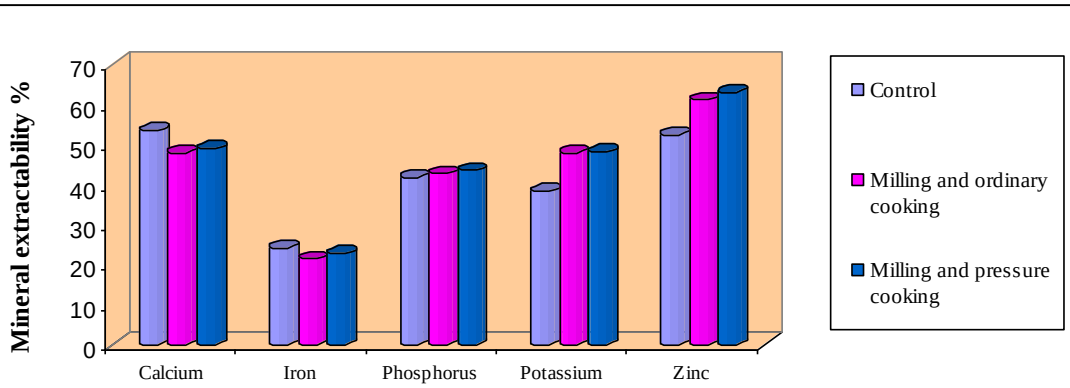

Fig.10(b) Effect of milling and cooking methods on mineral extractability in bengal gram

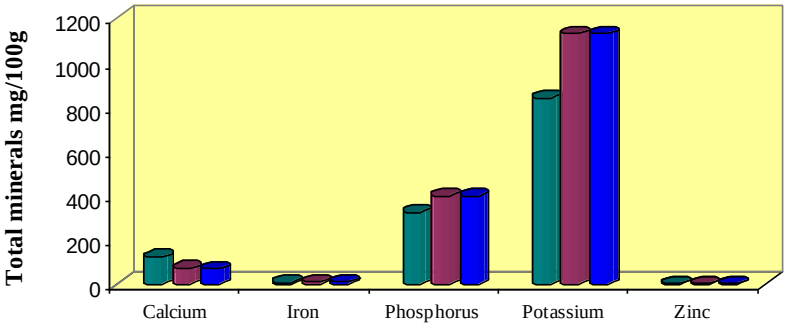

Fig.11(a) Effect of milling and cooking methods on total minerals in green gram

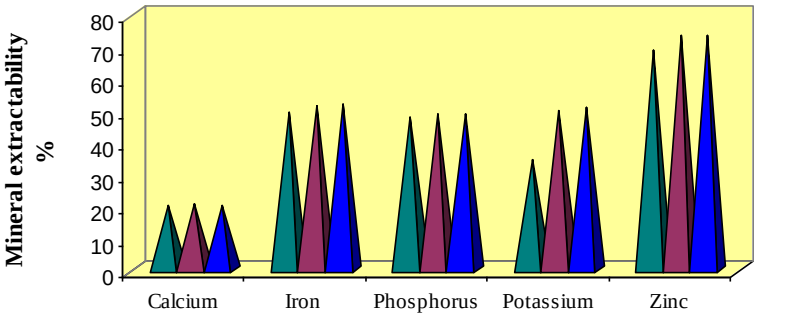

Fig.11(b) Effect of milling and cooking methods on mineral extractability in green gram

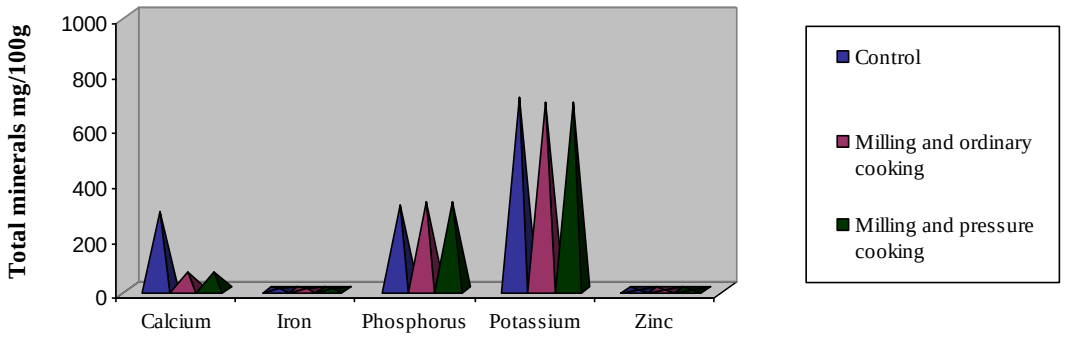

Fig.12(a) Effect of milling and cooking methods on total minerals in horse gram

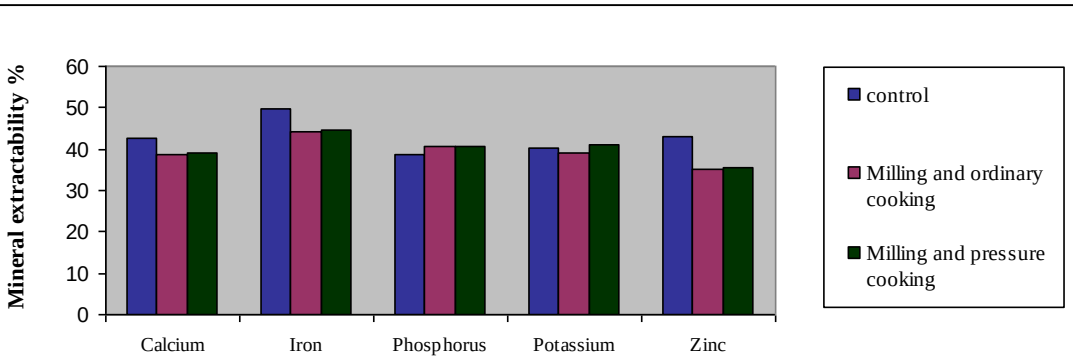

Fig.12(b) Effect of milling and cooking methods on mineral extractability in horse gram

reported earlier (Bishnoi and Khetarpaul, 1997; Duhan et *al.*, 1989). They found that during pressure cooking of unsoaked field peas there was 1-5 per cent and 2-3 per cent loss in total zinc and copper while in soaked and unsoaked dehulled seeds, it varied from 4-5 per cent and 8-10 per cent (zinc), 8-10 per cent and 10-12 per cent (copper) respectively. These results indicate that loss in total minerals was not because of pressure cooking but because of prior soaking and dehulling.

The present study revealed that various domestic processing and cooking methods have significant enhancing effect on the HCl extractability of dietary essential minerals. As the period of soaking increased from 6-12h, a significant increase in the extractability was witnessed. Ordinary cooking as well as pressure cooking could enhance the extractability of minerals of unsoaked pulses, but it was obviously less than that of the soaked or soaked dehulled pulses. Moist heating, i.e. pressure cooking could improve the extractability of pulses to a greater extent than ordinary cooking. These results are in agreement with the studies of Duhan *et al.*, (2004) who found that ordinary cooking as well as pressure cooking of unsoaked, soaked and soaked dehulled seeds of pigeon pea cultivars showed significant increase in zinc and copper extractability. On the contrary, studies conducted by Hemalatha *et al.* (2007) reported that zinc extractability from pulses was considerably reduced upon pressure cooking.

Milling showed varied results for total minerals with respect to pulses [Fig.10 (a), 10(b)]. Under ordinary cooking and pressure cooking milled bengal gram showed a significant reduction in total calcium (73%), total potassium (11%) and a reduction in total zinc by 44 per cent under ordinary cooking and by 33 per cent under pressure cooking. Under ordinary cooking, there was a significant increase in total iron by 13 per cent and by pressure cooking by 10 per cent. Total phosphorus showed a 6 per cent increase in ordinary and pressure cooking.

In green gram also, by both methods of cooking there were a significant reduction in total calcium by 43 per cent and a reduction of 16 per cent in total zinc under ordinary cooking but a 42 per cent reduction in pressure cooking. Total potassium showed an increase of 35 per cent and total phosphorus increased by 23 per cent in both methods of cooking. Total iron showed a significant increase by

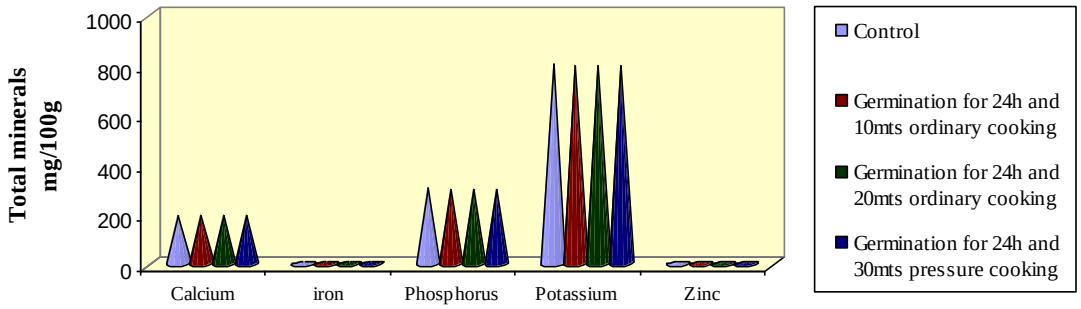

Fig.13(a) Effect of 24h germination and ordinary cooking on total minerals in bengal gram

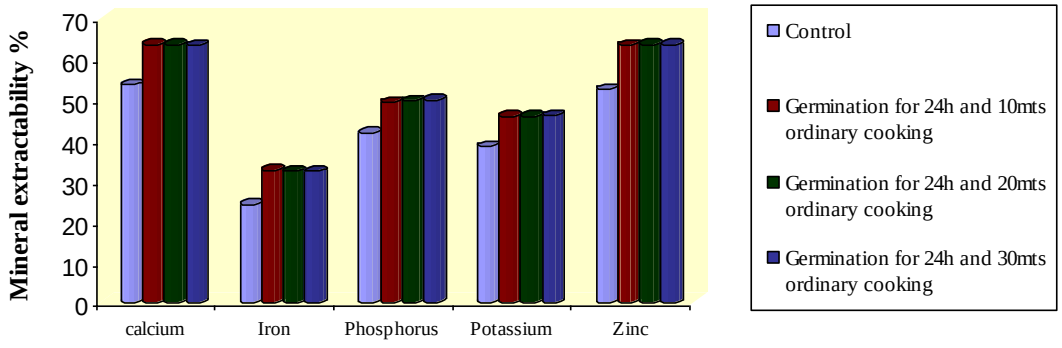

Fig.13(b) Effect of 24 h germination and ordinary cooking on mineral extractability in bengal gram

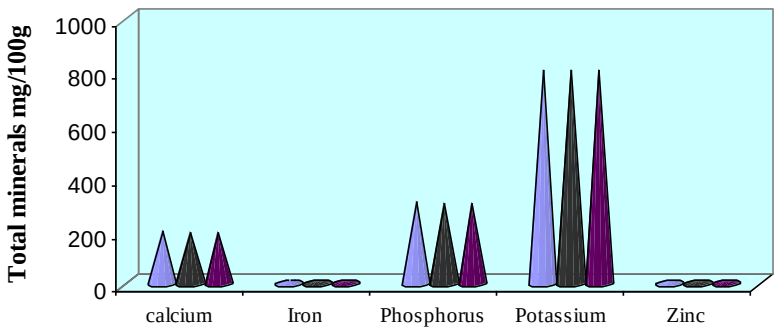

Fig.14(a) Effect of 24h germination and pressure cooking on total minerals in bengal gram

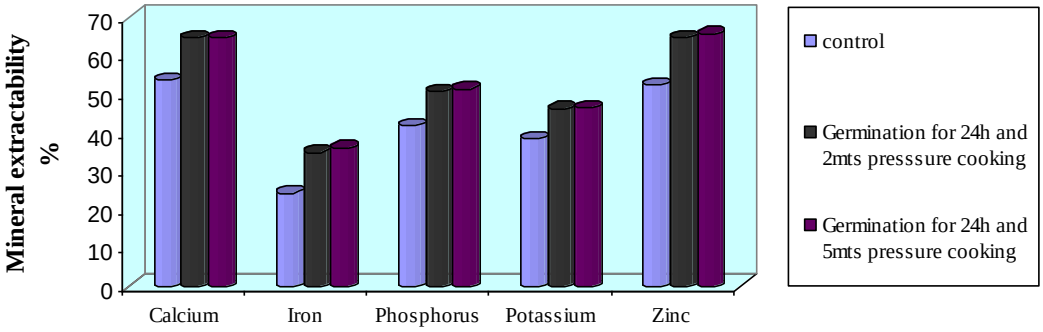

Fig.14(b) Effect of 24h germination and pressure cooking on mineral extractability in bengal gram

38 per cent under ordinary cooking and 34 per cent by pressure cooking [Fig.11 (a), 11(b)].

In horse gram there was a significant reduction in total calcium (77%) under both methods of cooking. A 2 per cent reduction was observed in total potassium under ordinary cooking but under pressure cooking a 20 per cent reduction was observed [Fig.12 (a), 12(b)]. Total phosphorus showed an increase of 4 per cent under both cooking methods and increase in total iron was not significant.

This result is in line with the results of a similar study by Annapurini and Murthy, (1984) who observed a 28 per cent increase in total iron in green gram and a 10 per cent increase in total iron in bengal gram due to milling and cooking. There was a significant reduction in total zinc in milled bengal gram and green gram which is in agreement with Sarojini *et al.*, (1996) who also reported a decrease in total zinc due to milling in bengal gram, green gram, black gram and lentils. Kumar, (2006) also revealed a reduction of 57 per cent in total zinc on milling and cooking of white bean. In the present study a reduction of 73 per cent, 43 per cent and 77 per cent in total calcium was observed in bengal gram, green gram and horse gram respectively due to milling and cooking. The maximum loss in calcium in milling has been reported by Duhan *et al.*, (2001) in pigeon pea. The reason being that calcium has been reported to be found mainly in the testa (61.4%) where as only 26.8 per cent and 11.8 per cent was present in embryo and cotyledon respectively (Singh *et al*., 1992).

HCl extractability of minerals showed a significant enhancing effect due to milling and cooking. In bengal gram milling and ordinary cooking enhanced calcium extractability 11 per cent but in pressure cooking this was 8 per cent. Iron extractability showed a significant increase by 12 per cent after milling and ordinary cooking which was 6 per cent after pressure cooking. Phosphorus extractability was increased by 2 per cent and 4 per cent by ordinary and pressure cooking of milled dhal. A 25 per cent and 26 per cent increase was noted in potassium extractability by ordinary and pressure cooking where as zinc extractability showed 17 per cent and 20 per cent increase due to ordinary and pressure cooking of milled bengal gram.

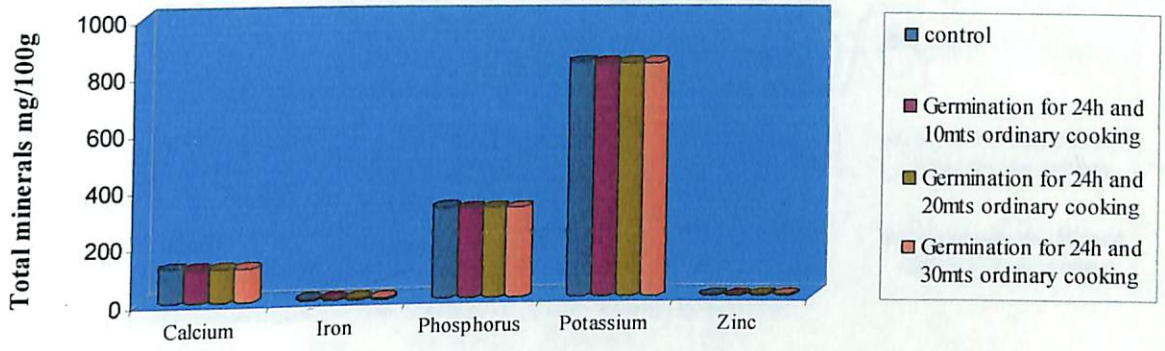

Fig.15(a) Effect of 24h germination and ordinary cooking on total minerals in green gram

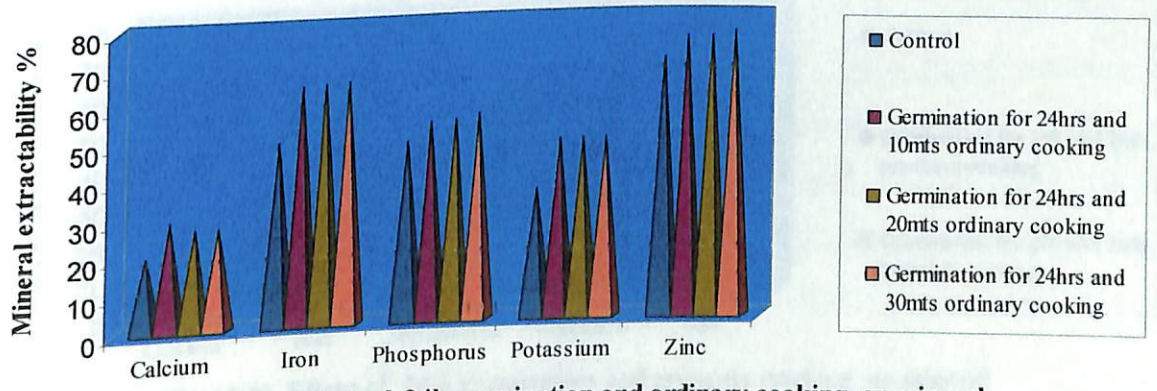

Fig.15(b) Effect of 24h germination and ordinary cooking on mineral extractability in green gram

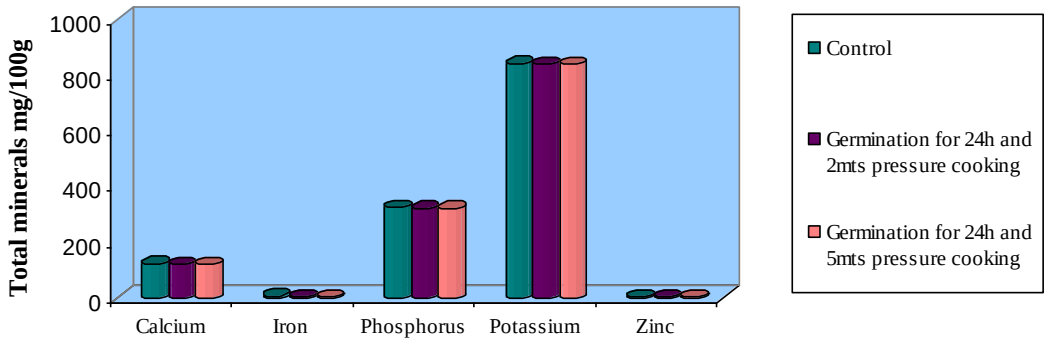

Fig.16(a) Effect of 24h germination and pressure cooking on total minerals in green gram

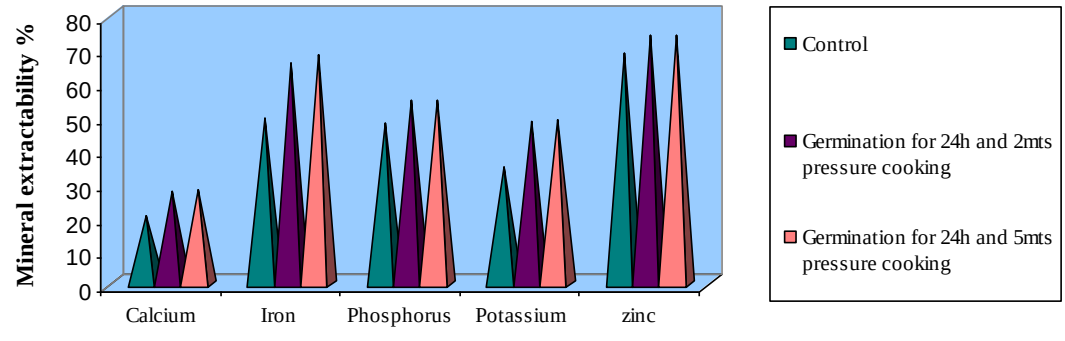

Fig.16(b) Effect of 24 h germination and pressure cooking on mineral extractability in green gram

In green gram, after milling there was a significant increase in calcium extractability (2%) and iron extractability (5%) under ordinary cooking but there was no significant increase with pressure cooking. Phosphorus extractability showed a 2 per cent increase and zinc extractability 7 per cent in both cooking methods. Maximum increase in the extractability was observed with potassium 44 per cent under ordinary cooking and 47 per cent increase in pressure cooked milled sample.

In horse gram a significant reduction in the extractability of calcium, iron and zinc was observed under both cooking methods but phosphorus extractability showed a significant increase of 4 per cent and 5 per cent in ordinary cooking and pressure cooking respectively after milling.

Germination and cooking of pulses brought out a reduction in total minerals [Fig.13 (a), 13(b)]. Ordinary cooking of 24h germinated bengal gram was done for 10, 20, and 30min and found that there was only 2 per cent reduction in total calcium with all the cooking times. Pressure cooking (2 and 5min) also showed a 2 per cent reduction in total calcium. Total iron also showed a reduction of 24-25 per cent in germinated and ordinary cooked (10, 20 and 30min) samples but during pressure cooking (2 and 5min) total iron showed a reduction of about 27-28 per cent. A reduction of about 1-2 per cent was observed in total phosphorus under ordinary cooking (10, 20 and 30min) but for pressure cooking (2 and 5min), the reduction was 2 per cent in total phosphorus. Total potassium showed only a slight reduction of about less than 1per cent due to germination and by ordinary and pressure cooking but maximum reduction was observed in total zinc. Under ordinary cooking (10, 20 and 30min) germinated bengal gram showed a maximum reduction in total zinc by 35 per cent in samples cooked for 30min. Pressure cooked samples also showed a 35 per cent reduction in total zinc [Fig.14(a), 14(b)].

In green gram 24h germinated samples under ordinary cooking (10, 20 and 30min) and pressure cooking (2 and 5min) showed a significant reduction in total calcium by 3 per cent [Fig.15 (a), 15(b)]. Total iron also showed a reduction of 20-22 per cent under ordinary cooking and pressure cooking (2 and 5min) showed a reduction of 23 per cent in total iron. The reduction in total phosphorus was only less than 1per cent in 24h germinated green gram cooked by ordinary (10,20 and 30min)

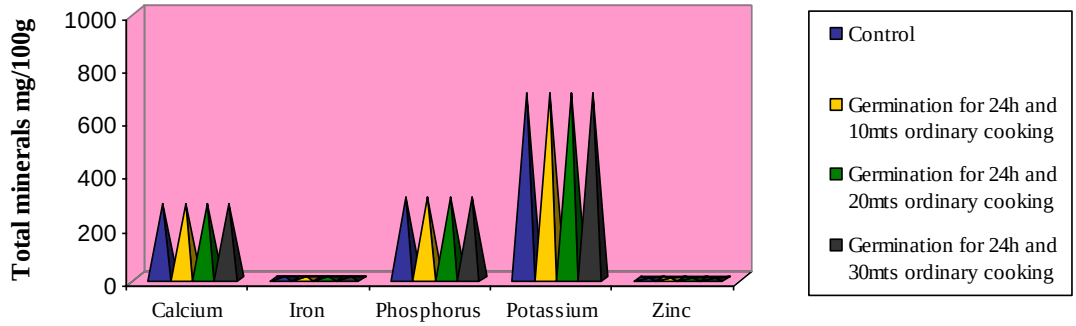

Fig.17(a) Effect of 24h germination and ordinary cooking on total minerals in horse gram

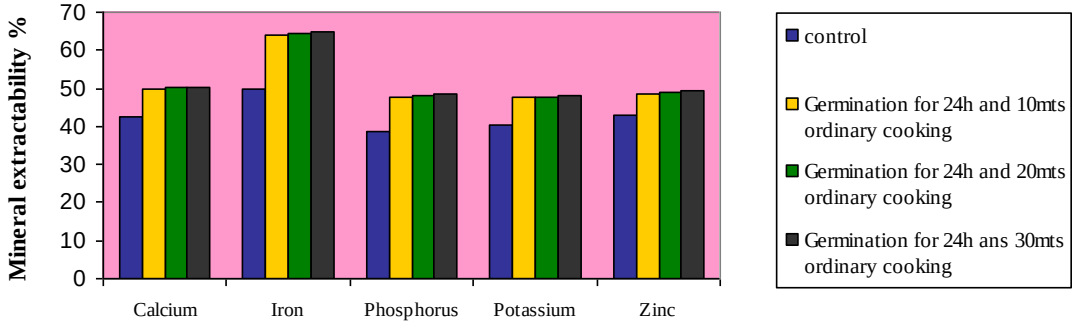

Fig.17(b) Effect of 24h germination and ordinary cooking on mineral extractabilitry in horse gram

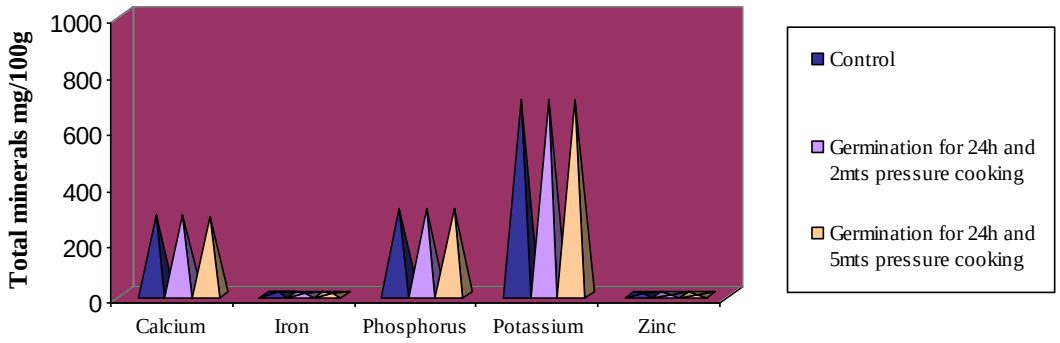

Fig.18(a) Effect of 24h germination and pressure cooking on total minerals in horse gram

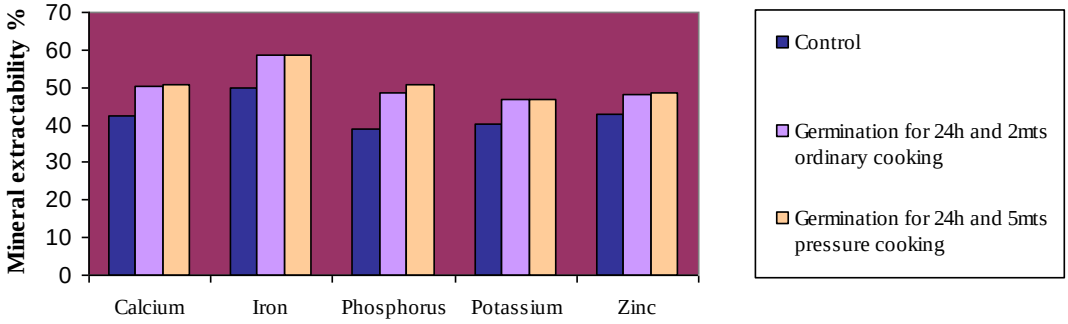

Fig.18(b) Effect of 24h germination and pressure cooking on mineral extractability in horse gram

and pressure cooking(2 and 5min) methods. Total potassium also showed a reduction less than 1 per cent in all the cooking methods. Total zinc was reduced by 8-11 per cent under ordinary cooking with maximum reduction in 10min and 30min cooking. In pressure cooking (2 and 5min) the reduction in total zinc was 8 per cent [Fig.16 (a), 16(b)].

In 24h germinated horse gram when cooked by ordinary (10, 20 and 30min) and pressure cooking method (2 and 5min) total calcium was reduced by less than 1 per cent to 2 per cent the maximum reduction being in pressure cooked samples for 5min (2%) [Fig.17 (a), 17(b)]. A 12-14 per cent reduction in total iron was observed with ordinary cooking (10, 20 and 30min) the maximum reduction being in 30min cooking. Under pressure cooking (2 and 5min) total iron was found to show a reduction by 18-20 per cent, maximum being in 5min pressure cooked sample. Total phosphorus showed 1 per cent reduction in all the cooking methods. In the case of total potassium a less than 1 per cent reduction was observed by ordinary cooking (10, 20 and 30min) but by pressure cooking (2 and 5min) about 1 per cent reduction was observed in 24h germinated horse gram. A 11 per cent reduction in total zinc was observed under ordinary cooking (10, 20 and 30min) but the reduction was only 10 per cent under pressure cooking (2 and 5min) [Fig.18(a), 18(b)].

Germination for 36h was found to have a profound effect on total minerals and mineral extractability [Fig.19 (a), 19(b)]. Germinated bengal gram for 36h under ordinary cooking (10, 20 and 30min) showed reduction in total calcium by 2, 3 and 6 per cent respectively. Pressure cooking (2 and 5min) showed a reduction of 2 and 3 per cent respectively. Extractability of calcium was increased by 25-26 per cent under ordinary cooking, the maximum being in 10min cooked samples. In pressure cooking (2 and 5min) calcium extractability was increased by 26 per cent.

Total iron showed a significant reduction in 36h germinated bengal gram, the maximum being in samples cooked for 20 and 30min (34%). In pressure cooking loss in total iron was still higher ie by 37 per cent in 5min pressure cooking. Iron extractability under ordinary cooking showed an increase by 57-59 per cent, the maximum in 30min cooking (59%). In pressure cooking maximum iron extractability

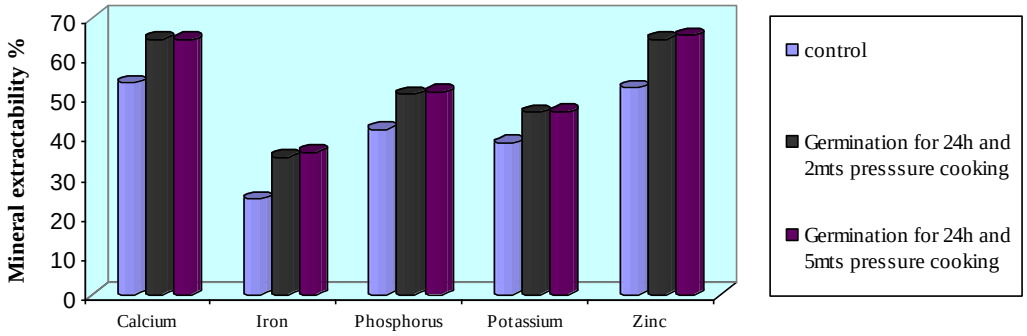

Fig.19(a) Effect of 36h germination and ordinary cooking on total minerals in bengal gram

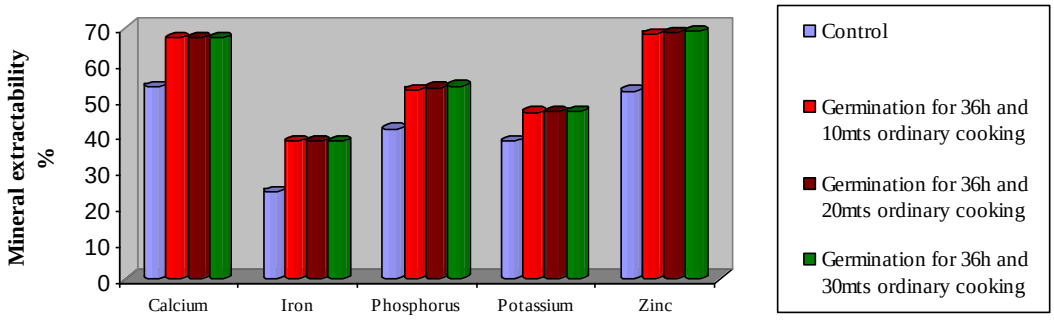

Fig.19(b) Effect of 36h germination and ordinary cooking on mineral extractability in bengal gram

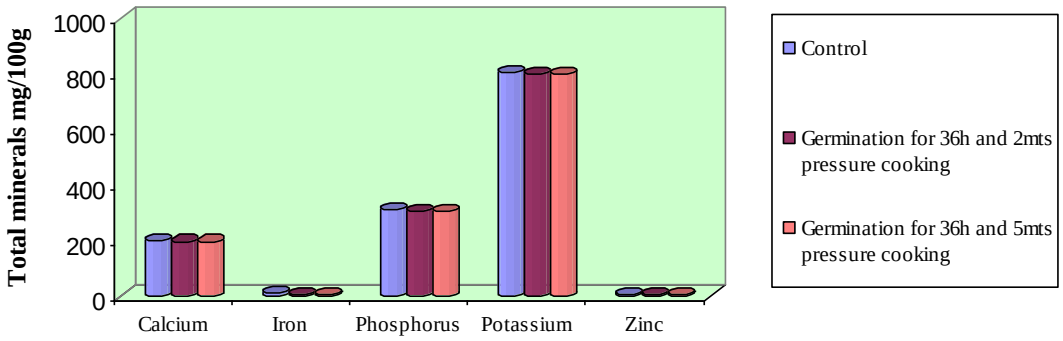

Fig.20(a) Effect of 36h germination and pressure cooking on total minerals in bengal gram

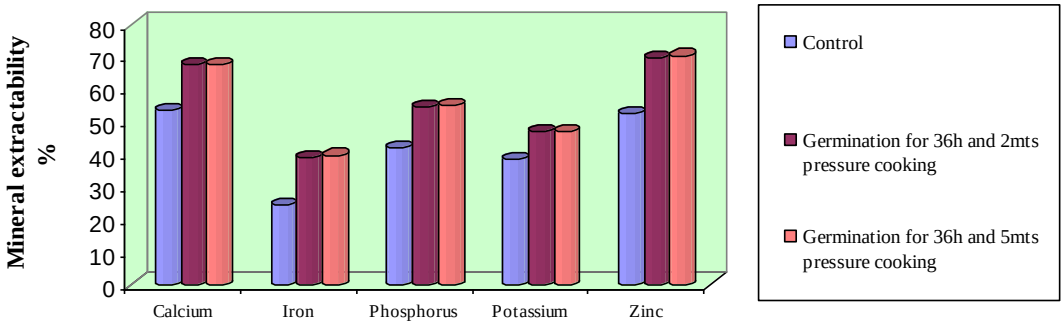

Fig.20(b) Effect of 36h germination and pressure cooking on mineral extractability in bengal gram

was observed. The maximum increase by 64 per cent was in 5min pressure cooked samples.

Total phosphorus also showed a significant reduction with ordinary cooking (10, 20and 30min) of 36h germinated bengal gram. About 2 per cent reduction was observed with all cooking times. Under pressure cooking also, a 2per cent reduction was observed in total phosphorus. Phosphorus extractability showed a significant increase under ordinary cooking by (10, 20 and 30min) 26, 28 and 28 per cent respectively, but under pressure cooking (2 and 5min) the phosphorus extractability showed a maximum increase by 32 per cent for 5min and 30 per cent for 2min pressure cooking.

Reduction in total potassium in ordinary cooking (10, 20and 30min) of 36h germinated bengal gram was found to be below 1 per cent but under pressure cooking (2 and 5min) a 1 per cent reduction was observed. Under ordinary cooking potassium extractability showed an increase by 21 per cent in 10min and 20min cooking while maximum increase in extractability was observed in 30min cooking (22%). Under pressure cooking potassium extractability was increased by 22 per cent for 2 min and maximum by 23 per cent in 5min pressure cooking [Fig. 20(a), 20(b)].

Total zinc showed a reduction by 40-42 per cent in 36h germinated bengal gram under ordinary cooking (10, 20and 30min). Maximum loss by 42 per cent was observed in 10min and 30min cooking. This loss was maximum (44 per cent) in 5min pressure cooking. Under ordinary cooking (10, 20and 30min) zinc extractability showed an increase by 30, 31, and 32per cent respectively but by pressure cooking (2 and 5min) this increase was by 33 and 34per cent respectively.

In green gram germinated for 36h, when cooked by ordinary method (10, 20 and 30min) there was a 4 per cent reduction in total calcium, but under pressure cooking (2 and 5min) the reduction in total calcium was only 2 per cent and 3 per cent respectively [Fig.21 (a), 21(b)]. Calcium extractability showed an increase of about 44 per cent under ordinary cooking but the increase was maximum in pressure cooking by 26 per cent.

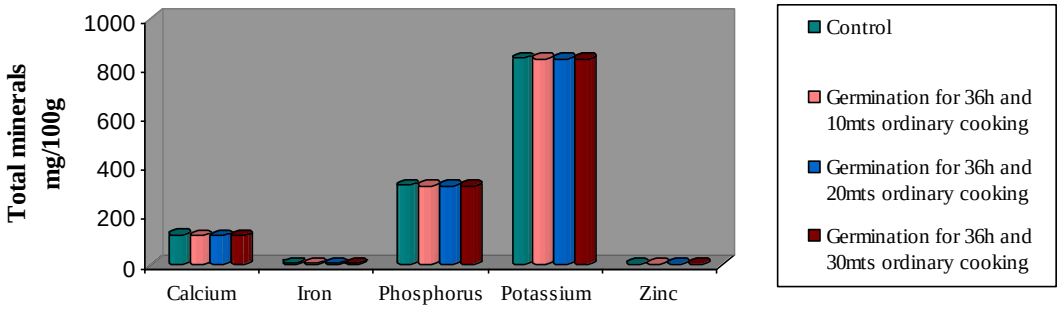

Fig.21(a) Effect of 36h germination and ordinary cooking on total minerals in green gram

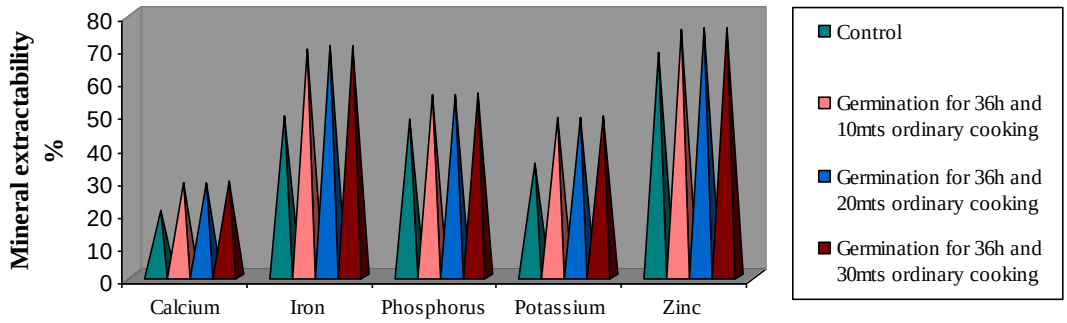

Fig.21(b) Effect of 36h germination and ordinary cooking on mineral extractability in green gram

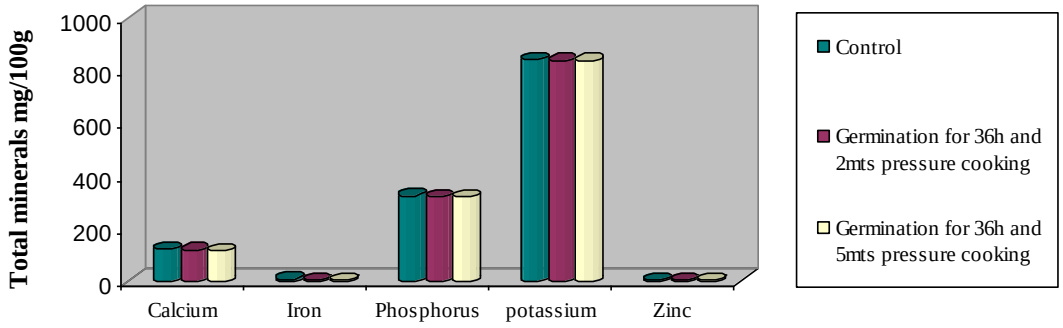

Fig.22(a) Effect of 36h germination and pressure cooking on total minerals in green gram

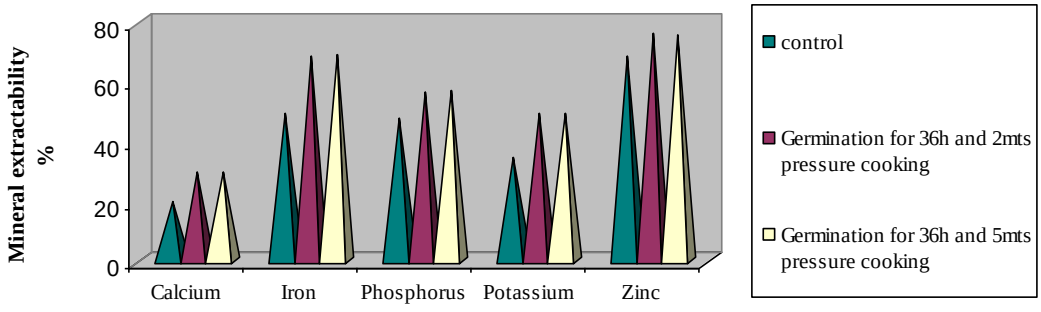

Fig.22(b) Effect of 36h germination and pressure cooking on mineral extractability in green gram

Total iron in 36h germinated green gram when cooked by ordinary method (10, 20 and 30min) showed an reduction by 26, 27 and 28 per cent respectively but maximum reduction was observed in 5min pressure cooked green gram by 37 per cent. Iron extractability was significantly increased by 41-43 per cent the maximum being in 20 and 30min cooked samples. Under pressure cooking, iron extractability showed the maximum increase by 64 per cent in 5min cooking.

There was a reduction in total phosphorus by 2 per cent in 36h germinated green gram when cooked by ordinary method and pressure cooking [Fig.22 (a), 22(b)]. Maximum increase in phosphorus extractability was in pressure cooked samples for 5min (32 %).

Total potassium showed a reduction of less than 1 per cent in 36h germinated green gram when cooked by ordinary method and a reduction of 1 per cent was observed in pressure cooked samples. Maximum increase in potassium extractability by 23 per cent was observed in pressure cooked samples for 5min.

Total zinc showed a reduction by 40-42 per cent in germinated green gram for 36h under ordinary cooking (10, 20 and 30min) but under pressure cooking for 5min a maximum loss of about 44 per cent was noted. Zinc extractability was increased to a maximum by 34 per cent in 5min pressure cooked sample.

Ordinary cooking (30min) of 36h germinated horse gram showed a maximum reduction by 2 per cent total calcium and also in pressure cooked samples. Only a 1 per cent reduction was observed in ordinary cooking for 10 and 20min. Maximum calcium extractability was observed in 5min pressure cooked samples by 23 per cent.

Minimum loss in total iron was found in samples cooked for 10min under ordinary cooking (17%) while during pressure cooking (2 and 5min) the increase in the loss was 22 and 24 per cent respectively. Iron extractability showed an increase by 39, 40 and 41 per cent under ordinary cooking (10, 20 and 30min respectively) but under pressure cooking (2 and 5min) the increase in iron extractability was only 22 per cent [Fig.23 (a), 23(b)].

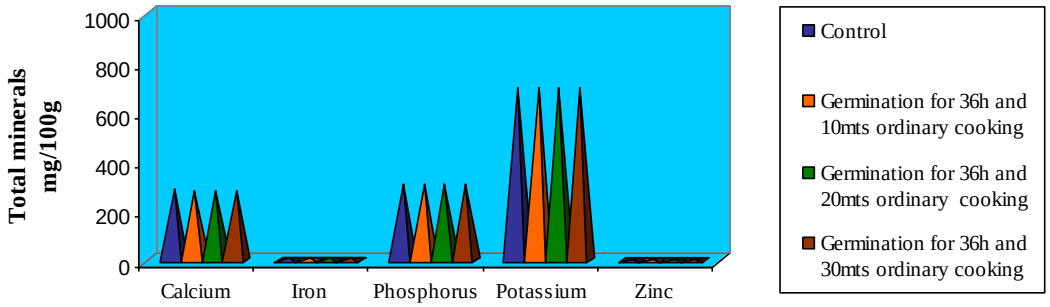

Fig.23(a) Effect of 36h germination and ordinary cooking on total minerals in horse gram

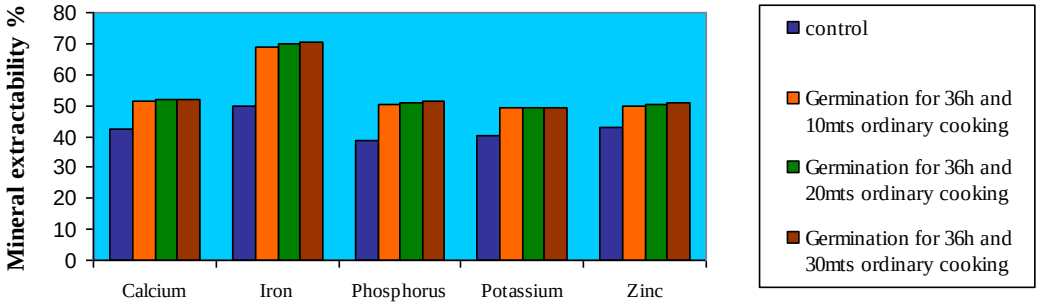

Fig.23(b) Effect of 36h germination and ordinary cooking on mineral extractability in horse gram

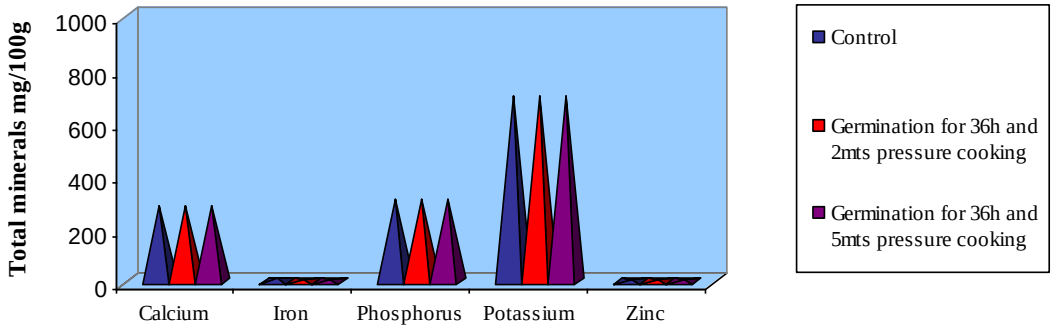

Fig.24(a) Effect of 36h germination and pressure cooking on total minerals in horse gram

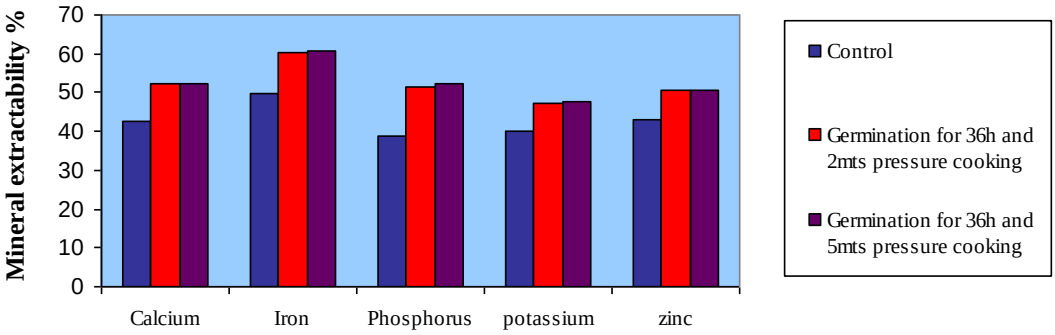

Fig.24(b) Effect of 36h germination and pressure cooking on mineral extractability in horse gram

The loss in total phosphorus was only 1 per cent in both ordinary and pressure cooking of 36h germinated horse gram, but a maximum increase in phosphorus extractability by 34 per cent was observed in 5min pressure cooked horse gram.

The loss in total potassium in 36h germinated horse gram under ordinary cooking was only less than 1 per cent but was found to be about 1 per cent in pressure cooking. Maximum increase in potassium by 23 per cent was in ordinary cooking by 20min.

Under ordinary cooking for 10min, 36h germinated horse gram showed a reduction in total zinc by 11 per cent but in all other cooking methods the loss was by 14 per cent. Maximum increase in zinc extractability by 19 per cent was observed for 30min ordinary cooking and also in 5min pressure cooking [Fig.24 (a), 24(b)].

In the present study germination was brought a loss in total minerals in pulses which is in line with the results of Duhan *et al.*, (2001) who found a loss of total calcium, phosphorus and iron in a high yielding pigeon pea cultivars and has reported that the loss was not due to germination alone but also due to soaking (12h) done prior to sprouting.

Ordinary cooking as well as pressure cooking has enhanced the extractability of minerals from bengal gram, green gram and horse gram, but pressure cooking was found to increase the extractability to a greater extent than ordinary cooking methods. In the present study maximum calcium and phosphorus extractability was found in 36h germinated and 5min pressure cooked samples. Same results have also been reported earlier on this aspect (Bishnoi and Khetarpaul, 1995; 1996 a & b, 1997).

5.2 Processing and cooking methods on phytic acid, total phosphorus, phytate phosphorus and extractability of phosphorus from selected pulses

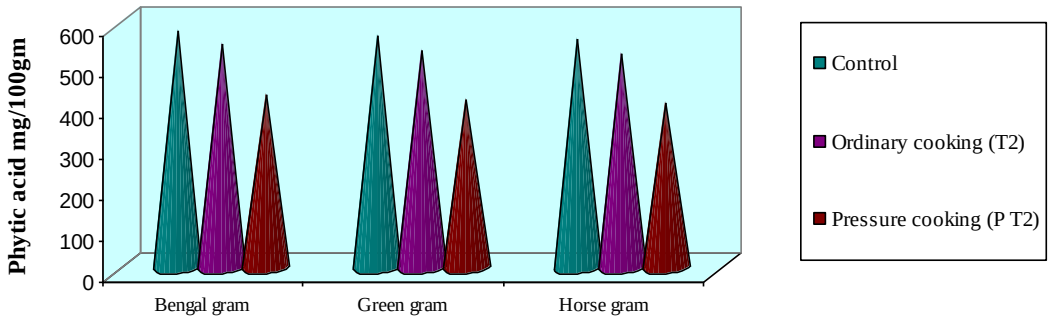

Fig.25 Effect of cooking methods on phytic acid in selected pulses

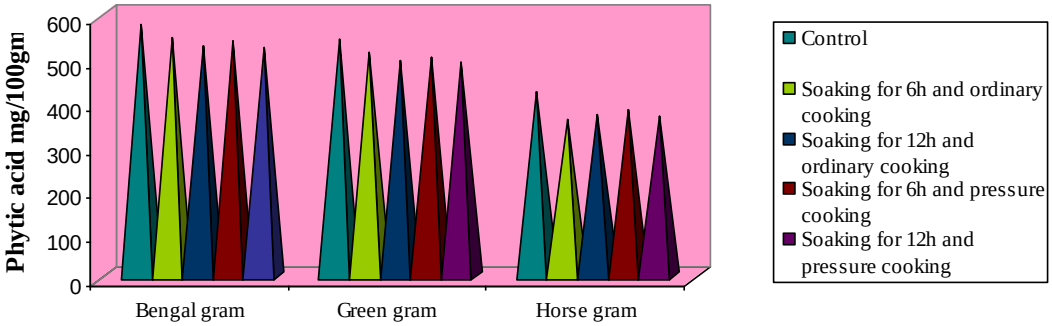

Fig.26 Effect of soaking and cooking methods on phytic acid in selected pulses

The content of phytic acid is known to be the major storage form of phosphorus and is considered to be an antinutritional factor. Soaking as well as milling contributed significantly in reducing the phytic acid content. The losses in phytates during soaking may be because of leaching out of phytate ion into soaking water under the influence of concentration gradient, which governs the rate of diffusion. Similar results for reduction in phytic acid in the soaked as well as soaked and dehulled or milled legumes have been reported earlier (Deshpande and Cheryan, 1983; Kataria *et al*., 1988; Duhan *et al*., 1989; Kaur and Kapoor 1990; Bishnoi *et al*., 1994 and Jood *et al*., 1998).

Ordinary cooking of unsoaked, soaked as well as soaked dehulled pulses brought about a significant decrease in phytic acid content, when compared to control. Pressure cooking resulted in a greater loss of phytic acid than in ordinary cooking.

According to Boland *et al*. (1975) the differences in the loss of phytic acid content during cooking can probably be explained on the basis that phytase activity at a temperature of $40\text{-}55^0$ may degrade inositol hexa phosphate to penta phosphate or lower molecular weight form. Kumar *et al*., (1978) observed that phytic acid content decreased because of the insoluble complex between phytate and other components which were formed during cooking.

Significant reduction in phytic acid was observed due to germination. This may be due to the hydrolytic activity of phytase reported to be present in legumes (Mandel *et al*., 1972; Lolas and Markakis, 1975).

Of the total phosphorus, unprocessed bengal gram contained 52.50 per cent of phytate phosphorus, where as in green gram it was 47.45 per cent and in horse gram it was 38.67 per cent. Variuous processing and cooking methods resulted in significant decrease with corresponding remarkable increase in non phytate phosphorus and HCl extractable phosphorus. Germination was found to be the best processing method followed by pressure cooking and ordinary cooking for reducing the content of phytate phosphorus and improving HCl extractability of phosphorus. Cleavage of phosphorus from phytic acid may explain the increased level of non

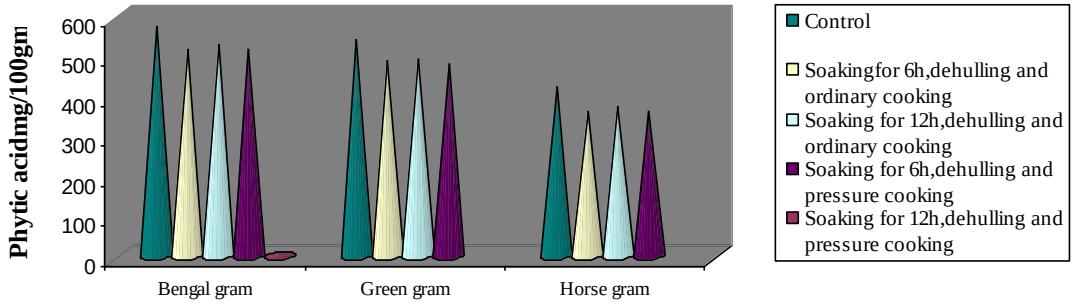

Fig .27 Effect of soaking,dehulling and cooking methods on phytic acid in selected pulses

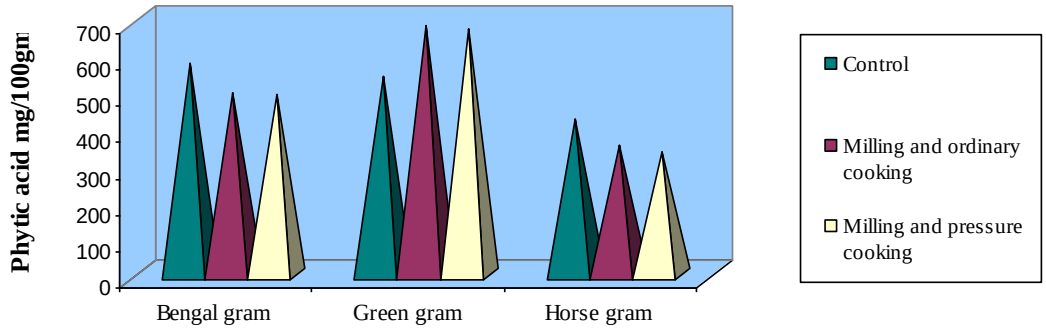

Fig.28 Effect of milling and cooking methods on phytic acid in selected pulses

phytate phosphorus and higher HCl extractability of phosphorus in the processed and cooked pulses. This result is in line with the findings of Duhan *et al.*, (2001) who found a maximum decrease in phytate content with subsequent increase in non phytate phosphorus brought about by germination, followed by pressure cooking of soaked pigeon pea.

5.3 Processing and cooking methods on phytic acid and mineral extractability from selected pulses

Phytic acid, (myo-inositol hexaphosphate), the major phosphorus bearing compound in grains and legumes is known to chelate divalent cation and there by restrict bioavailability of dietary essential minerals. Acid and phytatse enzymes hydrolyze phytate to lower inositol phosphate such as $1P_5$, $1P_4$, $1P_3$, $1P_2$ and $1P_1$ and also release some minerals. The extent of hydrolysis of phytate varies depending upon the type of processing, which in turn affect the bioavailability of minerals.

In the present study phytic acid content differed significantly from 497.66 mg/100gm to 579.10 mg/100gm in bengal gram, from 465.19 mg/100gm to 545.70 mg/100gm in green gram and from 334.9 mg/100gm to 424.75 mg/100gm in horse gram, due to various processing methods. The maximum phytic acid in all the pulses was observed in the control (T_1). A wide variation for phytic acid content of different pulse varieties was observed by different workers (Khokhar and chauhan, 1986; Vijayakumari *et al.*, 1998).

When unsoaked grains were cooked by ordinary method, a reduction of phytic acid by 2, 3and 4 per cent in bengal gram, green gram and horse gram respectively was observed and by pressure cooking of unsoaked grain this was 3, 4 and 5 per cent. Maximum reduction was observed in pressure cooking in all the pulses [Fig.25].

Calcium extractability was increased by 3, 2 and <1 per cent due to ordinary cooking of unsoaked bengal gram , green gram and horse gram, which was increased to 6, 3 and 3 per cent respectively after pressure cooking of unsoaked grains. Extractability of iron showed an increase by1-3 per cent, phosphorus by 1-8

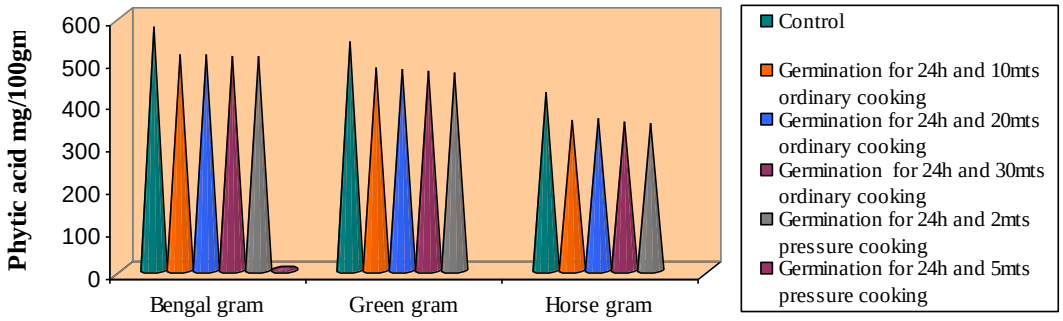

Fig.29 Effect of 24h germination and cooking methods on phytic acid in selected pulses

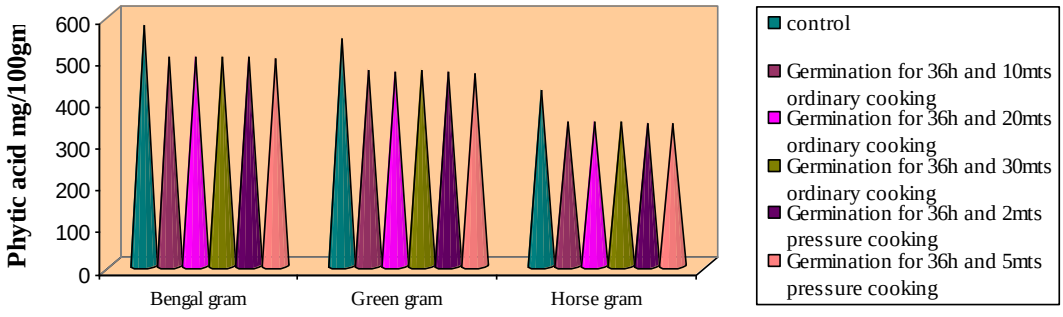

Fig.30 Effect of 36h germination and cooking methods on phytic acid in selected pulses

per cent, potassium by 2-7 per cent and zinc by 1-3 per cent in the three pulses after ordinary cooking. Pressure cooking of unsoaked grains increased the extractability of iron to 2-4 per cent, phosphorus by 2-9 per cent, potassium by 4-22 per cent, and zinc by 2-3 per cent. This shows that heat processing especially pressure cooking of pulses had an effect in lowering phytic acid content and there by an increase in mineral extractability. Earlier, a similar study conducted by Negi *et al.*, (2008) in 4 varieties of moth bean revealed that pressure cooking of unsoaked seeds reduced the phytic acid content by 20-22 per cent when compared to unprocessed seeds.

The apparent decrease observed in phytic acid content due to cooking (ordinary and pressure cooking) may be attributed to the formation of insoluble complexes between phytic acid and other components (Kumar *et al.*,1978). Similar decline in phytic acid content in heat treated samples of legumes have been reported earlier (Khalil and Mansour, 1995; Chau and Cheung, 1997). Decrease in the level of phytic acid by ordinary cooking and pressure cooking as reported by previous studies (Bishnoi and Khetarpaul, 1994; Bishnoi *et al*., 1994) may due to the release metallic iron in free form and may account for the increased HCl extractability of calcium, iron, phosphorus, potassium and zinc in the present study. Sandberg (1991) also reported that heat processing can have the potential to activate phytases and reduce the inhibitory action of phytic acid, thus improving mineral extractability from foods.

When the pulses were soaked for 6h before ordinary cooking a 5-15per cent reduction in phytic acid was observed with maximum reduction in horse gram. When this soaked (6h) grains were pressure cooked there was an increase in the loss of phytic acid in bengal gram by 6 per cent, in green gram by 7 per cent but in horse gram this was 10 per cent as against 15 per cent under ordinary cooking. When the soaking time was extended to 12h before ordinary cooking, phytic acid loss was found to vary from 9-12 per cent, but after pressure cooking this loss 9-13 per cent.

Mineral extractability also showed an increase with a decrease in phytic acid content [Fig.26]. When grains were soaked for 6h prior to ordinary cooking, extractability of calcium was increased by 6-11 per cent, iron by 4-7 per cent, and phosphorus by 2-13 per cent, potassium by 6-20 per cent and zinc by 2-5 per cent. After pressure cooking extractability of calcium was increased only in green

gram by 9 per cent. Iron extractability was increased in bengal gram and horse gram by11 and 6per cent respectively. Phosphorus extractability was increased by 3-13 per cent, potassium extractability by 8-27 per cent and zinc by 2-5 per cent. Mulimani *et al.,* (2003) has also reported a considerable reduction of phytic acid in soaking of the pulses. He revealed that phytic acid reduction due to 24h soaking was 11 and 10 per cent among two local varieties of red gram. Kataria *et al*. (1988) reported that phytic acid content lowered significantly in case of soaked black gram seeds. Zacharie and Ronald, (1994) observed a similar reduction in phytic acid content in dry beans after soaking followed by cooking. As observed in the present study Iyer *et al.,* (1980) also reported reduction in phytate content in "great Northern" pinto and kidney beans during a combined processing soaking and cooking. Tabekhia and Lu,(1980) reported that as the soaking time increased to 12h the reduction in phytic acid also increased between 9-19 per cent and cooking of soaked beans yielded a bean phytate loss between 8 and 36 per cent.

There was a significant negative correlation between phytic acid content and HCl extractability of minerals during soaking [Fig.27]. Soaking for 6h and dehulling of pulses were done before ordinary cooking and found a further reduction in phytic acid content between 7-10 per cent and by pressure cooking this loss was 8-11 per cent. When the soaking was extended to 12h and dehulled before ordinary cooking, the loss was 10-14 per cent and in pressure cooking the loss was found between 10-14 per cent. This shows a reduction resulting more from soaking and dehulling than from cooking. Soaking followed by dehulling further caused an increase in the HCl extractability of minerals. Soaking (6h) and dehulling before ordinary cooking increased HCl extractability of calcium by 9-15 per cent, iron by 10-20 per cent, phosphorus by 10-17 per cent, potassium by 9-29 per cent and zinc by 7-17 per cent. After pressure cooking increase in HCl extractability was not ed as 10-16 per cent, 7-24 per cent, 7-17 per cent, 9-28 per cent and 8-17 per cent in calcium, iron, phosphorus, potassium and zinc respectively.

When dehulled after soaking (12h) before ordinary cooking calcium extractability increased by 12-20 per cent and due to pressure cooking this further increased by 13-30 per cent. Similarly iron extractability was increased by 13-26 per

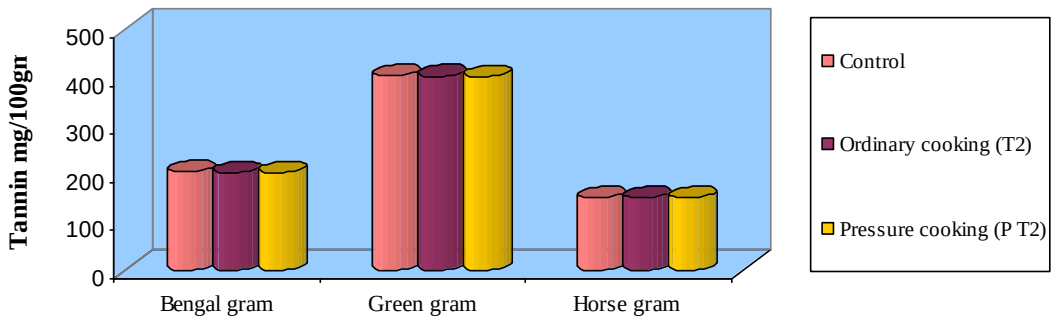

Fig.31 Effect of cooking methods on tannin in selected pulses

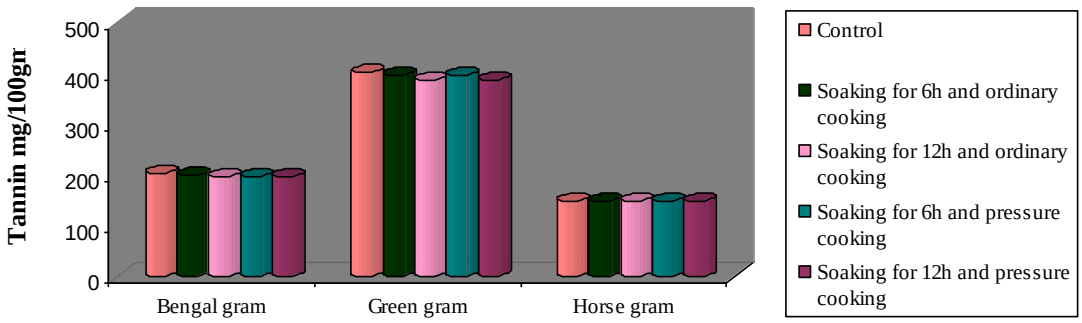

Fig.32 Effect of soaking and cooking methods on tannin in selected pulses

cent by ordinary cooking which showed a further increase by 15-28 per cent by pressure cooking.

Similar results for reduction in phytic acid in the soaked as well as soaked and dehulled legumes with an increase in the HCl extractability of minerals have been reported earlier (Deshpande and Cheryan, 1983; Kaur and Kapoor, 1990; Bishnoi *et al.,* 1994; Jood *et al.,* 1998).

In milled pulses, when cooked by ordinary method a 14-16 per cent reduction in phytic acid was observed only in bengal gram and horse gram. When pressure cooked the loss was 15-21 per cent in bengal gram and horse gram. Phytic acid was not reduced in green gram in ordinary as well as pressure cooking.

HCl extractability of minerals showed a wide variation with milled pulses. In bengal gram only phosphorus, potassium and zinc showed an increase in HCc extractability by 2, 25 and 17 per cent respectively and after pressure cooking this increased to 4, 26 and 20 per cent respectively. In green gram the HCl extractability of calcium, iron, phosphorus, potassium and zinc was increased by 2, 5, 2, 44 and 7 per cent respectively. But after pressure cooking further increase was observed only in potassium by 47 per cent In milled horse gram increase in HCl extractability was noted only in phosphorus by 4 per cent by ordinary cooking, which showed a further increase of 5 per cent after pressure cooking [Fig.28].

In the present study germination has significantly reduced the phytic acid content in selected pulses to a maximum extent. When germination for 24h and cooked for 10min by ordinary cooking method, there was a considerable reduction in phytic acid content of bengal gram, green gram and horse gram by 11-16 per cent. There was no change in the reduction of phytic acid by 20min ordinary cooking except in green gram where the reduction showed a 12 per cent increase as against 10per cent in 10min cooking. But pressure cooking of 24hour germinated legume 2min showed a further increase in the reduction of phytic acid by 12-17 per cent and no further increase with pressure cooking for 5min [Fig.29].

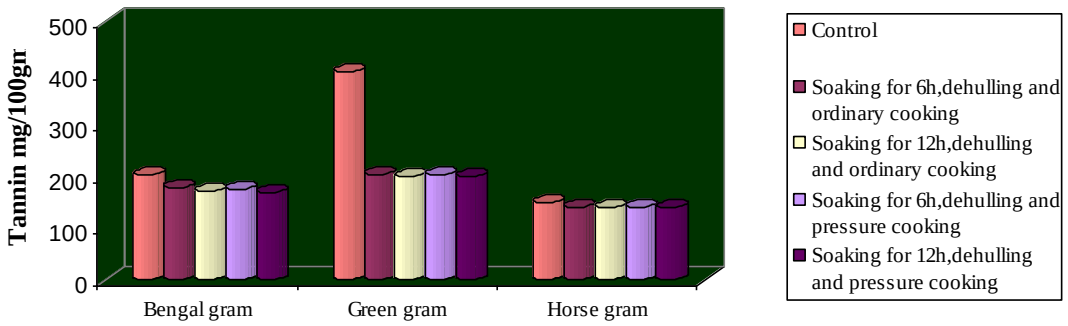

Fig.33 Effect of soaking ,dehulling and cooking methods on tannin in selected pulses

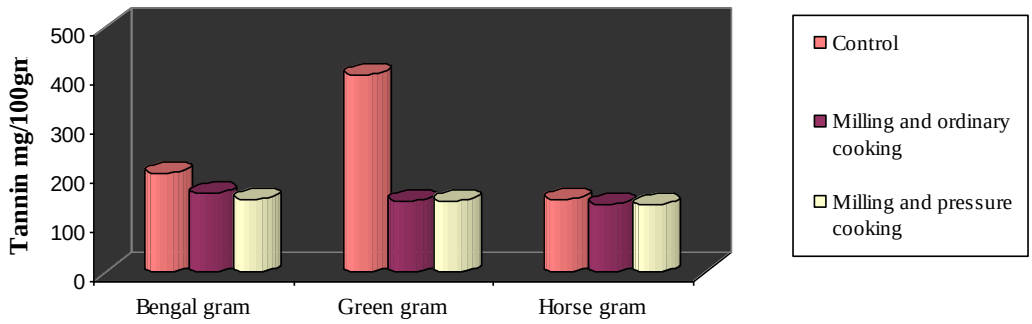

Fig.34 Effect of milling and cooking methods on tannin in selected pulses

HCl extractability of minerals also showed a significant negative correlation with phytic acid content. Legumes germinated for 24h when cooked by ordinary method, HCl extractability of calcium was increased by 17-34 per cent, the maximum being in green gram. Extractability of iron was increased by 29-35 per cent and the maximum was in bengal gram. Phosphorus extractability was increased by 12-23 per cent, with horse gram showing the highest phosphorus extractability. Potassium extractability showed an increase by 18-37 per cent with maximum in horse gram. Zinc extractability showed an increase by 9-21 per cent with maximum in bengal gram. With increased cooking time (20 and 30min) there was no much difference in the extractability of minerals.

Maximum reduction in phytic acid was observed during 36h germination of legumes [Fig.30]. When the germinated legumes were cooked by ordinary method, phytic acid was reduced by 13-18 per cent irrespective of cooking time. But pressure cooked legumes further reduced the phytic acid by 13-1 per cent by 2min and to a maximum reduction by 14-19 per cent by 5min pressure cooking.

HCl extractability of minerals also showed a negative correlation with phytic acid content. HCl extractability of calcium was increased by 21-44 per cent iron by 39-57 per cent, phosphorus by 16-30 per cent, potassium by 21-40 per cent and zinc by 10-30 per cent by ordinary cooking (10min). Cooking for 20min showed an increase in the HCl extractability of iron by 40-59per cent. Cooking for 30min showed an increase in the HCl extractability of phosphorus by 17-32 per cent and zinc by 19-32 per cent.

Pressure cooking of 36h germinated legumes showed the maximum HCl extractability of minerals. Calcium extractability has shown a maximum increase by 22-49 per cent, iron by 22-61per cent, phosphorus by 18-32per cent, potassium by 17-42 per cent and zinc by 11-33 per cent when pressure cooked for 2min. Five minutes pressure cooking further increased HCl extractability of minerals with calcium by 23-49 per cent, iron by 22-64 per cent, phosphorus by 18-34 per cent, potassium by 17-43 per cent and zinc by 10-34 per cent.

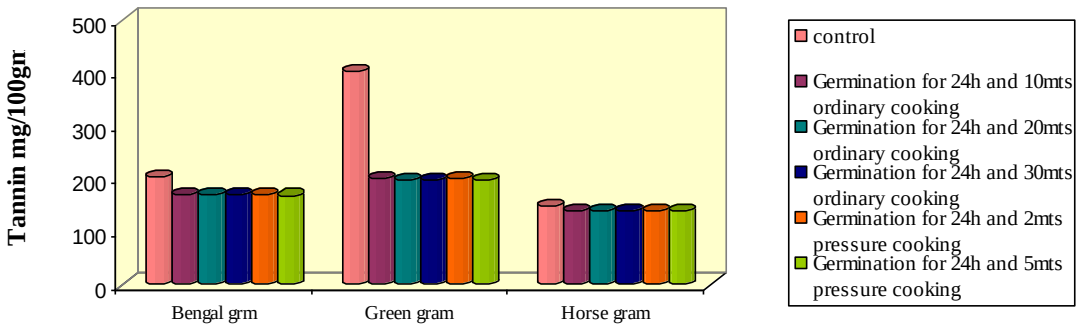

Fig.35 Effect of 24h germination and cooking methods on tannin in selected pulses

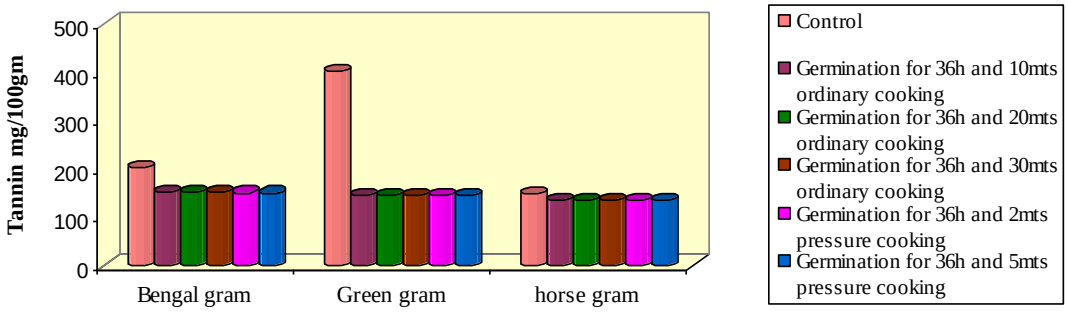

Fig.36 Effect of 36h germination and cooking methods on tannin in selected pulses

The results are in agreement with the report of Negi *et al.,* (2008) who stated that germination had marked lowering effect on the level of phytic acid. In their study with 4 varieties of moth bean, they revealed that soaking for 12h followed by germination for 36h, lowered phytic acid content by 66-68 per cent. Loss of phytic acid during germination may be attributed to hydrolytic activity of phytase. Earlier workers have also reported diminished amounts of phytic acid in germinated legumes (Khokar and Chauhan, 1986; Sharma and sehgal, 1992; Bishnoi *et al.,* 1994). Studies conducted by Agte *et al.,* (1998) in pulses also revealed that germination cum pressure cooking reduced the phytic acid content by 36 per cent. Germination changes the stored nutrients in the cotyledons to soluble nutrients through the hydrolysis of macro molecules and this may be contributing to the increased HCl extractability of minerals in germinated seeds. Grewal and Jood, (2006) also found a significant increase in the HCl extractability of calcium (32-56%) and zinc (62-67%) in green gram may be ascribed to the reduced content of phytic acid (35-39%) during germination and pressure cooking.

5.4 Processing and cooking methods on tannin content and extractability of minerals

Legumes contain varying amount of polyphenols and generally the amount are considered higher in the coloured seeds. This antinutritional factor lowers the nutritional value of pulses by lowering the bioavailability of minerals. Certain iron binding polyphenols like tannin are potent inhibitors of non heam iron absorption.

In the present study tannin content showed vide variation with pulse varieties. Maximum tannin was observed in green gram (403.08 mg/100gm) followed by bengal gram (203.16 mg/100gm) and the least in horse gram (149.15 mg/100gm).

Effect of processing and cooking methods had considerably reduced the tannin content to varying extents with an increase in the HCl extractability of minerals.

In ordinary cooking, of the unsoaked legumes, the loss of tannin was the maximum which varied from <1 to 1 per cent and pressure cooking of the

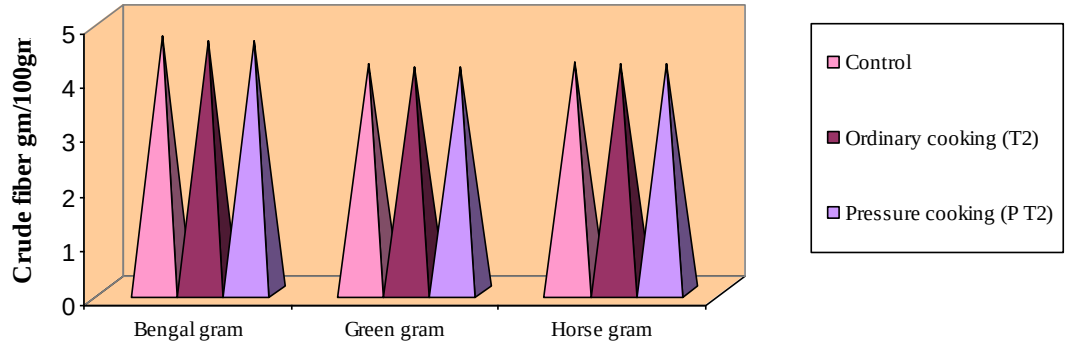

Fig.37 Effect of cooking methods on crude fiber in selected pulses

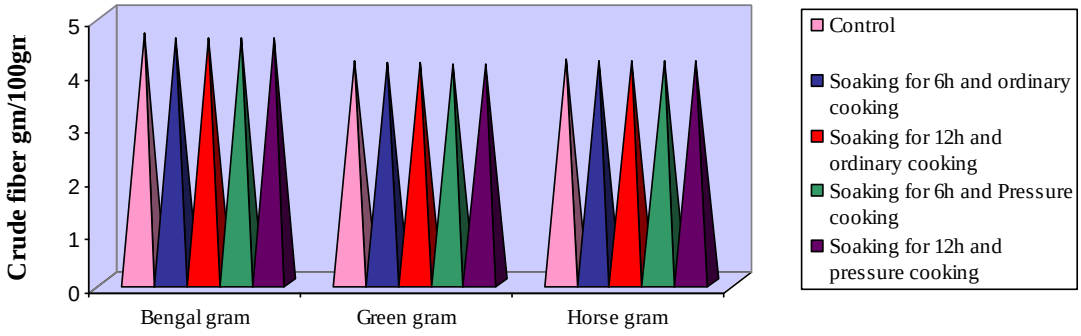

Fig.38 Effect of soaking and cooking methods on crude fiber in selected pulses

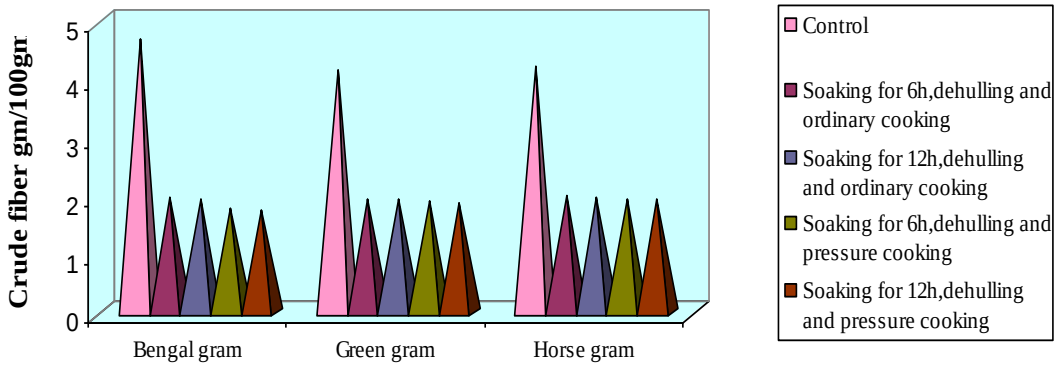

Fig.39 Effect of soaking,dehulling and cooking methods on crude fiber in selected pulses

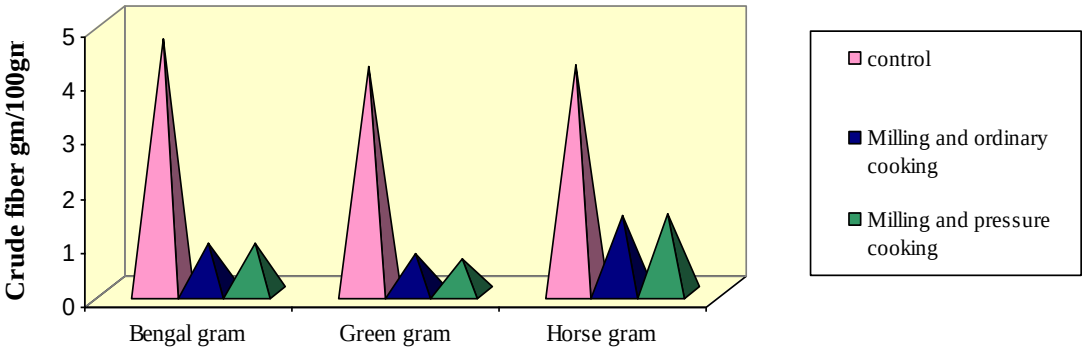

Fig.40 Effect of milling and cooking methods on crude fiber in selected pulses

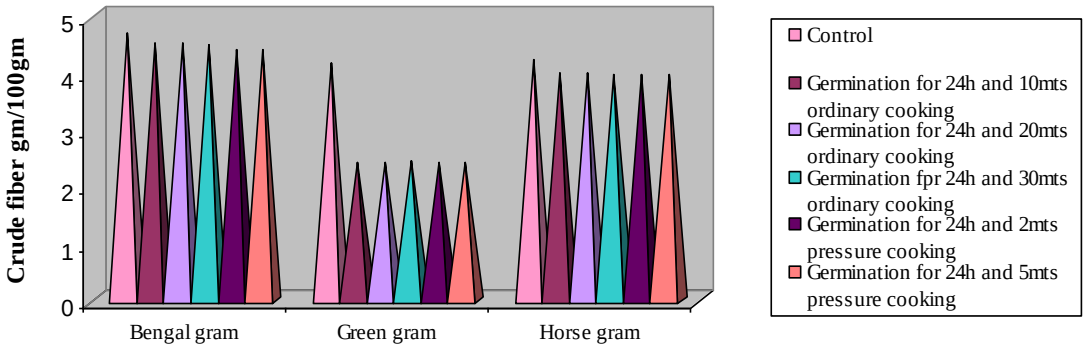

Fig.41 Effect of 24h germination and cooking methods on crude fiber in selected pulses

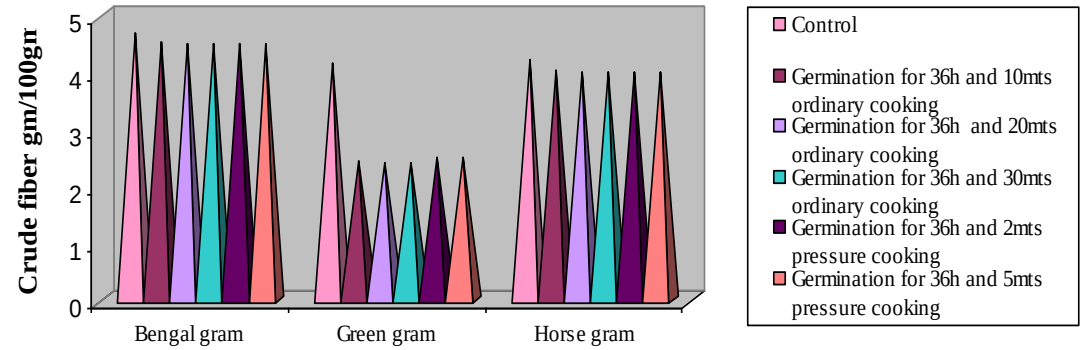

Fig.42 Effect of 36h germination and cooking methods on crude fiber in selected pulses

unsoaked legumes also showed no significant loss in tannin content in any of the legumes [Fig.31].

when legumes were soaked for 6h and cooked by ordinary method a reduction of <1 to 2 per cent was observed, but pressure cooking further reduced the tannin content by 1-3 per cent . When soaked for 12h and cooked by ordinary method tannin was reduced by 1- 4 per cent and pressure cooking did not show a further reduction in tannin content indicating the effect of soaking in the reduction of tannin content.

HCl extractability of minerals showed that in ordinary cooking of 6h soaked legumes an increase in calcium extractability by 6-11 per cent, iron by 4-7 per cent, potassium by 8-27 per cent and zinc by 2-5 per cent was observed pressure cooking showed a further increase only in iron extractability by 6-15 per cent. When soaking was extended for 12h and cooked by ordinary method calcium extractability showed an increase by 7-15 per cent, iron by 7-20 per cent, potassium by 5-14 per cent and zinc by 4-10 per cent [Fig.32]. Pressure cooked samples showed a further increase in the extractability of all minerals.

Soaking for 6h and dehulling before ordinary cooking showed a reduction in tannin content by 5-49 per cent, maximum in green gram. When pressure cooked there was no further significant increase in the reduction of tannin. When soaked for 12h and dehulled before ordinary cooking, the more reduction was found by 6-50 per cent and for pressure cooking a significant difference was not observed.

HCl extractability of minerals revealed that soaking (6h) and dehulling before ordinary cooking had increased the calcium extractability by 9-15 per cent, iron by 10-20 per cent, phosphorus by 10-17 per cent, potassium by 9-29 per cent and zinc by 7-17 per cent. Pressure cooking further increased the extractability of all minerals. When soaking period was increased to 12h and dehulled before ordinary cooking, showed a considerable increase in calcium extractability by 12-20 per cent, iron by 13-26 per cent, phosphorus by 11-22 per cent, potassium by 12-31 per cent and zinc by 8-20 per cent and on pressure cooking further increase up to 30 per cent in calcium and 28 per cent in iron was observed [Fig.33].

Milling and ordinary cooking of the legumes showed a reduction in tannin content by 6-64 per cent with a maximum in green gram. On pressure cooking this showed a slight increase as 8-64 per cent. But HCl extractability of minerals in milling was varying. Even though there was a reduction in tannin content, ordinary cooking of milled sample showed an increase only in phosphorus by 2-5 per cent and potassium by 1-47 per cent [Fig.34].

Germination of legumes for 24h and ordinary cooking for 10min showed a 6-50 per cent reduction in tannin and increasing the cooking time showed only slight difference in the tannin content. Pressure cooking of (2min) 24hr germinated legumes also showed a reduction of 6-50 per cent which further increased to 7-51 per cent on 5min pressure cooking [Fig.35].

When germination was extended for 36h and cooked by ordinary method 10min cooking showed the maximum reduction in tannin by 9-64 per cent [Fig.36]. Pressure cooking of these samples showed no difference in the reduction of tannin.

HCl extractability of minerals has also showed a significant negative correlation with tannin content. The result of this is in agreement with the results of earlier studies conducted by several workers. Kumar, (2006) conducted studies on the antinutritional factors in rice bean (*Vagina umbellate*) and reported that tannin content of cooked whole bean was 35 per cent lower than uncooked bean. In the present study only a one per cent reduction in tannin was observed due to cooking of unprocessed legumes. Decrease in the tannin content due to cooking has been noticed earlier by different workers in different legumes (Shinde *et al*., 1991; Adewusi and Flade, 1996).

Heat treatment of soaked legumes especially pressure cooking has significantly reduced the tannin content up to 4 per cent. Paramjyothi and Mulimani, (2001) also observed a decrease in tannin content of red gram as a result of pressure of soaked seeds. The loss can be attributed to two possibilities (1) Tannin are destroyed during the cooking process due to moist heat and (2) it is possible that the

tannin form complexes with other water soluble substances and get discarded with the soaked water. Kaur and Kapoor, (1990) also reported reduction in tannin when the soaked seeds of rice bean were subjected to pressure cooking.

Pressure cooking of soaked and dehulled legumes (12h soaking) reduced the tannin content by 6-50 per cent. This is in line with the studies of Negi *et al.,* (2008) who found 70-80 per cent reduction in tannin content of moth beans when subjected to pressure cooking after soaking (12h) and dehulling, Since polyphenolic compounds are present in the periphery of the grain, their leaching out into the soaking medium through seed coat is possible. Kumar and parvathi (2006) also showed that removal of husk from rice bean has reduced the tannin content by 12per cent.

Maximum reduction in tannin by 9-64 per cent was observed in 36h germination of legumes when cooked for 10min. A similar result was obtained by Negi *et al.,* (2008) in their study on four varieties of moth bean. They observed a 70 per cent reduction in tannin content of all the four varieties of moth bean. The loss of polyphenols during sprouting may be attributed to the presence of polyphenol oxidises and enzymatic hydrolysis. Some of the losses may also be expected from leaching of polyphenols into water (Giami, 1993)

HCl extractability of minerals showed a negative correlation with tannin content .Maximum reduction in tannin content was observed in processing methods like milling (27%) followed by germination for 36h and pressure cooking (26%). Maximum HCl extractability of calcium (23-49%), iron (22-64%), phosphorus (18-34%), potassium (17-43%) and zinc (10-34%) was also observed in these treatments.

5.5 Processing and cooking methods on crude fiber content and extractability of minerals

Fiber content in foods is a main cause of reduced mineral availability. In the present study crude fiber content of bengal gram was 4.68 g/100g, in green gram 4.17 g/100g and in horse gram 4.21 g/100g. Various processing and cooking

methods had significantly reduced the fiber content there by enhancing HCl extractability of minerals [Fig.37].

Cooking of unprocessed legumes showed no significant reduction in fiber content. When legumes were soaked for 6h, ordinary cooking showed no significant reduction, but after pressure cooking a significant reduction of about 2 per cent was observed in bengal gram. Soaking for 12h and ordinary cooking did not, decrease the fiber content, but pressure cooking brought about a 2 per cent reduction in crude fiber content of bengal gram [Fig.38].

Soaking and dehulling has considerably reduced the crude fiber content. Soaked (6h) and dehulled legumes when cooked by ordinary method fiber content was reduced by 52-57 per cent which showed a further reduction by 54-62 per cent on pressure cooking [Fig.39]. Soaked (12h) and dehulled legumes when pressure cooked reduce the crude fiber content of legumes by 54-63 per cent.

Milling had the highest effect in reducing the crude fiber content of legumes [Fig.40]. In this study milling of legumes reduced the fiber content by 80-83 per cent, and pressure cooking further reduced the fiber content by 80-85 per cent.

Sprouting of legumes for 24h and ordinary cooking for 10min and 20min reduced the fiber content by 5-42 per cent, but after pressure cooking the reduction in fiber content was 6-42 per cent [Fig.41]. Sprouting for 36h and ordinary cooking reduced the crude fiber content by 25 and 42 per cent in bengal gram and green gram respectively. Horse gram (36h germinated) showed no significant reduction in crude fiber content in any of the ordinary cooking (10, 20 and 30min) but pressure cooking showed a 5 per cent reduction in crude fiber content of horse gram [Fig.42].

Maximum HCl extractability of minerals was observed in 36h germinated legumes .When pressure cooked for 5min, calcium extractability was increased by 23-49 per cent, iron by 22-64 per cent, and phosphorus by 18-34 per cent, Potassium by 17-43 per cent and zinc by 10-34 per cent. Rehinhold *et al.*, (1975) suggested fiber to be the main cause of reduced zinc availability.

Summary

6. SUMMARY

The present study entitled "Bio-availability of minerals from pulses" was under taken with the aim of evaluating the effect of different processing and cooking methods on the *in vitro* availability of calcium, iron, phosphorus, potassium and zinc from commonly consumed pulses like bengal gram, green gram and horse gram.

The three pulses selected were subjected to various processing methods such as soaking, soaking and dehulling, milling and germination and two cooking methods such as ordinary cooking and pressure cooking.

HCl extractability in 0.03N HCl is considered as an index of bioavailability of minerals. Hence this method was adopted in the present study to find out the in vitro availability of minerals.

Significant increase was observed in mineral extractability in ordinary cooked samples than uncooked samples. After pressure cooking there was a significant increase in HCl extractability of minerals and reduction in the antinutrient contents such as phytic acid, tannin and crude fiber.

When pulses were cooked by ordinary method after soaking for 6h there was an increase in calcium extractability by 6-11 per cent and the maximum calcium extractability was in bengal gram. In pressure cooking no significant difference in calcium extractability was observed. Iron extractability showed an increase by 4-7 per cent and maximum was observed in bengal gram. A further increase in iron extractability by 6-11 per cent was observed by pressure cooking. Phosphorus extractability was increased by 2-13 per cent in ordinary cooking and further increased to 6-13 per cent by pressure cooking of soaked seeds. Potassium extractability showed an increase by 6-20 per cent in ordinary cooking while it increased to 8-27 per cent in pressure cooking and maximum potassium extractability was in green gram. Zinc extractability showed an increase by 2-5 per cent in ordinary

cooked sample without any significant differences in pressure cooked sample. Maximum zinc extractability was in Bengal gram.

When soaking period was extended to 12h there was a 7-12 per cent increase in calcium extractability by ordinary cooking, this was increased to 8-13 per cent in pressure cooking and maximum calcium extractability was observed in horse gram. Iron extractability showed an increase of 8-15 per cent under pressure cooking and maximum was in bengal gram. Maximum phosphorus and zinc extractability was also observed in pressure cooking (5-16% and 4-11% respectively).

Ordinary cooking of legumes soaked for 6h and dehulled showed a significant increase in the extractability of all the minerals. Maximum increase of calcium extractability (10-16%) was observed under pressure cooking. Iron extractability also increased by 10-20 per cent in pressure cooking. Maximum iron extractability was observed in bengal gram. Phosphorus extractability showed a maximum increase of 10-17 per cent in ordinary cooked sample. Similarly, potassium extractability was also maximum (16-29 %) in ordinary cooked samples. Zinc extractability showed an increase by 7-17 per cent in ordinary cooing and no significant increase after pressure cooking. Maximum zinc extractability was for bengal gram.

When soaking was extended for 12h, dehulled and ordinary cooked samples showed an increase in calcium extractability by 16-22 per cent and it was further increased to 30 per cent by pressure cooking. Maximum calcium extractability was in green gram. Increase in iron extractability was observed only in bengal gram and horse gram under pressure cooking. Ordinary cooking of all the pulses showed an increase in iron extractability by 13-31 per cent. Phosphorus extractability was increased by 11-22 per cent in ordinary cooking without significant increase in pressure cooking. Maximum phosphorus extractability was showed in horse gram. Potassium extractability also showed an increase by 12-31 per cent under ordinary cooking and zinc extractability was also increased by 8-20 per cent in ordinary cooking with out significant increase in pressure cooking.

Milling has brought varied results on mineral extractability in bengal gram. Only phosphorus, potassium and zinc extractability was enhanced. Phosphorus extractability showed an increase by 4 per cent, potassium by 26 per cent and zinc by 20 per cent after pressure cooking in bengal gram. In green gram (milled), all the mineral extractability was enhanced after cooking without significant change in pressure cooking. In horse gram only phosphorus showed an increase by 4 per cent in ordinary cooking and by 5 per cent under pressure cooking after milling. Maximum potassium extractability was observed for green gram under pressure cooking (4-7%). Zinc extractability was increased by 7-20 per cent in pressure crooking of milled samples.

Calcium extractability increased by 17-34 per cent in 24h germination and ordinary cooked samples (10, 20 and 30min). Pressure cooking further increased calcium extractability by 21-39 per cent. Iron extractability was found to be maximum under 30min ordinary cooking. Phosphorus, potassium and zinc extractability were also found to be enhanced due to ordinary cooking (10, 20 and 30min). A further increase in the extractability was observed after pressure cooking.

Germinated sample for 36h enhanced the calcium extractability by 21-40 per cent in ordinary cooking and further enhancement to 22-49 per cent in pressure cooking. Iron extractability was increased by 39-59 per cent in ordinary cooking and it was enhanced to a maximum of 22-69 per cent after pressure cooking with maximum iron extractability in bengal gram. Phosphorus extractability showed a maximum increase by 8-34 per cent by 5min pressure cooking. Potassium extractability was increased to 22-43 per cent in 5min pressure cooked samples. A 10-34 per cent increase in zinc extractability was observed in pressure cooked (5min) samples.

Mineral extractability showed an increase with decrease in phytic acid. Among legumes studied, green gram contained the maximum amount of phytic acid 540.70 mg/100g and which was reduced to 465.19 mg/100g due to various processing and cooking methods. Phytic acid was reduced to 497.19mg/100g from 579.10mg/100g in bengal gram and in horse gram it was reduced to 334.99mg/100g from 427.40mg/100g. Maximum reduction in phytic acid (15-24%) was observed

during pressure cooking of milled samples. 24h and 36h germination and pressure cooking for 5min showed a reduction by 14-19 per cent in phytic acid and these processing methods showed maximum HCl extractability of minerals.

There was a negative correlation between HCl extractability of minerals and tannin content. 24h germinated legume after pressure cooking for 5min reduced the tannin content by 7-51 per cent. 36h germinated seeds when cooked by ordinary method by 10min, the tannin content was reduced 9-64 per cent and by pressure cooking showed no difference in tannin content.

Crude fiber content in foods is a main cause of reduced mineral availability. Milling had the highest effect in reducing the crude fiber content in the present study. Ordinary cooking of milled legume reduced the fiber content by 80-83 per cent and pressure cooking further reduced it by 80-85 per cent. Soaking and dehulling reduced the crude fiber content. Soaked (12h) and dehulled legume when pressure cooked reduce the crude fiber by 54-63 percent.

Among the processing and cooking method studied germination for 36h and 5min pressure cooking was the best method for improving the extractability of minerals like calcium, iron, phosphorus and zinc in bengal gram. In green gram and horse gram maximum calcium and phosphorus extractability was observed by this method. This method is also suitable for reducing the tannin content in bengal gram, green gram and horse gram. Germination for 36h and 30min ordinary cooking can cause a further increase in iron extractability. In green gram and in horse gram iron, potassium and zinc extractability was increased by this method. Germination for 24 h and 30min ordinary cooked sample showed maximum zinc extractability in green gram. The milled and pressure cooked sample showed a maximum potassium extractability in bengal gram and horse gram. Milled and cooked samples showed a considerable reduction in crude fiber content.

Hence by adopting these processing and domestic cooking methods, antinutritional factors like tannin, phytic acid and fiber which interfere with mineral availability can be reduced to a maximum and thereby the mineral availability from pulses which form a major protein and mineral source in our diet can be enhanced.

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BIO - AVAILABILITY OF MINERALS FROM PULSES

By

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ABSTRACT OF THE THESIS

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ABSTRACT

Legume grains are generally processed before consumption depending on the cultural and taste preferences. In India the most common domestic methods of processing of legumes include soaking, soaking and dehulling, milling and germination. These methods have been reported to be beneficial for enhancing the nutritive value of various food legumes, by reducing the antinutritional factors and enhancing the bioavailability of minerals.

Bioavailability is the degree to which food nutrients are available for absorption and utilisation in the body. Extractable minerals in a food are those which are soluble in 0.03 N HCl, the concentration is found in human stomach. The amount of HCl extractable minerals indicates an index of their bioavailability from foods. In the present study an attempt was made to estimate the HCl extractability of minerals from pulses.

Three legumes such as bengal gram, green gram and horse gram were selected and subjected to various processing methods such as soaking, soaking and dehulling, milling and germination and two cooking methods such as ordinary cooking and pressure cooking.

Among the processing and cooking methods studied, germination for 36hrs and 5mts pressure cooking was the best method for improving the extractability of minerals like calcium (67.63%), iron (39.75%), phosphorus (55.08%) and zinc (70.41%) in bengal gram. In green gram and horse gram maximum calcium (29.78% and 52.35% respectively) and phosphorus (56.66% and 52.13% respectively) extractability was observed by this method. This method is also suitable for reducing the tannin content in bengal gram (73%), green gram (35%) and horse gram (90%). Germination for 36hrs and 30mts ordinary cooking can cause a further increase in iron extractability. In green gram iron extractability (70.19%) and in horse gram iron (70.23%), potassium (49.53%)

and zinc (50.83%) extractability was increased by this method. Germination for 24 hrs and 30mts ordinary cooked sample showed maximum zinc (76.01%) extractability in green gram. The milled and pressure cooked sample showed a maximum potassium extractability in bengal gram (48.23%) and green gram (50.69%). Milled and cooked samples showed a considerable reduction in phytic acid and crude fiber content.

Over all, the processing and cooking methods improved the HCl extractability of minerals from pulses. Maximum improvement was brought about by germination (24 and 36hrs) followed by pressure cooking and ordinary cooking and milling. As these processing methods are inexpensive in terms of time, energy and fuel saving, these methods can be used in household processing of legumes especially in developing countries like India where legumes are an integral part of the daily meal pattern.