DIGESTIBILITY OF CARBOHYDRATES IN SELECTED PULSES

By

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THESIS

SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENT FOR THE DEGREE OF
MASTER OF SCIENCE IN HOME SCIENCE
(FOOD SCIENCE AND NUTRITION)
FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF HOME SCIENCE
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM

1999

DECLARATION

I hereby declare that this thesis entitled **"Digestibility of carbohydrates in selected pulses"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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ACKNOWLEDGEMENT

At the very outset, the author wishes to place her deep indebtedness to GOD, THE ALMIGHTY for His bountiful blessings and eternal love showered at each and every moment without which this small endeavour would not have been completed.

The author wishes to express her deep sense of gratitude, profound feelings and hearty thanks to Dr. (Mrs.) L. Prema, Professor and Head, Department of Home Science and Chairperson of the Advisory Committee, for her learned counsel, valuable and gracious guidance, invaluable co-operation, constructive criticism and generosity throughout the period of research work and in the preparation of thesis.

The author owes a deep sense of gratitude and hearty thanks to Dr. P. Prabhakumari, Associate Professor, Department of Soil Science and Agricultural Chemistry, Dr. S. Chellammal, Associate Professor, KVK, Sadananthapuram and Dr. P.V. Nandini, Assistant Professor, Department of Home Science for their timely help, friendly approach and useful suggestions during the course of investigation and preparation of thesis.

The author avails this opportunity to express her hearty sincere thanks to Smt. N.K. Vimalakumari, Department of Home Science and Dr.

P. Rajendran, Department of Soil Science and Agricultural Chemistry, who have been gracious enough to render their timely and invaluable help, during the laboratory work.

The author is grateful to Shri. Ajith Kumar, C.E., Junior Programmer, Department of Statistics for his sincere co-operation and help rendered during the statistical analysis of the data and also to M/s. Athira Computers, Kesavadasapuram, Thiruvananthapuram for helping her in the accurate and neat preparation of the thesis.

The author specially remembers the great help rendered and the constant encouragement, mental support and timely help of all her friends during the course of investigation. The author specially thanks all of them.

Besides, the author have no words to express her thanks to her family members for their moral support which was a constant encouragement and all the help they have rendered to her at the various stage of the endeavour.

The author is also thankful to the Dean, College of Agriculture, Vellayani, for providing all the facilities for the conduct of this work and also to the Kerala Agricultural University for awarding a fellowship for carrying out the PG programme.

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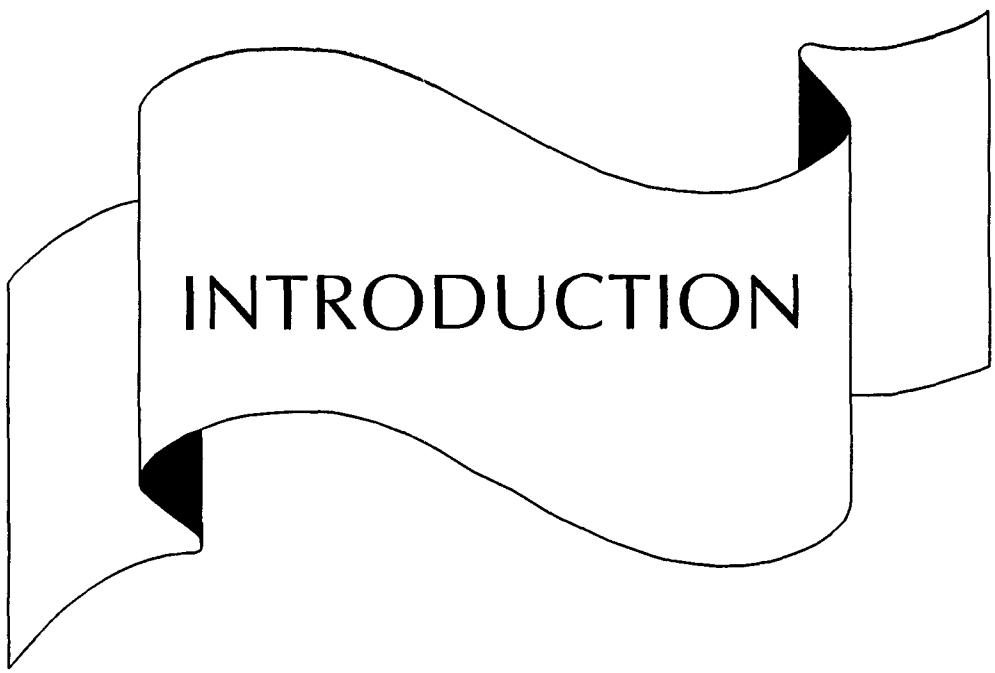

INTRODUCTION

1. INTRODUCTION

Legumes are recognized as a major source of carbohydrate and other important nutrients (Deshpande, 1992) and are essential in cereal based diets, because of their rich mineral and vitamin profile (Kumar, 1992). Starchy legumes have been consumed by humans since the earliest practice of agriculture and have been ascribed medicinal, cultural as well as nutritional roles (Phillips, 1993). Legumes not only add variety in human diet but also serve as an economical source of supplementary proteins for a large human population (Paroda and Chadha, 1996).

However, contributions of pulses in human diet is restricted by deficient essential aminoacids and presence of certain antinutritional factors including enzyme inhibitors (trypsin, chymotrypsin and α amylase inhibitors), lecithins, saponins, phytic acid and polyphenolic compounds (Kataria and Chauhan, 1987). There is a popular belief that starch in pulses are less digestible and their consumption leads to flatulence (Borejszo and Khan, 1992).

Digestibility of starch in pulses are also observed to be influenced by interaction of starch with fibre, phytate and protein in pulses and also due to the nature of starch itself (Phillips, 1993). Further understanding

of such factors which may influence starch digestibility will allow greater use of pulses in the dietaries, especially in the management of therapeutic diets.

In Kerala recipes, pulses are generally cooked as raw or after germination and fermentation. In order to improve the nutritional quality of the dry pulses, treatments such as soaking, cooking or germination are also widely applied. There is, however, little information on the changes that occur in the nature of starch in pulses due to processing and cooking. Hence an experiment on the nature and digestibility of carbohydrates in six commonly consumed pulses are taken up to assess their digestibility when processed and cooked in different forms.


REVIEW OF
LITERATURE

2. REVIEW OF LITERATURE

This chapter presents a review of earlier studies conducted on the nature and digestibility of carbohydrates in pulses affected by processing and cooking treatments with reference to :

2.1. Nutritional composition of pulses

2.2. Inhibitory constituents in pulses

2.3. Effect of processing and cooking on the nutritional composition of pulses

2.4. Effect of processing and cooking on the inhibitory constituents in pulses

2.5. Changes in pulses due to amylolysis

2.1 Nutritional composition of pulses

Pulses are reported to be good sources of nutritionally important dietary nutrients *viz.*, proteins, minerals (iron and calcium) and vitamins (niacin and thamine) (Rosaih *et al.*, 1993).

Among pulses, soyabean is found to contain about 40 per cent good quality protein as reported by Patil and Shukla (1990) and Gandhi (1991), while other legumes contain 18-32 per cent protein (Gabriel and Giovanni, 1991; Gopalan *et al.*, 1991; Kochar *et al.*, 1988; Rosaih *et al.*, 1993; Singh and Eggum 1984; Singh *et al.*, 1990). Pulse proteins, in general, are rich in lysine but limiting in sulphur amino acids (Phillips, 1993). Pulse proteins are also observed to vary greatly in their amino acid content (Henley and Kuster, 1994).

The low level of sulphur amino acids in pulses may not have serious nutritional implications since the pulses are usually consumed in combination with cereal based foods which are relatively high in methionine as suggested by Gabriel and Giovanni (1991) and Rosaih *et al.* (1993).

One of the draw backs in this context is that sulphur amino acid content in legumes is correlated negatively with protein content because sulphur amino acid generally declines as protein concentration is increased and a higher percentage of protein in the food legume would therefore represent poorer protein quality especially with respect to sulphur amino acids (Deshpande, 1992).

Pulses provide a significant amount of calories, principally from starch, which typically comprises of 25.00 - 50.00 per cent of the seed weight (Babu and Bhat, 1997; Gopalan *et al.*, 1991; Salunkhe *et al.*, 1985).

Antia and Abraham (1997) had reported that pulses provide the same amount of calories as cereals.

According to Bressani (1985) pulses are an important source of calories and cowpea contains 65 per cent carbohydrate, while it is 62.55 to 64.55 per cent in greengram (Sharma *et al.*, 1991) and 52.40 to 70.90 per cent in chickpea (Chavan *et al.*, 1994). In most grain legumes, the principal storage polysaccharide is starch (Reddy *et al.*, 1989; Wiseman and Cole, 1988)

The mechanism by which pulses promote gas formation is not fully known but it is some way related to the action of microflora of the large intestine on the indigestible carbohydrate components of the food stuff as reported by Ogun *et al.* (1989). Pulses are reported to contain a number of oligosaccharides which include raffinose, stachyose and verbascose which are not digestible due to the absence of suitable enzymes in the human digestive system and promote gas production (Echardallou and Eltimay, 1985; Ogun *et al.*, 1989). There are however wide variation in the capacity of flatus formation by different pulses. Bengal gram is shown to be more flatus forming than red gram, green gram and black gram (Ogun *et al.*, 1989).

Lin and Markakis (1987) found that in soyabeans, sucrose, raffinose and stachyose concentrations increased significantly with maturation.

According to Jood *et al.* (1985) total soluble sugars, reducing sugars and non reducing sugar content varies widely in the pulses.

Pulses contain low fat ranging from 0.70 to 19.5 per cent as reported by Snook *et al.* (1985) and Weisweiler *et al.* (1986).

Pulses are also good sources of minerals. However major portion of phosphorous in pulses is reported to exist in its phytate form as reported by Ophage *et al.* (1984). Wide variation in mineral concentrations are reported by Haytowitz and Mathews (1986) in different pulse grains.

According to Geervani and Theophilus (1980), Bressani (1985) and Deosthale (1986) pulses are fair sources of thiamine, riboflavin and niacin.

Along with macronutrients leguminous seeds contain appreciable amounts of minerals and vitamins as well as dietary fibre (Phillips, 1993). Phillip (1996) reported that crude fibre content in pulses ranged from 3.17 g per cent to 7.55 g per cent.

According to Liener (1989) and Khokhar and Khokhar (1995), fibre will greatly reduce the bioavailability of trace minerals and calcium in Indian vegetarian diets.

2.2 Inhibitory constituents in pulses

Most grain legumes contain an array of secondary metabolites which constitute important defences of the plant against insects and herbivores and which are resistant to gastric and intestinal digestion. These so called anti nutritional factors often have detrimental effects on mammalian digestion and metabolism (Dixon and Hosking, 1992).

Legumes contain a variety of undesirable chemical substances also called inhibitory constituents that are known to exert a deleterious effect when ingested by man or animals. These substances include phytic acid, trypsin inhibitors, flatus producing oligosaccharides and tannins which can cause adverse physiological responses or inhibit the availability of certain nutrients to animals or humans. Protein and fibre are also known to inhibit the digestion and absorption of nutrients (Phillips, 1993).

A large number of antinutritional factors occur in legume seeds and have been identified in grain legumes (Annapurani and Gomathy, 1991; Liener, 1980; Poel, 1990 ; Salunkhe and Kadam, 1989). Many of these constituents are heat labile and heat stable with inherent resistance to digestion of the major globulins (Phillips, 1993).

Antinutrients like tannins are reported to reduce the activity of enzymes concerned with digestion and fermentation in the gastrointestinal tract (Nyman and Bjorck, 1989). Bernal and Lugo (1990) reported that

the rate of hydrolysis of phytate contributes to the seed susceptibility and hardening in different bean varieties.

As reported by Singh and Krikorian (1982) and Vaintraul and Bulmaga (1991) phytate strongly interacts with the basic residues of protein inhibiting the action of pepsin and trypsin.

Blood glucose response was found lowered with the increasing content of phytic acid in the food items (Pagani *et al.*, 1986; Yoon *et al.*, 1983).

According to Phirke *et al.* (1982) the polyphenol content varied in seeds of different colour, being highest in black seeds and lowest in white ones mainly due to the crude nature of the legume protein concentrate (Liener *et al.*, 1984).

The antinutrients have no effect either on starch digestion or on fibre fermentation except in reduction of the activity of enzymes concerned with digestion and fermentation in the gastrointestinal tract (Bjorck and Nyman, 1987; Nyman and Bjorck, 1989) and on the disruption of seed coat by mechanical means (Dixon and Hosking, 1992).

Phytic acid accounts for about 80 per cent of the total phosphorous in most legume seeds with varietal variation (Beal and Mehta, 1985; Goyal, 1991; Kataria and Chauhan, 1987; Reddy *et al.*, 1982).

Complexing between phytate and proteins in several cereals and legumes are reported by Cheryan (1980) and this might affect the protein digestibility and bioavailability (Chitra and Vimala, 1996).

As a consequence of the nonselective binding to proteins, phytate has been shown to inhibit the action of a number of enzymes important in digestion, including pepsin, trypsin and alpha-amylase (Caldwell, 1992; Reddy *et al.*, 1988).

Phytic acid is reported to have antinutritional properties with respect to mineral absorption (Forbes and Erdman, 1983). It has also been suggested that phytic acid has either no inhibitory effect (Hunter, 1981) or may even enhance mineral absorption in certain circumstances (Wetter *et al.*, 1984). However phytic acid (Myo-inositol hexa phosphate) in grains and legumes, is known to chelate divalent cations and thereby restrict bioavailability and essential elements (Beal and Mehta, 1985).

Phytic acid is observed to cause proteins to be more resistant to proteolytic digestion (Deshpande and Cheryan, 1984; Knuckles *et al.*, 1985; Liener, 1976; Reddy *et al.*, 1982; Serraino *et al.*, 1985; Singh and Krikorian, 1982) mainly due to its strong interaction with the basic residues of protein (Vaintraul and Bulmaga, 1991). Phytic acid is also found to reduce the digestibility of lipids (Nyman and Bjorck, 1989) and proteins and starch (Goyal and Khetarpaul, 1995; Sutardi and Buckle, 1985).

Phytate is reported to inhibit amylases (Bjorck and Nyman, 1987; Deshpande and Cheryan, 1984; Goyal and Khetarpaul, 1995; Serraino *et al.,* 1985; Yoon *et al.*, 1983).

Trowell *et al.* (1985) defined the term dietary fibre as 'the sum of polysaccharides and lignin which are not digested by endogenous secretions of human gastrointestinal tract'. Dietary Fibre is found to affect bowel function, restrict calorie intake; slow gastric and small bowel transit faecal bulk; support bacterial growth and modify stool transit (Bijlani, 1985). The effect of various types of Dietary Fibre (DF) on gastrointestinal function relates highly to their physico chemical properties and is strongly dependent on the chemical composition and structural integrity of the plant cell wall (Johansen *et al.*, 1995; Morris, 1992).

Seed coats of pulses, contain more dietary fibre (Sharma and Kawatra, 1995; Singh *et al.*, 1984).

The effect of fibre on N balance and N excretory patterns is influenced by many factors, including its chemical composition and degradability (Eggum *et al.*, 1984).

Non Starch Polysaccharides (NSP) are reported to be the main constituents of dietary fibre (Beames and Eggum, 1981; British Nutrition Foundation, 1990)

Studies of the nutritional effects on colonic fermentation of dietary fibres have been widely developed during the past decade and *in vitro* fermentation methods have made it possible to predict some of the physiological effects of fibre (Adiotomre *et al.*, 1990; Burney and Thompson, 1989). Short Chain Fatty Acids (SCFA), the main end-products of dietary fibre fermentation, are extensively absorbed and metabolized. As fibre is indigestible in the small intestine, its energy content is conventionally considered to be zero, but this appears to be untrue, especially when substantial quantities of fibre is fermented (Livesey, 1990).

Fibre may act directly on colonic motility either by mechanical stimulation of submucosal neural receptors or by an effect of fermentation on end products eg. Short Chain Fatty Acids (SCFA) and on the contractile activity of the colon (Cherbut, 1995). Dietary fibre is reported to affect stool output by increasing unfermented residues, faecal water and microbial mass (Cummings, 1986; Edwards, 1995).

Among different fibres, insoluble fibres are known to be degraded by colonic flora than soluble ones (Mortensen and Andersen, 1993).

Insoluble types of dietary fibre such as cellulose and wheat bran have shown little or no effect on the rate of passage, digestion and absorption in stomach and small intestine (Low, 1990; Stephen and Cummings, 1980). This effect is thought to be mediated by a reduced rate of gastric emptying (Nunes and Malmlof, 1992).

Dietary fibre has been found to cause increased mucus secretion in the digestive tract resulting in a more rapid transit and impaired nutrient absorption (Satchithanandam *et al.*, 1990).

A reduced dietary fibre intake in digestive disturbances such as changes in the Caecal Fermentative Activity (CFA) (Bellier, 1994) and slow transit (Gidenne, 1994) are reported to favour the occurrence of diarrhoea (Bellier and Gidenne, 1996).

A general view is that high fibre diets have a low energy density due to the low digestibility (Eggum *et al.*, 1984; Just *et al.*, 1983) and low net energy values of fibre digested (Livesey, 1992). Starch was almost completely digested at the end of the small intestine although there was a lower digestibility of starch for the high fibre diet (Jorgensen *et al.*, 1996).

However, the high levels of butyrate produced from the fermentation of starch in small intestine may be of benefit to health (Cummings, 1995; Rombeau *et al.*, 1990).

Digestibility of other dietary constituents is certainly influenced by the fibre in the cell walls that may hinder the access of digestive enzymes to the cell contents (Knudsen *et al.*, 1993).

The presence of fibre decreases the digestibility of protein by increasing the faecal excretions as reported by Janakamma and Reddy

(1994). They have also reported that dietary fibre has a role in slow release of sugar and in turn its role in management of diabetics.

Soluble fibres are reported to reduce apparently serum cholesterol concentration, whereas insoluble ones are usually ineffective (Glore *et al.*, 1994). Other properties, such as viscosity and the ability to sequester bile salts of fibre, can also influence glucose and cholesterol metabolism (Wolever, 1995).

Protein solubility may contribute to cooking time of legume seeds (Hentges *et al.*, 1991).

A positive correlation was reported by Akinyele *et al.* (1986) between cooking time of cowpea and protein content. During germination of the seed, storage proteins are degraded and mobilized. They are broken down to amino acids which are used for the synthesis of various enzymes, structural proteins , non nitrogenous compounds or for energy (Shutov and Vaintraub, 1987; Wilson *et al.*, 1986). The rapid increase in proteinase activity is usually associated with the mobilization of protein resources and may indicate the participation of the proteinases in the degradation process, during germination. These enzymes are not observed in dry seeds and found after two or more days of germination (Shutov and Vaintraub, 1987).

A number of compounds have been characterised as interfering with the release of amino acids during digestion or during their subsequent absorption (Chitra *et al.*, 1995; Liener, 1980).

Antinutritional factors like trypsin inhibitors, phytate, tannins and polyphenols adversely affect protein digestibility (Bressani *et al.*, 1988; Hernandez and Martinez, 1991; Kataria and Chauhan, 1987; Singh, 1984).

The formation of tannin complexes with dietary protein and digestive enzymes may contribute to the low digestibility of cooked beans (Bressani and Elias, 1980; Deshpande, 1992; Reddy *et al.*, 1985; Singh and Eggum, 1984).

Tannins are observed to reduce α-amylase activity as well as digestibility of available carbohydrates (Nyman and Bjorck, 1989).

2.3 Effect of processing and cooking on the nutritional composition of pulses

Processing is a pre condition for the consumption of all foods including legumes (Obizoba, 1992).

According to Singh *et al.* (1989), processing methods greatly affect the nutrient composition of pulses, *viz.*, protein, aminoacids, minerals and vitamins.

Soaking in water overnight and subsequent germination is a common practice of pulse consumption (Rao and Deosthale, 1982). Soaking in water is reported to result in the loss of water soluble vitamins

in pulses (Rao and Deosthale, 1982) and also oligosaccharides (Terri *et al.*, 1990).

Soaking is reported to increase protein content, starch digestibility, firmness and volume of cooked seeds (Bakr and Gawish, 1992; Sharma and Singh, 1991) by modifying the composition as reported by Valverde *et al.* (1992). They had further observed that soaking in $NaHCO_3$ increase the availability of fibre in pulses.

Salunkhe *et al.* (1986) and Singh *et al.* (1989) had reported that considerable amounts of calcium and iron were removed by dehulling but the process did not adversely affect the protein quality in terms of amino acids. Akincyle and Akinlosote (1991) had reported that dehulling decreased the oligosaccharide content in pulses. Duhan *et al.* (1995) have reported that the digestibility of starch and protein of dehulled redgram improved significantly when compared to that of raw unprocessed seeds. Singh (1995) had observed that dehulling reduces cooking time, improves protein quality and digestibility of pulses.

While loss of calcium, zinc and manganese due to dehulling in pulses were reported by Attia *et al.* (1994). Igbasan and Guenter (1996) found marginal decrease in moisture, protein and fibre content in dehulled pulses.

Germination is a very active process and several enzyme systems are triggered in the germinating seeds as reported by Ninanna and Phillips

(1990). According to Deosthale (1983), Annapurani and Gomathy (1991), Sylvester *et al.* (1994) and Gupta (1995), germination enhances the nutritive value of cereals and pulses by increasing the essential amino acids, protein digestibility, amino acid availability and certain vitamins including thiamine, riboflavin, niacin, folic acid and ascorbic acid.

Obizoba (1992) reported that germination caused increase in mineral levels except for phosphorous. According to Neerja and Hira (1993) germination resulted in significant loss of calcium. The beneficial effect of germination is reflected in improved availability of iron in pulses as reported by Rao and Deosthale (1994).

Ikemfuna and Obizoba (1989) had reported that germination also increases magnesium retention in pulses.

Germination modifies the starch content in pulses improving their digestibility (Phillips, 1993). He also reports that when pulses are germinated the oligosaccharides which causes flatulence are reduced.

Fermentation is one of the processes which can be used to increase the nutrient content of foods as reported by Kasturba and Phadnis (1987).

Parker (1986) had reported that fermented pulses are important sources of minerals (Ca, P and Fe) while Ejiofar and Oti (1987) had stated that fermentation reduces oligosaccharides in pulses.

According to Dentis and Bisping (1994) and Gupta (1995) as a result of fermentation, there is an increase in vitamin content (especially thiamine, riboflavin and niacin) to nearly the original amounts. They have also reported that the content of vitamin C and folic acid increases but no vitamin B_{12} appears after fermentation in pulses.

Thulasidas (1986) reports that fermented soy-products are known for their better nutritional properties and freedom from flatus factors.

The *in vitro* digestibility of starch improved significantly as a result of fermentation as reported by Yadav and Khetarpaul (1995).

Cooking tend to modify the composition of pulses and increase the availability of nutrients in them (Valverde *et al.*, 1992).

Kelkar *et al.* (1996) had reported that pressure cooking improved carbohydrate digestibility in pulses.

The puffing and roasting quality of pulses also observed to be related to the nature of their starch content (Deosthale, 1986). The flour of the puffed pulses is found to have a reduced paste thickness.

Gahlawat and Sehgal (1994) had reported that domestic processing techniques like roasting resulted in 16-20 per cent increase in starch digestibility and 17-32 per cent increase in protein digestibility. A 16-32 per cent increase in iron availability was also observed.

Jacorzynski *et al.* (1981) had reported that soaking and cooking considerably decreased soluble sugars by 16 per cent in peas and 70 to 80 per cent in soyabeans.

Tuan and Phillips (1992) had reported that boiling cowpea seeds improved both overall nutritive and protein quality when compared to raw seeds.

Phillip (1996) had reported that boiling of soaked pulses caused maximum loss in protein content as well as flatus causing raffinose sugars probably due to the leaching of solids in water used as the cooking medium.

When pulses are soaked in minimum amounts of water and cooked in steam under pressure, the nutritive value of proteins is observed to enhance (Deosthale, 1983). He also reports that the losses of some B vitamins are appreciable when cooked in steam under pressure.

Poel *et al.* (1992) indicated that steam treatment at 119°C for five to ten minutes damaged protein as measured by total and available lysine. Ziena *et al.* (1992) had reported that almost all essential amino acids declined after cooking at temperature 100-125°C for one to two hours.

Chandrasekhar and Jayalakshmi (1978) observed that roasted seeds, bengalgram and greengram had higher PER and biological values.

Kochappan (1995) had reported that in greengram, frying caused maximum loss of minerals such as calcium, iron, magnesium, zinc and copper.

According to Gupta (1995) frying causes loss of vitamins in pulses.

According to Goyal and Mathews (1985), after cooking there was no significant decrease in protein but a significant decrease in lysine, tryptophan and sugar content in pulses.

Cooking brought about a great reduction in the level of oligosaccharides as reported by Richard and Esther (1992).

Rao and Deosthale (1983) had reported that cooking of raw pulse samples resulted in significant loss of Ca (44 per cent), Fe (29 per cent) and Mg (23 per cent).

According to Rao and Vakil (1983) irradiation reduced the oligasaccharide content of germinated greengram.

Kochappan (1995) reported that micro wave oven cooked pulses showed maximum loss of phosphorus, magnesium, manganese, zinc and copper.

Heating can affect the fibre content or modify the fibre distribution between water soluble and insoluble fractions in pulses (Lintas

and Cappeloni, 1988). Goonerathne *et al.* (1994) had reported that cooking of legume seeds resulted in significant degradation of fibre.

According to Neerja and Hira (1993) roasting and pressure cooking resulted in a significant loss of phosphorus in faba bean.

2.4 Effect of processing and cooking on the inhibitory constituents of pulses

Sathe and Salunkhe (1984) reported that among the processing methods germination appeared to be quiet effective in decreasing phytic acid concentration.

Salunkhe (1982), Rao and Deosthale (1983), Ologhobo and Fetuga (1984), Beal and Mehta (1985), Lalitha *et al.* (1987), Khan *et al.* (1988), Arti *et al.* (1989), Bishnoi *et al.* (1994) and Attia *et al.* (1994) have given an account of significant losses of inhibitory constituents by germination, soaking and cooking. Ologhobo and Fetuga (1984), Reddy *et al.* (1985) and Igbedioh *et al.* (1994) have observed that dehulling and boiling resulted in great loss of phytic acid and removed about 53 per cent in pigeon pea.

As observed by Yadav and Khetarpaul (1994) indigenous fermentation of coarsely ground dehulled blackgram dhal slurry at 25, 30 and 35°C for 12 and 18 h reduced concentrations of phytic acids and polyphenols.

Cooking brought about a significant decrease in phytic acid content and the loss appeared to be more in soaked and cooked grains than in unsoaked and cooked grains as reported by Kataria *et al.* (1989), Bishnoi *et al.* (1993) and Sylvester *et al.* (1994). Similar reduction in phytic acid content during the combined process of soaking and cooking has been reported in legumes like moth and faba bean by Khokhar (1984), Iyer *et al.* (1989), Kataria *et al.* (1989), Sharma (1989) and Sylvester *et al.* (1994).

Bakr and Gawish (1988) reported that the foliar application with gibberellic acid and white wash, especially under saline conditions improved the nutritive value of raw cowpea seeds by reducing antinutritional factors like trypsin inhibitors and tannins.

Germination also resulted in a significant reduction of phytic acid in blackgram (Reddy *et al.*, 1978), in soya bean (Ologhobo and Fetuga, 1984) and in field and vegetable pea and as the germination increased, successive reduction in phytic acid content was observed in peas by Bishnoi *et al.* (1993).

Deshpande and Cheryan (1983) have also stated significant loss of tannin occurred upon soaking.

Different treatments like soaking, soaking and dehulling and boiling, roasting and autoclaving had an effect on crude fibre of pulses as observed by Igbedioh *et al.* (1994) and Goonerathne *et al.* (1994).

Long cooking time for legume seeds have been related to low phytate content (Kon and Sanshuck, 1981; Marfo *et al.*, 1990) mainly due to the presence of water soluble sodium or potassium phytate (Cheryan, 1980). Milling is also observed to reduce the content of phytic acid and dietary fibre (Turk and Sandberg, 1992).

Processing has a minimal effect on the total nitrogen and protein content of dry beans and peas (Elias *et al.*, 1979; Singh, 1986; Terri *et al.*, 1990).

Srivastava *et al.* (1988) reported decrease in protein content due to leaching, during soaking.

Meiners *et al.* (1976) reported that the cooking of cowpea reduced crude protein levels. According to Usha *et al.* (1981) and Burns (1987) processing improved the protein quality of legumes significantly.

The increased nutritional value may be the result of an increased accessibility of beans proteins to enzymatic attack as reported by Romero and Ryan (1978).

Poel *et al.* (1992) indicated that steam treatment at 119°C for five to ten minutes seem to be a good compromise in terms of inactivation of antinutritional factors.

2.5 Changes in pulses due to amylolysis

Differences in physical properties of legume starches can be attributed to difference in amylose content or size of the starch granules (Geervani and Theophilus, 1983). Roopa *et al.* (1998) have reported that starch digestibility was increased, when foods were subjected to condition that increased the accessibility to amylose.

It is reported that cereal starch containing amylopectin is more accessible to digestion than legume starch containing amylose (Sanderstedt *et al.*, 1962). Particle size and surface area to starch ratio are reported to be important in starch hydrolysis (Snow and O'Dea, 1981).

Generally legume starch pastes are more viscous than those of cereal starches, indicating that legume starches have a higher resistance to swelling and rupture than do cereal starches (Lineback and Ke, 1975). Part of the slow rate of digestion of the starch in some foods is clearly the result of starch being trapped very firmly within cell-wall structures, it may resist digestion in the small intestine completely and it will be measured *in vitro* as physically inaccessible starch (Englyst *et al.*, 1992).

Retrogradation, the formation of crystallites (predominantly small aggregates of highly structured hydrogen - bonded amylose), results in a fraction of the starch becoming resistant to hydrolysis by alpha-amylase both *in vitro* and *in vivo* (Bjorck *et al.*, 1986; Faulks *et al.*, 1989).

According to Holm *et al.* (1983) other starch complexes, like starch lipid have been shown to be susceptible to slow digestion by alpha-amylase.

Studies of the enzymic hydrolysis of starch by pancreatic alpha-amylase *in vitro* confirm that the proportion of total starch that is rapidly digestible is different for different starchy foods (Englyst *et al.*, 1996).

Starch fractions resistant to alpha-amylase are collectively called Resistant Starch (RS) (Englyst *et al.*, 1982). According to Metzger *et al.* (1996) resistant starch is the fraction of starch that escapes digestion and hydrolysis after incubation with alpha-amylase.

It is known that the efficiency of *in vivo* digestion is generally greater than that found *in vitro* (Faulks *et al.*, 1989). However, starch that is trapped within whole plant cells or within the food matrix and some starch granules that have not been fully gelatinized are also observed to be hydrolyzed only very slowly by alpha-amylase and therefore may escape complete digestion in the small intestine (Englyst *et al.*, 1992).

On the basis of these observations a new nutritional classification of starch into Rapid Digestible Starch (RDS), Slowly Digestible Starch (SDS) and Resistant Starch (RS) has been proposed (Englyst *et al.*, 1992).

Starch present in beans and peas is resistant to hydrolysis by alpha-amylase. Besides the physical nature of starch granules, the type

of crystal structure present in starch granules may influence its digestibility. This is mainly due to relatively higher concentration of Slowly Digestible Starch (SDS) and Resistant Starch (RS) (Englyst *et al.*, 1995).

A significant and negative correlation was found between the *in vitro* digestibility and the antinutrients as reported by Yadav and Khetarpaul (1994).

Tannic acid is reported to reduce the total recovery of starch during enzymic starch hydrolysis while the activity of cellulases and hemi cellulases were found not affected by phytic acid or catechin (Bjorck and Nyman, 1987).

The starch of raw beans, which had been soaked overnight, is about 20 per cent digestible (Satwadhar *et al.*, 1981). Disruption of the cells, especially before cooking, increases the susceptibility of starch to alpha-amylase digestion (Wursh *et al.*, 1986).

Legume starch is more slowly digested than starch from cereals and tubers and produce less abrupt changes in plasma glucose and insulin upon ingestion (Phillips, 1993). Differences in the rate of starch digestion is observed to provide a plausible mechanism for differences in glycaemic responses to starchy foods (Englyst *et al.*, 1995).

Low glycaemic response is found to be associated with slow rate of starch hydrolysis in the gastro intestinal tract of man (Gruchala and Pomeranz, 1992).

Gahlawat and Sehgal (1994) reports that processing of grains resulted in 16-20 per cent increase in starch digestibility. *In vitro* digestibility of starch improved with increase in the temperature as well as in the period of fermentation (Yadav and Khetarpaul, 1994). The rate of starch hydrolysis in pulses, having similar form of starch is likely to be affected by the method of preparation and food combinations (Roopa *et al.*, 1998).

A simple *in vitro* system that measures rates of starch hydrolysis in foods may be useful in predicting the starch digestion *in vitro* (Holm *et al.*, 1983; Jenkins *et al.*, 1980).

In *in vitro* studies, increased concentration of dietary fibre and its components are reported to decrease the pancreatic enzyme activity (Trowell et al., 1985). The physiological effects of dietary fibre is associated with the low glycaemic response of the particular food (Gruchala and Pomeranz, 1992). The dietary fibre present with encapsulation by the thick plant cell walls may be related to the relatively large proportions of Slowly Digestible Starch (SDS) and Resistant Starch (RS) measured in most of the legumes (Englyst *et al.*, 1995).

The presence of saponins, glycosides, tannins, alkaloids, conjugates of protein with phytin or hemicellulose and these substances inhibit the action of digestive enzyme trypsin in different pulses, adversely affecting their digestibility (Gupta, 1981).

Cooked starch, once cooled, may contain regions where the starch chains (mainly amylose) have aggregated into a configuration with very low level of susceptibility to pancreatic amylase. The gelatinization of starch granules and the retrogradation of starch on cooking during food preparation clearly influence the physical structure and hence, the digestibility of starchy foods, some of which are inedible without some form of food processing (Englyst *et al.*, 1996).

Englyst *et al.* (1982) had also reported that a fraction of starch in cooled, cooked foods was highly resistant to digestion by pancreatic amylase *in vitro.*

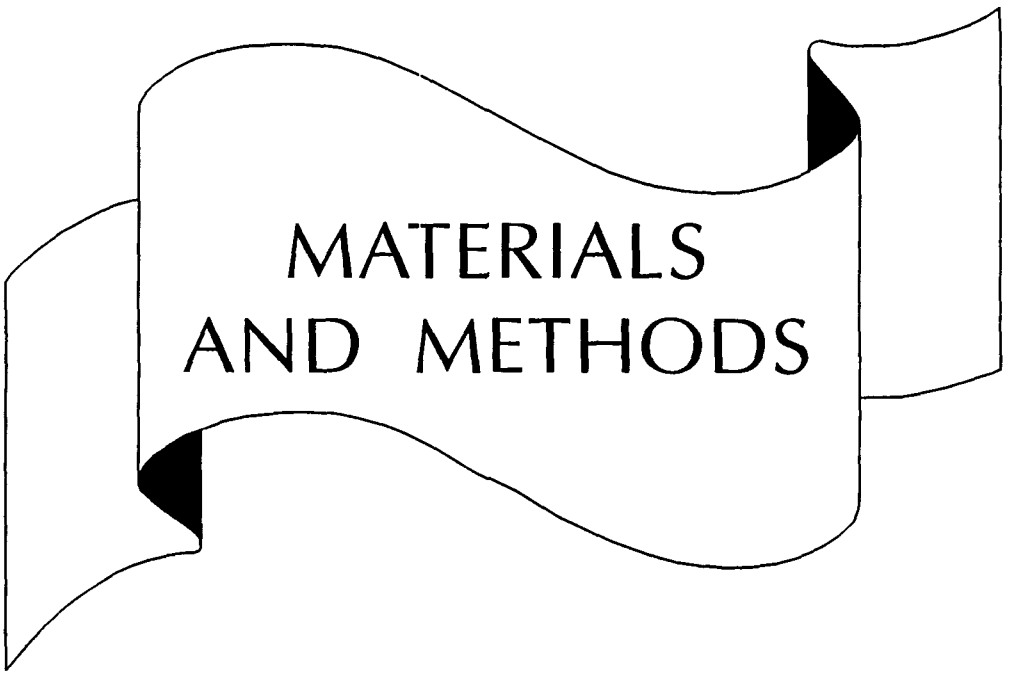
The cooking time of legumes on the other hand, does influence the blood glucose response, and the digestibility of starch *in vitro* (Jenkins *et al.*, 1982), probably because of the slow swelling and only partial gelatinization of the starch from whole legumes (Englyst *et al.*, 1996).

Use of a thermostable alpha amylase enzyme during extrusion cooking of grain starches also resulted in reduction of retrogradation and rapid saccharification rates during production of maltose syrups (Linko

et al., 1980). Amylases used in spray and roller drum drifting partially hydrolysed starch and reduced viscosity of slurries. This aided coating on the drying rolls and increased digestibility and sweetness of the mixture (Harper and Jansen, 1985).

Gelatinized starch readily absorbed water to form paste that had higher final viscosity at room temperature than native starch (El-Dash *et al.*, 1984). The higher viscosity decreased slightly with increasing enzyme concentration. The slight reduction of viscosity with higher alpha amylase concentration might indicate increased starch hydrolysis with increased enzyme.

Review of the earlier research findings revealed that processing and cooking are effective in removing or reducing flatulence factors in pulses and increased the nutritional quality and digestibility of pulses.


MATERIALS
AND METHODS

3. MATERIALS AND METHODS

The present study was taken upto elicit information on the digestibility of carbohydrates of selected pulses when processed and cooked in different forms.

3.1 Selection of samples

Pulses were procured from selected grocerie shops in Thiruvananthapuram district.

Pulses listed below were selected for the present study.

1. Cowpea
2. Blackgram
3. Redgram
4. Greengram
5. Soyabean
6. Bengalgram

3.1.1 Fresh (untreated) pulses, T_1

Fresh pulses collected were cleaned. Foreign matter and damaged seeds were manually removed. Each pulse sample was washed initially to remove surface contamination and dried at 60° to 70°C.

3.2 Pre treatments on pulses

Pre treatments administered to pulses prior to processing and cooking were :

Soaking in plain water for six hours (T_1)

Soaking in plain water for three hours (T_2) and

Soaking in water containing $NaHCO_3$ for three hours (T_3).

3.3 Processing techniques administered on raw samples

Different methods of processing were administered on both fresh (T_1) and pretreated samples (T_2 and T_3). They included germination (T_4), fermentation (T_5) and grinding (T_6).

3.3.1 Germination

The soaked pulses were germinated following the procedure recommended by Rajalakshmi (1974).

3.3.2 Fermentation

Fresh samples (T_1) as well as the pretreated pulse samples (T_2 and T_3) were fermented (T_5), following the method standardised by Paul (1997).

3.3.3 Grinding

Samples selected for this process were fresh (T_1) as well as pretreated (T_2 and T_3). Pulses were ground until a smooth batter was obtained (T_6).

3.4 Cooking

Cooking methods administered on pulse samples (T_4, T_5, T_6), were cooking by boiling method (T_7), steaming (T_8), cooking under pressure (T_9), roasting (T_{10}).

On the basis of the different processing and cooking treatments administered, there were 37 groups in each pulse sample as detailed below.

Untreated (T_1)

$P_1T_1T_4T_7$	$P_1T_1T_4T_8$	$P_1T_1T_4T_9$	$P_1T_1T_4T_{10}$
$P_1T_1T_5T_7$	$P_1T_1T_5T_8$	$P_1T_1T_5T_9$	$P_1T_1T_5T_{10}$
$P_1T_1T_6T_7$	$P_1T_1T_6T_8$	$P_1T_1T_6T_9$	$P_1T_1T_6T_{10}$
$P_1T_2T_4T_7$	$P_1T_2T_4T_8$	$P_1T_2T_4T_9$	$P_1T_2T_4T_{10}$
$P_1T_2T_5T_7$	$P_1T_2T_5T_8$	$P_1T_2T_5T_9$	$P_1T_2T_5T_{10}$
$P_1T_2T_6T_7$	$P_1T_2T_6T_8$	$P_1T_2T_6T_9$	$P_1T_2T_6T_{10}$
$P_1T_3T_4T_7$	$P_1T_3T_4T_8$	$P_1T_3T_4T_9$	$P_1T_3T_4T_{10}$
$P_1T_3T_5T_7$	$P_1T_3T_5T_8$	$P_1T_3T_5T_9$	$P_1T_3T_5T_{10}$
$P_1T_3T_6T_7$	$P_1T_3T_6T_8$	$P_1T_3T_6T_9$	$P_1T_3T_6T_{10}$

For the different cooking treatments aliquot of 50g each of the sample were taken.

All the samples from various treatments were dried at 60 to 70°C and then powdered before analysis.

3.5 Estimation of nutrients and constituents present in pulses

Powdered pulse samples were used for various chemical analysis. Estimations on various constituents of pulses were carried out using the following standard methods.

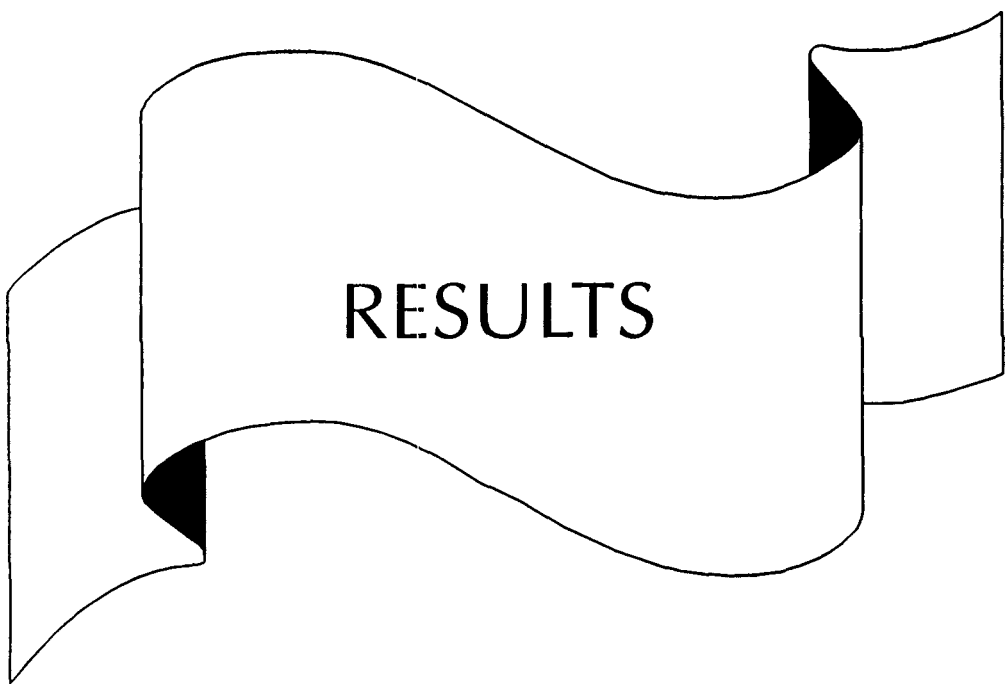
Constituents	Methods
Moisture	Raghuramulu *et al.* (1983)
Total soluble sugars	A.O.A.C. (1976)
Reducing sugars	A.O.A.C. (1976)
Non reducing sugars	A.O.A.C. (1976)
Starch	A.O.A.C. (1976)
Protein	Micro kjeldahl method, Sadasivam and Manickam (1992)
Crude fibre	Sadasivam and Manickam (1992)
Phytate	Sadasivam and Manickam (1992)

3.6 *In vitro* digestibility of carbohydrates or rate of alpha amylolysis

The principle adopted by Fischer and Stein (1961) for alpha amylolysis was followed.

3.7 Statistical analysis of data

Influence of different processing techniques and cooking treatments on the digestibility of pulses were statistically tested, applying analysis of variance technique and significance tested by F test (Snedecor and Cochran, 1975).


RESULTS

4. RESULTS

The study entitled "Digestibility of carbohydrates in selected pulses" presents a comprehensive information on the influence of various processing and cooking treatments on the digestibility of carbohydrates of selected pulses such as cowpea, blackgram, redgram, greengram, soyabean and bengalgram. For this purpose, informations on different carbohydrate constituents in the pulses (processed and cooked as well as untreated ones) were elicited. Influence of processing or cooking techniques on the *in vitro* digestibility of the carbohydrates and informations on constituents inhibiting this action were also ascertained.

Results of the study are presented under:

Influence of different processing and cooking treatments on

4.1 Carbohydrate constituents

4.2 Inhibitory constituents

4.3 and on the *in vitro* digestibility of carbohydrates in untreated, processed and cooked pulses.

4.1 CARBOHYDRATE CONSTITUENTS IN PULSES

Different carbohydrate constituents viz. starch, Total Soluble Sugars (TSS), Reducing Sugars (RS) and Non Reducing Sugars (NRS) were assessed in all the six pulses. The values are expressed as per 100 g seed weight.

4.1.1 Carbohydrate constituents in untreated pulses (Table 1)

In the untreated pulses, starch content was found to be in the range of 10.30 g to 51.60 g with the lowest concentration in soyabean followed by cowpea, blackgram, redgram, bengalgram and greengram. TSS in the pulses (untreated) analysed were in the range of 7.00 g to 13.86 g on dry weight basis, with the highest concentration in cowpea followed by soyabean, bengalgram, blackgram, greengram and redgram. In all the untreated pulses, the concentration of NRS was higher when compared to RS, prior to any treatment.

4.1.2 Influence of pretreatments, processing and cooking on the carbohydrate constituents of different pulses (Tables 2-13)

Different pretreatments attempted in the study were soaking in distilled water for six hours (T_1), soaking in distilled water for three hours (T_2) and soaking in distilled water with $NaHCO_3$ for three hours (T_3). Processing treatments administered on pretreated pulse samples were germination (T_4), fermentation (T_5) and grinding (T_6). Pretreated and processed pulse samples were cooked using different cooking methods

Table 1. Carbohydrate constituents in untreated pulse samples (100g) (mean values)

Pulses	Carbohydrate constituents			
	Starch (g)	TSS (g)	RS (g)	NRS (g)
1. Cowpea	42.40	13.86	1.90	11.96
2. Blackgram	49.50	8.14	2.00	6.14
3. Redgram	49.50	7.00	2.70	4.23
4. Greengram	51.60	7.90	2.20	5.70
5. Soyabean	10.30	10.20	3.60	6.60
6. Bengalgram	51.60	8.20	2.30	5.90
SE	0.165	0.517	5.198	0.120
CD	0.458	0.143	0.144	0.334
F	11357.37**	2362.42**	175.76**	482.44**

** Significant at 1 per cent level

viz. boiling (T_7), steaming (T_8), cooking under pressure (T_9), roasting (T_{10}) and there was also pretreated, processed, uncooked samples (T_0). Pulses listed under T_1 (4.1.1) except redgram, were selected for the statistical analysis. Carbohydrate constituents analysed in the pretreated or processed or cooked samples were starch, TSS, RS and NRS.

Table 2 details the starch content of different kinds of pulses on which different treatments were administered. A comparison of starch content of the samples, after three types of pretreatments revealed significant variations. The highest fluctuation was observed in soyabean followed by cowpea, bengalgram, blackgram and greengram in the case of soaking for six hours (T_1). In soaking for three hours, also similar trend was observed except in the case of blackgram and bengalgram. Similar trends were observed in the pulse samples after processing and cooking treatments also.

Influence of processing and cooking techniques on the starch content of different pretreated pulses irrespective of the kind is presented in Table 3. This also revealed significant variation in the starch content. Among different processing treatments administered, germination (T_4) was found to have the maximum effect followed by fermentation (T_5) and grinding (T_6). Similar trend was observed in a comparison among pretreated and cooked pulse samples on their starch content. Among the different cooking treatments administered, pressure cooking (T_9) was found to have the maximum effect followed by boiling (T_7), steaming (T_8) and roasting (T_{10}).

Table 2. Starch content of different treated pulses (mean values) (g/100g)

Pulses	Untreated	Pretreated samples			Pretreated and processed samples			Uncooked	Pre treated, processed and cooked samples			
	T_1	T_1	T_2	T_3	T_4	T_5	T_6	T_0	T_7	T_8	T_9	T_{10}
Cowpea	42.40	30.19	31.31	36.98	31.64	32.76	34.08	33.77	31.34	33.67	29.37	35.98
Blackgram	49.50	36.09	36.93	42.04	36.76	38.70	39.60	38.83	37.50	39.23	35.36	40.84
Greengram	51.60	39.09	40.46	45.06	40.72	41.55	42.34	40.19	41.08	42.56	39.69	44.16
Soyabean	10.30	8.79	8.84	9.45	8.94	9.04	9.09	7.92	9.20	9.40	9.00	9.60
Bengalgram	51.60	33.96	40.39	42.77	37.01	39.17	40.94	38.81	38.42	39.89	35.88	42.20
F	11357.37**		1833.34**			285.68**				371.02**		
CD	0.458		0.118			0.118				0.153		
SE	0.165		0.043			0.043				0.055		

** Significant at 1 per cent level

Table 3. Influence of processing and cookingtreatments on the starch content of pretreated pulses(g/100g)

Pretreatments	Processing treatments			Uncooked	Cooking treatments			
	T_4	T_5	T_6	T_{10}	T_7	T_8	T_9	T_{10}
T_1	28.83	29.58	30.47	28.37	29.29	30.69	27.54	32.23
T_2	30.53	31.64	32.58	30.09	31.22	32.68	29.57	34.37
T_3	33.68	35.51	36.58	37.26	34.02	35.48	32.47	37.06
F		110.425**				656.551**		
CD		0.092				0.118		
SE		0.033				0.043		

** Significant at 1 per cent level

In Table 4, a comparison of different cooking treatments on the pretreated, processed samples with reference to their starch content is presented and the results revealed significant fluctuations. The starch content of processed pulses when different cooking methods were administered was observed to vary considerably.

A comparison of cooking treatments alone revealed significant variation in starch content of uncooked pulses, with considerable reduction in cooking under pressure followed by boiling. Steamed and roasted samples were observed to retain starch content when compared to uncooked ones. This fluctuation was also found to be statistically significant.

When TSS content of different pulses were analysed, it was found that pretreatments, processing and cooking treatments on pulses had significant impact. As revealed in the Table 5, a comparison of TSS content of different pulses, after three types of pretreatments revealed significant variations. The highest fluctuation was observed in blackgram followed by greengram, bengalgram, soyabean and cowpea in the case of soaking for six hours (T_1). When soaking for three hours was considered, the highest fluctuation was observed in greengram followed by blackgram, bengalgram, soyabean and cowpea. Significant variations were observed in the TSS content of different pulse samples after processing and cooking treatments.

Table 4. Influence of different cooking treatments on the starch content of the pretreated and processed pulses (g/100g)

Processing treatments	Uncooked T_0	Cooking treatments			
		T_7	T_8	T_9	T_{10}
T_4	33.48	29.79	31.14	28.08	32.57
T_5	31.88	31.60	32.96	30.03	34.75
T_6	30.35	33.13	34.75	31.47	36.34
F	1222.38**				
CD	0.118				
SE	0.043				

** Significant at 1 per cent level

Table 5. Total soluble sugar content of different treated pulses (mean values) (g/100 g)

Pulses	Untreated	Pretreated samples			Pretreated and processed samples			Uncooked	Pre treated, processed and cooked samples			
	T_1	T_1	T_2	T_3	T_4	T_5	T_6	T_0	T_7	T_8	T_9	T_{10}
Cowpea	13.86	13.90	13.90	13.27	13.92	13.61	13.53	18.09	12.49	12.69	12.29	12.89
Blackgram	8.41	6.68	7.77	7.59	7.47	7.21	7.35	8.09	7.11	7.32	6.78	7.42
Greengram	7.90	7.84	7.76	7.47	7.85	7.67	7.57	10.27	7.00	7.10	6.90	7.20
Soyabean	10.20	10.04	10.02	9.53	10.01	9.84	9.75	12.94	9.00	9.20	8.80	9.40
Bengalgram	8.20	8.21	8.10	7.71	8.22	7.91	7.89	11.54	7.02	7.24	6.79	7.43
F	2362.42**		645.571**			23.680**				1948.944**		
CD	0.143		0.037			0.037				0.048		
SE	0.517		0.013			0.013				0.017		

** Significant at 1 per cent level

Influence of pretreating and processing on the TSS content of different pretreated pulses irrespective of the kind is presented in Table 6. This also revealed significant variations. Among different processing treatments administered, grinding (T_6) was found to have the maximum effect followed by fermentation (T_5) and germination (T_4). Similar trend was observed in a comparison among pretreated and cooked pulse samples on their TSS content (Table 6). Among the different cooking treatments administered, cooking under pressure (T_9) was found to have the maximum effect followed by boiling (T_7), steaming (T_8) and roasting (T_{10}).

In Table 7, a comparison of different cooking treatments on the pretreated, processed samples with reference to their TSS content is presented and the results revealed significant fluctuations. A comparison of cooking treatments alone revealed significant variation in TSS content of uncooked pulses was found to be reduced considerably in cooking under pressure followed by boiling, steaming and roasting. This fluctuation was also found to be statistically significant.

As revealed in Table 8, a comparison of RS content of different pulses, after pretreatments revealed significant variations with the highest fluctuation in blackgram, followed by cowpea, bengalgram, greengram and soyabean when soaked for six hours (T_1). In reduced duration of soaking (T_2 and T_3) the fluctuation was higher in cowpea, than in blackgram. Significant variation was observed in the TSS content of different pulse samples after processing and cooking treatments.

Table 6. Influence of processing and cookingtreatments on the total soluble sugar content of pretreated pulses(g/100g)

Pretreatments	Processing treatments			Uncooked	Cooking treatments			
	T_4	T_5	T_6	T_0	T_7	T_8	T_9	T_{10}
T_1	9.52	9.29	9.20	13.23	8.25	8.47	8.07	8.64
T_2	9.82	9.39	9.32	13.04	8.57	8.74	8.31	8.89
T_3	9.14	9.06	9.14	10.27	8.75	8.92	8.55	9.07
F		162.86**				3860.68**		
SE		0.010				0.013		
CD		0.029				0.037		

** Significant at 1 per cent level

Table 7. Influence of different cooking treatments on the total soluble sugar content of the pretreated and processed pulses (g/ 100g)

Processing treatments	Uncooked T_0	Cooking treatments			
		T_7	T_8	T_9	T_{10}
T_4	13.73	8.36	8.55	8.13	8.69
T_5	11.86	8.51	8.69	8.31	8.87
T_6	10.95	8.71	8.89	8.49	9.05
F	2813.58**				
CD	0.037				
SE	0.013				

** Significant at 1 per cent level

Table 8. Reducing sugar content of different treated pulses (mean values) (g/100 g)

Pulses	Untreated	Pretreated samples			Pretreated and processed samples			Uncooked	Pre treated, processed and cooked samples			
	T_1	T_1	T_2	T_3	T_4	T_5	T_6	T_0	T_7	T_8	T_9	T_{10}
Cowpea	1.90	1.51	1.59	1.53	1.48	1.57	1.57	2.36	1.29	1.39	1.18	1.50
Blackgram	2.00	1.48	1.62	1.63	1.56	1.63	1.55	2.51	1.30	1.40	1.19	1.50
Greengram	2.20	1.85	1.92	1.82	1.81	1.90	1.88	2.72	1.60	1.70	1.50	1.80
Soyabean	3.60	3.24	3.35	3.11	3.18	3.29	3.22	4.40	2.89	2.99	2.79	3.09
Bengalgram	2.30	1.56	1.63	1.69	1.52	1.63	1.73	2.78	1.24	1.41	1.09	1.60
F	175.76**		25.626**			11.77**				33.395**		
CD	0.144		0.037			0.037				0.048		
SE	5.198		0.013			0.013				0.017		

** Significant at 1 per cent level

Influence of processing techniques on the RS content of different pretreated pulses irrespective of the kind is presented in Table 9. Among different processing treatments administered, germination (T_4) was found to have the maximum effect followed by grinding (T_6) and fermentation (T_5) in the case of soaking for six hours (T_1). In the case of soaking without $NaHCO_3$ for three hours (T_2), the maximum effect was caused by grinding (T_6) followed by germination (T_4) and fermentation (T_5). While in the case of soaking for three hours with $NaHCO_3$ (T_3), germination (T_4) was found to have the maximum effect followed by fermentation (T_5) and grinding (T_6). Similar trend was observed in a comparison among pretreated and cooked pulse samples on their RS content. Among the different cooking treatments administered, cooking under pressure (T_9) was found to have the maximum effect followed by boiling (T_7), steaming (T_8) and roasting (T_{10}).

In Table 10, a comparison of different cooking treatments on the pretreated, processed samples with reference to their RS content is presented and the results also revealed significant variations.

A comparison of cooked samples with uncooked samples revealed significant variation in RS content. Rate of loss was higher in cooking under pressure followed by boiling, steaming and roasting.

Table 11 details that the NRS content of treated pulses revealed significant variation. The highest fluctuation was observed in blackgram followed by greengram, bengalgram, soyabean and cowpea. Processed and cooked pulse samples revealed significant variation.

Table 9. Influence of processing and cookingtreatments on the reducing sugar content of pretreated pulses(g/100g)

Pretreatments	Processing treatments			Uncooked	Cooking treatments			
	T_4	T_5	T_6	T_0	T_7	T_8	T_9	T_{10}
T_1	1.87	1.98	1.93	3.30	1.53	1.64	1.42	1.75
T_2	2.01	2.08	1.98	3.24	1.67	1.77	1.53	1.90
T_3	1.85	1.96	2.06	2.32	1.80	1.92	1.69	2.04
F		38.996**				514.021**		
CD		0.029				0.037		
SE		0.010				0.013		

** Significant at 1 per cent level

Table 10. Influence of different cooking treatments on the reducing sugar content of the pretreated and processed pulses (g/ 100g)

Processing treatments	Uncooked T_0	Cooking treatments			
		T_7	T_8	T_9	T_{10}
T_4	3.12	1.55	1.67	1.43	1.78
T_5	3.11	1.67	1.78	1.57	1.91
T_6	2.64	1.77	1.89	1.65	2.01
F	152.338**				
CD	0.037				
SE	0.013				

** Significant at 1 per cent level

Table 11. Non reducing sugar content of different treated pulses (mean values) (g/100 g)

Pulses	Untreated	Pretreated samples			Pretreated and processed samples			Uncooked	Pre treated, processed and cooked samples			
	T_1	T_1	T_2	T_3	T_4	T_5	T_6	T_0	T_7	T_8	T_9	T_{10}
Cowpea	11.96	12.68	12.37	11.75	12.48	12.13	12.19	16.32	11.20	11.29	11.12	11.39
Blackgram	6.14	5.20	6.14	5.95	5.91	5.58	5.80	5.58	5.80	5.92	5.59	5.92
Greengram	5.70	6.00	5.73	5.66	6.03	5.66	5.69	7.55	5.40	5.40	5.22	5.40
Soyabean	6.60	6.81	6.67	6.43	6.83	6.55	6.54	8.53	6.11	6.21	6.01	6.31
Bengalgram	5.90	6.64	6.47	6.02	6.70	6.26	6.16	8.74	5.78	5.83	5.69	5.83
F	482.44**		125.55**			6.986**				446.46**		
CD	0.334		0.086			0.086				0.111		
SE	0.120		0.031			0.031				0.040		

** Significant at 1 per cent level

Table 12 revealed significant variations among different processing treatments administered with maximum effect in fermentation (T_5) followed by grinding (T_6) and germination (T_4). In samples soaked with $NaHCO_3$ (T_3), maximum effect was observed in grinding (T_6) followed by fermentation (T_5) and germination (T_4). Similar trend was observed in a comparison among pretreated and cooked pulse samples on their NRS content. Among the different cooking treatments administered, cooking under pressure (T_9) was found to have the maximum effect followed by boiling (T_7), steaming (T_8) and roasting (T_{10}).

In Table 13, a comparison of different cooking treatments on the NRS content of pretreated, processed samples is presented and the results revealed significant variations.

A comparison of cooking treatments alone revealed considerable reduction in NRS content in cooking under pressure followed by boiling, steaming and roasting.

4.1.3. **Carbohydrate constituents in cowpea** (Tables 14 and 15)

A comparison between the untreated and processed cowpea revealed significant variation in starch and sugar contents. Among the three processing techniques administered germinated cowpea was observed to retain more starch content followed by fermented and ground samples.

Table 12. Influence of processing and cooking treatments on the non reducing sugar content of pretreated pulses(g/100g)

Pretreatments	Processing treatments			Uncooked	Cooking treatments			
	T_4	T_5	T_6	T_0	T_7	T_8	T_9	T_{10}
T_1	7.65	7.35	7.40	10.22	6.73	6.83	6.65	6.89
T_2	7.84	7.25	7.34	9.87	6.89	6.96	6.66	6.99
T_3	7.29	7.10	7.09	7.95	6.95	7.00	6.86	7.03
F		19.88**				352.61**		
CD		0.067				0.086		
SE		0.024				0.031		

** Significant at 1 per cent level

Table 13. Influence of different cooking treatments on the non reducing sugar content of the pretreated and processed pulses (g/100g)

Processing treatments	Uncooked T_0	Cooking treatments			
		T_7	T_8	T_9	T_{10}
T_4	10.65	6.81	6.88	6.70	6.91
T_5	8.84	6.83	6.91	6.63	6.96
T_6	8.54	6.93	7.01	6.85	7.04
F	293.40**				
CD	0.086				
SE	0.031				

** Significant at 1 per cent level

Table 14. Effect of processing and cooking techniques on the carbohydrate constituents of cowpea (100 g) soaked for six hours

Pulses	Carbohydrate constituents / 100 g			
	Starch (g)	TSS (g)	RS (g)	NRS (g)
1. Untreated				
T_1	42.40	13.86	1.90	11.96
2. Processed				
$P_1T_1T_4$	35.94	23.56	2.82	20.79
$P_1T_1T_5$	31.82	20.72	2.97	18.97
$P_1T_1T_6$	29.68	18.21	2.23	19.18
3. Processed and cooked				
$P_1T_1T_4T_7$	26.9	11.8	1.0	10.8
$P_1T_1T_4T_8$	27.6	12.10	1.2	10.8
$P_1T_1T_4T_9$	26.4	11.6	0.9	10.7
$P_1T_1T_4T_{10}$	29.6	12.2	1.3	10.9
$P_1T_1T_5T_7$	27.6	12.0	1.2	10.8
$P_1T_1T_5T_8$	29.6	12.2	1.3	10.9
$P_1T_1T_5T_9$	26.9	11.8	1.0	10.8
$P_1T_1T_5T_{10}$	33.9	12.0	1.4	11.0
$P_1T_1T_6T_7$	29.6	12.4	1.3	11.1
$P_1T_1T_6T_8$	33.9	12.6	1.4	11.2
$P_1T_1T_6T_9$	27.6	12.2	1.2	11.0
$P_1T_1T_6T_{10}$	35.9	12.4	1.5	11.3
SE	0.074	0.023	0.023	0.054
CD	0.205	0.064	0.064	0.249
F	168.493**	166.633**	26.319**	19.815**

** Significant at 1 per cent level

All the three processing techniques significantly reduced the starch in the untreated cowpea. Among the different cooking treatments, cooking under pressure and boiling were found to hydrolyse more starch components. While roasting as well as steaming were found to conserve more starch.

A comparison of TSS, NRS and RS content of cooked cowpea revealed that hydrolysis of TSS was at faster rates in samples boiled and cooked under pressure. Similar trends was observed in the case of RS also.

Significant variation in the carbohydrate constituents was observed in all processed and cooked pulse samples. However there was no significant variation between the germinated ($P_1T_1T_4$) and ground, roasted samples ($P_1T_1T_6T_{10}$). Similar trend was observed in a comparison between ground ($P_1T_1T_6$) and germinated, roasted ($P_1T_1T_4T_{10}$), fermented and steamed ($P_1T_1T_5T_8$) and ground, boiled samples ($P_1T_1T_6T_7$). Starch content of cowpea, which is pretreated, ground, roasted ($P_1T_1T_6T_{10}$) was found to be maximum. There was significant variation between the pulse sample treated in this manner ($P_1T_1T_6T_{10}$) and the untreated sample (T_1).

The TSS, RS and NRS contents of the processed and cooked samples were found to be significantly lower, when compared to the untreated sample.

Table 15. Effect of processing and cooking techniques on the carbohydrate constituent of soaked cowpea (100g) soaked for three hours

Pulses	Without $NaHCO_3$				Pulses	With $NaHCO_3$			
	Starch (g)	TSS (g)	RS (g)	NRS (g)		Starch (g)	TSS (g)	RS (g)	NRS (g)
1. Untreated					**1. Untreated**				
T_1	42.40	13.86	1.90	11.96	T_1	42.40	13.86	1.90	11.96
2. Processed					**2. Processed**				
$P_1T_2T_4$	33.38	21.74	2.91	19.32	$P_1T_3T_4$	40.25	15.16	1.80	13.36
$P_1T_2T_5$	28.76	18.39	2.78	15.76	$P_1T_3T_5$	39.43	14.28	1.76	12.52
$P_1T_2T_6$	25.98	15.98	2.14	1410	$P_1T_3T_6$	38.65	14.74	1.82	12.92
3. Processeed and cooked					**3. Processed and cooked**				
$P_1T_2T_4T_7$	27.6	12.4	1.2	11.2	$P_1T_3T_4T_7$	33.9	12.6	1.3	11.3
$P_1T_2T_4T_8$	29.6	12.6	1.3	11.3	$P_1T_3T_4T_8$	35.9	12.8	1.4	11.4
$P_1T_2T_4T_9$	26.9	12.2	1.0	11.2	$P_1T_3T_4T_9$	29.6	12.4	1.2	11.2
$P_1T_2T_4T_{10}$	33.9	12.8	1.4	11.4	$P_1T_3T_4T_{10}$	37.1	13.0	1.5	11.5
$P_1T_2T_5T_7$	29.6	12.6	1.3	11.3	$P_1T_3T_5T_7$	35.9	12.8	1.4	11.4
$P_1T_2T_5T_8$	33.9	12.8	1.3	11.4	$P_1T_3T_5T_8$	37.1	13.0	1.5	11.5
$P_1T_2T_5T_9$	27.5	12.4	1.2	11.2	$P_1T_3T_5T_9$	33.9	12.6	1.3	11.3
$P_1T_2T_5T_{10}$	35.9	13.0	1.5	11.5	$P_1T_3T_5T_{10}$	39.5	13.2	1.6	11.6
$P_1T_2T_6T_7$	33.9	12.8	1.5	11.4	$P_1T_3T_6T_7$	37.1	13.0	1.5	11.5
$P_1T_2T_6T_8$	35.9	13.0	1.5	11.5	$P_1T_3T_6T_8$	39.5	13.2	1.6	11.6
$P_1T_2T_6T_9$	29.6	12.6	1.3	11.3	$P_1T_3T_6T_9$	35.9	12.8	1.4	11.4
$P_1T_2T_6T_{10}$	37.1	13.2	1.6	11.6	$P_1T_3T_6T_{10}$	40.9	13.4	1.7	11.7
SE	0.074	0.023	0.023	0.054	SE	0.074	0.023	0.023	0.054
CD	0.205	0.064	0.064	0.149	CD	0.205	0.064	0.064	0.149
F	168.493**	166.633**	26.319**	19.815**	F	168.493**	166.633**	26.319**	19.815**

** Significant at 1 per cent level

Table 15 details the carbohydrate constituents in cowpea soaked for three hours with and without $NaHCO_3$. Reduction in soaking duration has been found to conserve TSS and starch constituents irrespective of the cooking treatments administered since higher values for the above two variables (samples soaked with and without $NaHCO_3$ for three hours) were observed in all the treatments when compared to the value obtained for the cowpea samples soaked for six hours.

A significant variation in different carbohydrate constituents was observed in soaked cowpea samples with and without $NaHCO_3$. Samples soaked with $NaHCO_3$ and cooked by different methods were noted to conserve the total carbohydrate constituents more.

Findings related to RS indicated that addition of $NaHCO_3$ had enhanced the rate of hydrolysis of TSS to RS.

No significant variation was observed between processed and cooked samples viz., between samples germinated, steamed; fermented, boiled; ground, pressure cooked samples soaked for three hours without $NaHCO_3$. The carbohydrate constituents were highest for the ground and roasted samples.

In the pulse samples soaked with $NaHCO_3$, there was no significant variation between germinated, steamed samples ($P_1T_3T_4T_8$); fermented, boiled samples ($P_1T_3T_5T_7$) and ground, pressure cooked samples ($P_1T_3T_6T_9$). Similar results were observed in the case of fermented, roasted samples ($P_1T_3T_5T_{10}$), ground, steamed samples

($P_1T_3T_6T_8$), germinated, roasted samples ($P_1T_3T_4T_{10}$), fermented, steamed samples ($P_1T_3T_5T_8$) and ground, boiled samples ($P_1T_3T_6T_7$) in their starch content. There was no significant variation between processed ($P_1T_3T_5$) and processed and cooked samples ($P_1T_3T_5T_{10}$, $P_1T_3T_6T_8$).

4.1.4. Effect of different processing and cooking techniques on the carbohydrate constituents of blackgram (Tables 16 and 17)

Among the three processing techniques administered, germinated blackgram was observed to retain more starch content followed by fermented and ground samples.

As revealed in Table 16 starch in processed and cooked blackgram was found to be significantly hydrolysed reducing considerably the starch content. There was variation in the starch content of germinated blackgram, when different cooking treatments were applied. Among the cooking treatments boiling and cooking under pressure were found to hydrolyse more starch components. While roasting as well as steaming methods were found to conserve more starch.

Table 17 reveal that reduction in carbohydrate constituents in blackgram trend was similar to cowpea, when soaked for different durations.

Similarly blackgram samples soaked with $NaHCO_3$ and cooked by different methods were noted to conserve the total carbohydrate constituents more. However variation in RS and NRS among different treatments were found not significant.

Table 16. Effect of processing and cooking techniques on the carbohydrate constituents of blackgram (100 g) soaked for six hours

Pulses	Carbohydrate constituents / 100 g			
	Starch (g)	TSS (g)	RS (g)	NRS (g)
1. Untreated				
T_1	49.50	8.14	2.00	6.14
2. Processed				
$P_2T_1T_4$	42.08	6.15	2.98	3.17
$P_2T_1T_5$	37.13	5.27	3.13	2.14
$P_2T_1T_6$	34.65	4.69	2.34	2.35
3. Processed and cooked				
$P_2T_1T_4T_7$	31.25	6.80	1.00	5.80
$P_2T_1T_4T_8$	33.90	7.00	1.10	5.90
$P_2T_1T_4T_9$	29.60	6.50	0.90	5.60
$P_2T_1T_4T_{10}$	35.90	7.10	1.20	5.90
$P_2T_1T_5T_7$	35.90	6.90	1.10	5.80
$P_2T_1T_5T_8$	37.10	7.10	1.20	5.90
$P_2T_1T_5T_9$	32.00	6.80	1.00	5.80
$P_2T_1T_5T_{10}$	39.50	7.20	1.30	5.90
$P_2T_1T_6T_7$	37.10	7.20	1.20	6.00
$P_2T_1T_6T_8$	39.50	7.30	1.30	6.00
$P_2T_1T_6T_9$	34.90	6.80	1.10	5.70
$P_2T_1T_6T_{10}$	40.90	7.40	1.40	6.00
SE	0.074	0.023	0.023	0.054
CD	0.205	0.064	0.064	0.149
F	168.493**	166.633**	26.319**	19.815**

** Significant at 1 per cent level

Table 17. Effect of processing and cooking techniques on the carbohydrate constituent of soaked blackgram (100g) soaked for three hours

Pulses	Without $NaHCO_3$				Pulses	With $NaHCO_3$			
	Starch (g)	TSS (g)	RS (g)	NRS (g)		Starch (g)	TSS (g)	RS (g)	NRS (g)
1. Untreated					**1. Untreated**				
T_1	49.50	8.14	2.00	6.14	T_1	49.50	8.14	2.00	6.14
2. Processed					**2. Processed**				
$P_2T_2T_4$	38.61	12.71	3.06	9.65	$P_2T_3T_4$	42.07	8.87	1.90	6.97
$P_2T_2T_5$	33.66	8.81	2.92	5.89	$P_2T_3T_5$	46.03	8.38	1.86	6.52
$P_2T_2T_6$	30.21	9.27	2.26	7.01	$P_2T_3T_6$	45.05	8.63	2.12	6.51
3. Processeed and cooked					**3. Processed and cooked**				
$P_2T_2T_4T_7$	33.9	6.9	1.3	5.6	$P_2T_3T_4T_7$	39.5	7.2	1.4	5.8
$P_2T_2T_4T_8$	35.9	7.2	1.4	5.8	$P_2T_3T_4T_8$	40.9	7.4	1.5	5.9
$P_2T_2T_4T_9$	31.2	6.6	1.2	5.4	$P_2T_3T_4T_9$	37.1	6.8	1.3	5.5
$P_2T_2T_4T_{10}$	37.1	7.3	1.5	5.8	$P_2T_3T_4T_{10}$	42.4	7.5	1.6	5.9
$P_2T_2T_5T_7$	37.1	7.0	1.4	5.6	$P_2T_3T_5T_7$	40.9	7.3	1.5	5.8
$P_2T_2T_5T_8$	39.5	7.3	1.5	5.8	$P_2T_3T_5T_8$	42.4	7.5	1.6	5.9
$P_2T_2T_5T_9$	35.9	6.7	1.3	5.4	$P_2T_3T_5T_9$	39.5	6.9	1.4	5.5
$P_2T_2T_5T_{10}$	40.9	7.4	1.6	5.8	$P_2T_3T_5T_{10}$	43.0	7.6	1.7	5.9
$P_2T_2T_6T_7$	39.5	7.3	1.2	6.0	$P_2T_3T_6T_7$	42.4	7.4	1.6	5.8
$P_2T_2T_6T_8$	40.9	7.5	1.3	6.2	$P_2T_3T_6T_8$	43.0	7.6	1.7	5.9
$P_2T_2T_6T_9$	37.1	6.9	1.0	5.9	$P_2T_3T_6T_9$	40.9	7.0	1.5	5.5
$P_2T_2T_6T_{10}$	42.4	7.6	1.4	6.2	$P_2T_3T_6T_{10}$	45.5	7.7	1.8	5.9
SE	0.074	0.023	0.023	0.054	SE	0.074	0.023	0.023	0.054
CD	0.205	0.064	0.064	0.149	CD	0.205	0.064	0.064	0.149
F	168.493**	166.633**	26.319**	19.815**	F	168.493**	166.633**	26.319**	19.815**

** Significant at 1 per cent level

Findings related to RS indicated that addition of $NaHCO_3$ resulted in the hydrolysis of higher concentration of total soluble sugars to reducing sugars.

Statistical treatment of the data revealed that among the processed pulse samples germinated ($P_2T_1T_4$), fermented ($P_2T_1T_5$) and ground pulse samples ($P_2T_1T_6$) there was significant variation in all the carbohydrate constituents. A comparison between the processed and cooked samples after processing also revealed similar results. There was no significant variation between processed ($P_2T_1T_5$) and processed and cooked samples ($P_2T_1T_5T_8$ and $P_2T_1T_6T_7$). A comparison between the germinated, roasted ($P_2T_1T_4T_{10}$) and fermented, boiled sample ($P_2T_1T_5T_7$), between fermented, roasted sample ($P_2T_1T_5T_{10}$) and ground, steamed ($P_2T_1T_6T_8$) also revealed reduction in the starch content.

There was no significant variation between germinated, boiled ($P_2T_1T_4T_7$) and fermented, pressure cooked samples ($P_2T_1T_5T_9$) and ground, pressure cooked sample ($P_2T_1T_6T_9$) in their TSS content. This was true in the case of germinated and roasted samples ($P_2T_1T_4T_{10}$) and fermented, steamed samples ($P_2T_1T_5T_8$) also between fermented, roasted samples ($P_2T_1T_5T_{10}$) and ground, boiled samples ($P_2T_1T_6T_7$).

RS content among pulse samples were also significantly varied except between germinated, steamed ($P_2T_1T_4T_8$), fermented, boiled ($P_2T_1T_5T_7$) and ground, pressure cooked ($P_2T_1T_6T_9$) samples. Similar

findings were noted between fermented, roasted ($P_2T_1T_5T_{10}$) and ground, steamed ($P_2T_1T_6T_8$) samples, in the case of germinated, roasted samples ($P_2T_1T_4T_{10}$), fermented, steamed samples ($P_2T_1T_5T_8$) and ground, boiled ($P_2T_1T_6T_7$) samples.

Significant variation in NRS content was observed, except among germinated, boiled samples ($P_2T_1T_4T_7$), fermented, boiled samples ($P_2T_1T_5T_7$) and fermented, pressure cooked samples ($P_2T_1T_5T_9$). A comparison among germinated, steamed ($P_2T_1T_4T_8$), germinated, roasted ($P_2T_1T_4T_{10}$), fermented, steamed ($P_2T_1T_5T_8$), and fermented, roasted ($P_2T_1T_5T_{10}$) samples also revealed similar results. This was also same in the case of germinated, pressure cooked ($P_2T_1T_4T_9$) and ground, pressure cooked ($P_2T_1T_6T_9$) samples and also among ground, boiled ($P_2T_1T_6T_7$), steamed ($P_2T_1T_6T_8$) and roasted ($P_2T_1T_6T_{10}$) samples. There was significant variation between untreated and all the other treated samples.

In the case of samples soaked for three hours with and without $NaHCO_3$, there was significant variation in their starch content between the untreated (T_1) and the germinated ($P_2T_2T_4$), fermented ($P_2T_2T_5$) and ground ($P_2T_2T_6$) samples. However there was no significant variation between germinated, steamed ($P_2T_2T_4T_8$) and fermented, pressure cooked ($P_2T_2T_5T_9$) samples and between germinated, roasted samples ($P_2T_2T_4T_{10}$) and fermented, boiled ($P_2T_2T_5T_7$) samples and also ground, pressure cooked ($P_2T_2T_6T_9$) samples.

The TSS content was varying significantly between the different treated samples except in the case of germinated, boiled ($P_2T_2T_4T_7$) samples and ground, pressure cooked ($P_2T_2T_6T_9$) samples, and in the case of germinated, roasted ($P_2T_2T_4T_{10}$), fermented, steamed ($P_2T_2T_5T_8$) and ground, boiled ($P_2T_2T_6T_7$) samples.

Maximum retention was observed in ground, roasted ($P_2T_2T_6T_{10}$) samples next to untreated (T_1) samples.

In samples soaked with $NaHCO_3$ also, variation in starch content between the different treated samples germinated, boiled ($P_2T_3T_4T_7$) and fermented, pressure cooked ($P_2T_3T_5T_9$) and also between germinated, steamed ($P_2T_3T_4T_8$) and fermented, boiled ($P_2T_3T_4T_7$), and ground pressure cooked ($P_2T_3T_6T_9$) samples were not significant. A comparison between germinated, roasted ($P_2T_3T_4T_{10}$), fermented, steamed ($P_2T_3T_5T_8$) and ground, boiled ($P_2T_3T_6T_7$) samples and also between fermented, roasted ($P_2T_3T_5T_{10}$) and ground, steamed ($P_2T_3T_6T_8$) samples revealed similar results.

There was no significant variation between germinated, steamed ($P_2T_3T_4T_8$) and ground, boiled sample ($P_2T_3T_6T_7$) in TSS reduction. This was also true in the case of germinated, roasted samples ($P_2T_3T_4T_{10}$) and fermented, steamed samples ($P_2T_3T_5T_8$) and also between fermented, roasted samples ($P_2T_3T_5T_{10}$) and ground, steamed sample ($P_2T_3T_6T_8$).

RS and NRS content of untreated (T_1), germinated ($P_2T_3T_4$), fermented ($P_2T_3T_5$) and ground samples ($P_2T_3T_6$) revealed significant variation among themselves and also between processed and cooked samples.

4.1.5. Effect of processing and cooking techniques on the carbohydrate constituents of redgram (Tables 18 and 19)

Among the two processing techniques administered, as it has been found in the case of other pulses, fermented redgram was observed to retain more starch content than ground redgram (Table 18).

RS content was found to be positively influenced by different processing treatments. Among the cooking treatments boiled and pressure cooked samples were found to be hydrolysed more while roasting as well as steaming methods were found to conserve more starch.

Statistical treatment of the data revealed that among the processed pulse samples ($P_3T_1T_5$ and $P_3T_1T_6$), between the processed and cooked samples and also between treated and untreated samples there was significant variation. However there was no significant variation between the ground pulse samples ($P_3T_1T_6$) and the ground, pressure cooked samples ($P_3T_1T_6T_9$).

Conservation in TSS and starch irrespective of the cooking treatment administered, was observed in the carbohydrate constituents in redgram soaked for three hours with and without $NaHCO_3$ (Table 19).

Table 18. Effect of processing and cooking techniques on the carbohydrate constituents of red gram (100 g) soaked for six hours

Pulses	Carbohydrate constituents / 100 g			
	Starch (g)	TSS (g)	RS (g)	NRS (g)
1. Untreated				
T_1	49.50	7.00	2.70	4.23
2. Processed				
$P_3T_1T_5$	38.61	10.43	4.21	6.22
$P_3T_1T_6$	34.65	9.17	3.16	6.01
3. Processed and cooked				
$P_3T_1T_5T_7$	35.90	5.80	1.50	4.30
$P_3T_1T_5T_8$	37.10	6.00	1.70	4.30
$P_3T_1T_5T_9$	32.00	5.40	1.30	4.10
$P_3T_1T_5T_{10}$	39.50	6.10	1.90	4.20
$P_3T_1T_6T_7$	37.10	5.80	1.60	4.20
$P_3T_1T_6T_8$	39.50	6.10	1.80	4.30
$P_3T_1T_6T_9$	34.90	5.60	1.40	4.20
$P_3T_1T_6T_{10}$	40.90	6.20	2.00	4.20
SE	0.222	5.275	5.275	5.518
CD	0.628	0.149	0.149	0.156
F	375.98**	1290.54**	1158.14**	599.58**

** Significant at 1 per cent level

Table 19. Effect of processing and cooking techniques on the carbohydrate constituent of soaked red gram (100g) soaked for three hours

Pulses	Without $NaHCO_3$				Pulses	With $NaHCO_3$			
	Starch (g)	TSS (g)	RS (g)	NRS (g)		Starch (g)	TSS (g)	RS (g)	NRS (g)
1. Untreated					**1. Untreated**				
T_1	49.50	7.00	2.70	4.23	T_1	49.50	7.00	2.70	4.23
2. Processed					**2. Processed**				
$P_3T_2T_5$	33.71	9.31	4.21	5.1	$P_3T_3T_5$	46.04	9.10	7.64	1.46
$P_3T_2T_6$	30.21	13.11	3.21	9.9	$P_3T_3T_6$	45.01	11.20	9.41	1.79
3. Processeed and cooked					**3. Processed and cooked**				
$P_3T_2T_5T_7$	37.1	6.0	1.7	4.3	$P_3T_3T_5T_7$	40.9	6.1	1.8	4.3
$P_3T_2T_5T_8$	39.5	6.1	2.0	4.1	$P_3T_3T_5T_8$	42.4	6.3	2.1	4.2
$P_3T_2T_5T_9$	35.9	5.6	1.5	4.1	$P_3T_3T_5T_9$	39.5	6.0	1.6	4.4
$P_3T_2T_5T_{10}$	40.9	6.2	2.1	4.1	$P_3T_3T_5T_{10}$	43.0	6.4	2.2	4.2
$P_3T_2T_6T_7$	39.5	6.0	1.7	4.3	$P_3T_3T_6T_7$	42.4	6.2	2.0	4.2
$P_3T_2T_6T_8$	40.9	6.2	2.0	4.2	$P_3T_3T_6T_8$	43.0	6.4	2.2	4.2
$P_3T_2T_6T_9$	37.1	5.8	1.5	4.3	$P_3T_3T_6T_9$	40.9	6.1	1.8	4.3
$P_3T_2T_6T_{10}$	42.4	6.3	2.2	4.2	$P_3T_3T_6T_{10}$	45.5	6.5	2.4	4.2
SE	0.222	5.275	5.275	5.518	SE	0.222	5.275	5.275	5.518
CD	0.628	0.149	0.149	0.156	CD	0.628	0.149	0.149	0.156
F	375.98**	1290.54**	1158.14**	599.58**	F	375.98**	1290.54**	1158.14**	599.58**

** Significant at 1 per cent level

In samples soaked with $NaHCO_3$ for three hours variation in RS and NRS were found not significant.

Statistical treatment of the data revealed that there was significant variation among untreated (T_1), fermented ($P_3T_2T_5$) and ground samples ($P_3T_2T_6$) and also among the processed and cooked samples when compared to untreated samples. However there was no significant variation between fermented, boiled ($P_3T_2T_5T_7$) and ground, pressure cooked samples ($P_3T_2T_6T_9$) and also between fermented, steamed sample ($P_3T_2T_5T_8$) and ground, boiled samples ($P_3T_2T_6T_7$) and also between fermented, roasted ($P_3T_2T_5T_{10}$) and ground, steamed samples ($P_3T_2T_6T_8$).

TSS, RS and NRS content also showed significant variation except between fermented, boiled ($P_3T_2T_5T_7$) and ground, boiled samples ($P_3T_2T_6T_7$) and also between fermented, roasted ($P_3T_2T_5T_{10}$) and ground, steamed ($P_3T_2T_6T_8$) samples.

The starch content of the samples soaked with $NaHCO_3$ when fermented, boiled ($P_3T_3T_5T_7$) ground, pressure cooked samples ($P_3T_3T_6T_9$) revealed no significant variation as also in the case of fermented, steamed sample ($P_3T_3T_5T_8$) and ground, boiled samples ($P_3T_3T_6T_7$). A comparison between fermented, roasted ($P_3T_3T_5T_{10}$) and ground, steamed samples ($P_3T_3T_6T_8$) also revealed similar results.

TSS, RS and NRS content of the untreated (T_1), processed and processed and cooked samples showed significant variation except

between fermented, boiled ($P_3T_3T_5T_7$) and ground, pressure cooked samples ($P_3T_3T_6T_9$) and also between fermented, roasted ($P_3T_3T_5T_{10}$) and ground, steamed ($P_3T_3T_6T_8$) samples.

4.1.6. Effect of different processing and cooking techniques on the carbohydrate constituents of greengram (Tables 20 and 21)

Among the three processed samples more starch was retained in the germinated greengram followed by fermented and ground samples.

As revealed in Table 20, by processing and cooking treatments, starch in greengram was found to be significantly hydrolysed. Among the cooking treatments boiling and cooking under pressure were found to hydrolyse more starch components in the greengram while roasting as well as steaming methods were found to conserve more starch.

Statistical treatment of the data revealed that there was significant variation between untreated and treated samples and also with all the processed and cooked samples. However there was no significant variation between germinated, boiled ($P_4T_1T_4T_7$) and fermented, pressure cooked ($P_4T_1T_5T_9$) samples in their starch and TSS contents. This was also true in the case of germinated, steamed ($P_4T_1T_4T_8$) and fermented, boiled ($P_4T_1T_5T_7$) and ground, pressure cooked ($P_4T_1T_6T_9$) samples and fermented, roasted ($P_4T_1T_5T_{10}$) and ground, steamed ($P_4T_1T_6T_8$) samples.

Table 20. Effect of processing and cooking techniques on the carbohydrate constituents of green gram (100 g) soaked for six hours

Pulses	Carbohydrate constituents / 100 g			
	Starch (g)	TSS (g)	RS (g)	NRS (g)
1. Untreated				
T_1	51.60	7.90	2.20	5.70
2. Processed				
$P_4T_1T_4$	43.86	13.35	3.12	10.23
$P_4T_1T_5$	38.70	11.77	3.43	8.34
$P_4T_1T_6$	36.12	10.35	2.57	7.78
3. Processed and cooked				
$P_4T_1T_4T_7$	37.10	6.70	1.40	5.30
$P_4T_1T_4T_8$	38.30	6.80	1.50	5.30
$P_4T_1T_4T_9$	35.90	6.60	1.30	5.30
$P_4T_1T_4T_{10}$	39.50	6.90	1.60	5.30
$P_4T_1T_5T_7$	38.30	6.80	1.50	5.30
$P_4T_1T_5T_8$	39.50	6.90	1.60	5.30
$P_4T_1T_5T_9$	37.10	6.70	1.40	5.30
$P_4T_1T_5T_{10}$	40.90	7.00	1.70	5.30
$P_4T_1T_6T_7$	39.50	6.90	1.60	5.30
$P_4T_1T_6T_8$	40.90	7.00	1.70	5.30
$P_4T_1T_6T_9$	38.30	6.80	1.50	5.30
$P_4T_1T_6T_{10}$	42.40	7.10	1.80	5.30
SE	0.074	0.023	0.023	0.054
CD	0.205	0.064	0.064	0.149
F	168.493**	166.633**	26.319**	19.815**

** Significant at 1 per cent level

RS and NRS content were also found to have significant variation between the samples.

Reduction in soaking duration had been found to conserve TSS and starch constituents irrespective of the cooking treatments administered since higher values for the above two variables (samples soaked with and without $NaHCO_3$ for three hours) were observed in all the treatments when compared to the values obtained for the greengram samples soaked for six hours (Table 21). Samples soaked with $NaHCO_3$ and cooked by different methods were noted to conserve the total carbohydrate constituents more. Variation in RS and NRS in these samples were found not significant. Addition of $NaHCO_3$ resulted in the hydrolysis of higher concentration of TSS to RS.

There was significant variation between untreated and treated samples. However there was no significant variation between germinated, boiled samples ($P_4T_2T_4T_7$) and fermented, pressure cooked samples ($P_4T_2T_5T_9$), and also between germinated, steamed samples ($P_4T_2T_4T_8$) and fermented, boiled samples ($P_4T_2T_5T_7$) and ground and pressure cooked samples ($P_4T_2T_6T_9$). A comparison between germinated, roasted samples ($P_4T_2T_4T_{10}$) and fermented, steamed sample ($P_4T_2T_5T_8$) and also fermented, roasted sample ($P_4T_2T_5T_{10}$) and ground, steamed samples ($P_4T_2T_6T_8$) also revealed similar trend. This was also true in the case of TSS, RS and NRS. Pulse samples soaked for three hours with $NaHCO_3$ were also found to have similar variations.

Table 21. Effect of processing and cooking techniques on the carbohydrate constituent of soaked green gram (100g) soaked for three hours

Pulses	Without $NaHCO_3$				Pulses	With $NaHCO_3$			
	Starch (g)	TSS (g)	RS (g)	NRS (g)		Starch (g)	TSS (g)	RS (g)	NRS (g)
1. Untreated					**1. Untreated**				
T_1	51.60	7.90	2.20	5.70	T_1	51.60	7.90	2.20	5.70
2. Processed					**2. Processed**				
$P_4T_2T_4$	40.25	12.32	3.37	8.95	$P_4T_3T_4$	41.86	8.61	2.09	6.52
$P_4T_2T_5$	34.41	10.51	3.21	7.30	$P_4T_3T_5$	48.11	8.14	2.05	6.09
$P_4T_2T_6$	31.48	9.01	2.49	6.52	$P_4T_3T_6$	46.96	8.37	2.11	6.26
3. Processed and cooked					**3. Processed and cooked**				
$P_4T_2T_4T_7$	39.5	6.9	1.50	5.4	$P_4T_3T_4T_7$	42.4	7.1	1.6	5.5
$P_4T_2T_4T_8$	40.9	7.0	1.60	5.4	$P_4T_3T_4T_8$	43.9	7.2	1.7	5.5
$P_4T_2T_4T_9$	38.3	6.8	1.40	5.4	$P_4T_3T_4T_9$	40.9	7.0	1.5	5.5
$P_4T_2T_4T_{10}$	42.4	7.1	1.70	5.4	$P_4T_3T_4T_{10}$	45.7	7.3	1.8	5.5
$P_4T_2T_5T_7$	40.9	7.0	1.60	5.4	$P_4T_3T_5T_7$	43.9	7.2	1.7	5.5
$P_4T_2T_5T_8$	42.4	7.1	1.70	5.4	$P_4T_3T_5T_8$	45.7	7.3	1.8	5.5
$P_4T_2T_5T_9$	39.5	6.9	1.50	5.4	$P_4T_3T_5T_9$	42.4	7.1	1.6	5.5
$P_4T_2T_5T_{10}$	43.9	7.2	1.80	5.4	$P_4T_3T_5T_{10}$	47.5	7.4	1.9	5.5
$P_4T_2T_6T_7$	42.4	7.1	1.70	5.4	$P_4T_3T_6T_7$	45.7	7.3	1.8	5.5
$P_4T_2T_6T_8$	43.8	7.2	1.80	5.4	$P_4T_3T_6T_8$	47.5	7.4	1.9	5.5
$P_4T_2T_6T_9$	40.9	7.0	1.60	5.4	$P_4T_3T_6T_9$	43.9	7.2	1.7	5.5
$P_4T_2T_6T_{10}$	45.7	7.3	1.90	5.4	$P_4T_3T_6T_{10}$	49.4	7.5	2.0	5.5
SE	0.074	0.023	0.023	0.054	SE	0.074	0.023	0.023	0.054
CD	0.205	0.064	0.064	0.149	CD	0.205	0.064	0.064	0.149
F	168.493**	166.633**	26.319**	19.815**	F	168.493**	166.633**	26.319**	19.815**

** Significant at 1 per cent level

4.1.7. **Effect of different processing and cooking treatments on the carbohydrate constituents of soyabean** (Tables 22 and 23)

In soyabean by processing and cooking treatments starch was found to be significantly hydrolysed (Table 22). Among the cooking treatments boiling and cooking under pressure were found to hydrolyse more starch components in soyabean.

There was significant variation in carbohydrate constituents among all the treated pulse samples except between germinated, boiled samples ($P_5T_1T_4T_7$) and fermented, pressure cooked samples ($P_5T_1T_5T_9$) and also between germinated, steamed samples ($P_5T_1T_4T_8$) and fermented, boiled samples ($P_5T_1T_5T_7$) and ground, pressure cooked samples ($P_5T_1T_6T_9$). This was also true in the comparison of germinated, roasted samples ($P_5T_1T_4T_{10}$) and fermented, steamed samples ($P_5T_1T_5T_8$) and ground, boiled samples ($P_5T_1T_6T_7$), and also between fermented, roasted samples ($P_5T_1T_5T_{10}$) and ground, steamed samples ($P_5T_1T_6T_8$).

Table 23 details the carbohydrate constituents in soyabean soaked for three hours with and without $NaHCO_3$. Reduction in soaking duration had been found to conserve TSS and starch constituents irrespective of the cooking treatments administered.

There was significant variation in starch between untreated and treated samples. But among treated samples, there was no significant variation between germinated, boiled samples ($P_5T_2T_4T_7$) and fermented,

Table 22. Effect of processing and cooking techniques on the carbohydrate constituents of soyabean (100 g) soaked for six hours

Pulses	Carbohydrate constituents / 100 g			
	Starch (g)	TSS (g)	RS (g)	NRS (g)
1. Untreated				
T_1	10.30	10.20	3.60	6.60
2. Processed				
$P_5T_1T_4$	8.16	16.32	5.04	11.28
$P_5T_1T_5$	7.73	14.28	5.40	8.88
$P_5T_1T_6$	6.71	13.26	4.32	8.94
3. Processed and cooked				
$P_5T_1T_4T_7$	8.80	8.60	2.60	6.00
$P_5T_1T_4T_8$	9.00	8.80	2.70	6.10
$P_5T_1T_4T_9$	8.60	8.40	2.50	5.90
$P_5T_1T_4T_{10}$	9.20	9.00	2.80	6.20
$P_5T_1T_5T_7$	9.00	8.80	2.80	6.00
$P_5T_1T_5T_8$	9.20	9.00	2.90	6.10
$P_5T_1T_5T_9$	8.80	8.60	2.70	5.90
$P_5T_1T_5T_{10}$	9.40	9.20	3.00	6.20
$P_5T_1T_6T_7$	9.20	9.00	2.90	6.10
$P_5T_1T_6T_8$	9.40	9.20	3.00	6.20
$P_5T_1T_6T_9$	9.00	8.80	2.80	6.00
$P_5T_1T_6T_{10}$	9.60	9.40	3.10	6.30
SE	0.074	0.023	0.023	0.054
CD	0.205	0.064	0.064	0.149
F	168.493**	166.633**	26.319**	19.815**

** Significant at 1 per cent level

Table 23. Effect of processing and cooking techniques on the carbohydrate constituent of soaked soyabean (100g) soaked for three hours

Pulses	Without $NaHCO_3$				Pulses	With $NaHCO_3$			
	Starch (g)	TSS (g)	RS (g)	NRS (g)		Starch (g)	TSS (g)	RS (g)	NRS (g)
1. Fresh					**1. Fibre**				
T_1	10.30	10.20	3.60	6.60	T_1	10.30	10.20	3.60	6.60
2. Processed					**2. Processed**				
$P_5T_2T_4$	8.03	15.91	5.51	10.4	$P_5T_3T_4$	8.76	11.12	3.42	7.70
$P_5T_2T_5$	7.00	13.61	5.26	8.35	$P_5T_3T_5$	9.58	10.51	3.35	7.16
$P_5T_2T_6$	6.22	11.63	4.07	7.56	$P_5T_3T_6$	9.37	9.79	3.26	6.53
3. Processed and cooked					**3. Processed and cooked**				
$P_5T_2T_4T_7$	9.0	8.8	2.8	6.0	$P_5T_3T_4T_7$	9.2	9.0	2.9	6.1
$P_5T_2T_4T_8$	9.2	9.0	2.9	6.1	$P_5T_3T_4T_8$	9.4	9.2	3.0	6.2
$P_5T_2T_4T_9$	8.8	8.6	2.7	5.9	$P_5T_3T_4T_9$	9.0	8.8	2.8	6.0
$P_5T_2T_4T_{10}$	9.4	9.2	3.0	6.2	$P_5T_3T_4T_{10}$	9.6	9.4	3.1	6.3
$P_5T_2T_5T_7$	9.2	9.0	2.9	6.1	$P_5T_3T_5T_7$	9.4	9.2	3.0	6.2
$P_5T_2T_5T_8$	9.4	9.2	3.0	6.2	$P_5T_3T_5T_8$	9.6	9.4	3.1	6.3
$P_5T_2T_5T_9$	9.0	8.8	2.8	6.0	$P_5T_3T_5T_9$	9.2	9.0	2.9	6.1
$P_5T_2T_5T_{10}$	9.6	9.4	3.1	6.3	$P_5T_3T_5T_{10}$	9.8	9.6	3.2	6.4
$P_5T_2T_6T_7$	9.4	9.2	3.0	6.2	$P_5T_3T_6T_7$	9.6	9.4	3.1	6.3
$P_5T_2T_6T_8$	9.6	9.4	3.1	6.3	$P_5T_3T_6T_8$	9.8	9.6	3.2	6.4
$P_5T_2T_6T_9$	9.2	9.0	2.9	6.1	$P_5T_3T_6T_9$	9.4	9.2	3.0	6.2
$P_5T_2T_6T_{10}$	9.8	9.6	3.2	6.4	$P_5T_3T_6T_{10}$	10.0	9.8	3.3	6.5
SE	0.074	0.023	0.023	0.054	SE	0.074	0.023	0.023	0.054
CD	0.205	0.064	0.064	0.149	CD	0.205	0.064	0.064	0.149
F	168.493**	166.633**	26.319**	19.815**	F	168.493**	166.633**	26.319**	19.815**

** Significant at 1 per cent level

pressure cooked samples ($P_5T_2T_5T_9$). A comparison between germinated, roasted samples ($P_5T_2T_4T_{10}$) with fermented, steamed samples ($P_5T_2T_5T_8$) and ground, boiled samples ($P_5T_2T_6T_7$) also revealed similar results. There was also no significant variation between germinated, steamed samples ($P_5T_2T_4T_8$) and fermented, boiled ($P_5T_2T_5T_7$) and ground, pressure cooked samples ($P_5T_2T_6T_9$). This was also true in the case of fermented, roasted ($P_5T_2T_5T_{10}$) and ground, steamed samples ($P_5T_2T_6T_8$). Similar findings were observed in the case of TSS, RS and NRS.

Samples soaked for three hours with $NaHCO_3$ also revealed similar results.

4.1.8. Effect of different processing and cooking techniques on the carbohydrate constituents of bengalgram (Tables 24 and 25)

Among the three processed samples, germinated bengalgram was observed to retain more starch than fermented and ground samples.

As revealed in Table 24, by processing, starch in bengalgram was found to be significantly hydrolysed.

There was significant variation between untreated and treated samples. But among treated samples there was no significant variation in their starch content content between germinated, boiled samples ($P_6T_1T_4T_7$) and ground, pressure cooked samples ($P_6T_1T_6T_9$). A comparison between germinated, steamed ($P_6T_1T_4T_8$); and fermented,

Table 24. Effect of processing and cooking techniques on the carbohydrate constituents of bengal gram (100 g) soaked for six hours

Pulses	Carbohydrate constituents / 100 g			
	Starch (g)	TSS (g)	RS (g)	NRS (g)
1. Untreated				
T_1	51.60	8.20	2.30	5.90
2. Processed				
$P_6T_1T_4$	26.37	14.76	3.69	11.07
$P_6T_1T_5$	24.80	13.23	2.87	10.36
$P_6T_1T_6$	21.76	12.59	2.65	9.94
3. Processed and cooked				
$P_6T_1T_4T_7$	34.90	6.70	1.00	5.70
$P_6T_1T_4T_8$	35.90	6.90	1.10	5.80
$P_6T_1T_4T_9$	31.20	6.30	0.90	5.40
$P_6T_1T_4T_{10}$	37.10	7.10	1.20	5.90
$P_6T_1T_5T_7$	35.90	6.70	1.10	5.60
$P_6T_1T_5T_8$	37.10	7.10	1.20	5.90
$P_6T_1T_5T_9$	32.00	6.50	1.00	5.50
$P_6T_1T_5T_{10}$	39.50	7.30	1.40	5.90
$P_6T_1T_6T_7$	38.30	6.50	1.20	5.30
$P_6T_1T_6T_8$	39.50	7.20	1.40	5.80
$P_6T_1T_6T_9$	34.90	6.70	1.10	5.60
$P_6T_1T_6T_{10}$	42.40	7.50	1.60	5.90
SE	0.074	0.023	0.023	0.054
CD	0.205	0.064	0.064	0.149
F	168.493**	166.633**	26.319**	19.815**

** Significant at 1 per cent level

boiled ($P_6T_1T_5T_7$) also revealed similar results. No significant variation was found between fermented, roasted samples ($P_6T_1T_5T_{10}$) and ground, steamed samples ($P_6T_1T_6T_8$) and also between germinated, roasted ($P_6T_1T_4T_{10}$) and fermented, steamed ($P_6T_1T_5T_8$) samples.

Reduction in soaking duration had been found to conserve TSS irrespective of the processing and cooking treatments administered (Table 25).

A comparison between the two samples of different soaking durations revealed significant variation in different carbohydrate constituents. Samples soaked with $NaHCO_3$ and cooked by different methods were noted to conserve the constituents more. However variation in RS and NRS after processing and cooking were found not significant. Findings related to RS indicate that addition of $NaHCO_3$ resulted in the hydrolysis of higher concentration of TSS to RS as in the case of other pulses.

There was significant variation between untreated and treated samples in their starch content. However there was no significant variation germinated, roasted ($P_6T_2T_4T_{10}$) between fermented, boiled samples ($P_6T_2T_5T_7$) and ground, pressure cooked samples ($P_6T_2T_6T_9$). A comparison between germinated, steamed ($P_6T_2T_4T_8$) and fermented, pressure cooked samples ($P_6T_2T_5T_9$) also revealed similar results.

Table 25. Effect of processing and cooking techniques on the carbohydrate constituent of soaked bengal gram (100g) soaked for 3 hours

Pulses	Without $NaHCO_3$				Pulses	With $NaHCO_3$			
	Starch (g)	TSS (g)	RS (g)	NRS (g)		Starch (g)	TSS (g)	RS (g)	NRS (g)
1. Untreated					**1. Untreated**				
T_1	51.60	8.20	2.30	5.90	T_1	51.60	8.20	2.30	5.90
2. Processed					**2. Processed**				
$P_6T_2T_4$	43.94	13.76	2.89	10.87	$P_6T_3T_4$	48.67	11.67	2.15	9.52
$P_6T_2T_5$	44.76	11.21	3.04	8.17	$P_6T_3T_5$	46.54	8.85	2.56	6.29
$P_6T_2T_6$	44.89	10.81	2.67	8.14	$P_6T_3T_6$	47.57	6.94	2.51	4.43
3. Processed and cooked					**3. Processed and cooked**				
$P_6T_2T_4T_7$	35.90	6.90	1.10	5.80	$P_6T_3T_4T_7$	37.10	7.00	1.20	5.80
$P_6T_2T_4T_8$	37.10	7.10	1.20	5.90	$P_6T_3T_4T_8$	39.50	7.20	1.40	5.80
$P_6T_2T_4T_9$	32.90	6.50	0.80	5.70	$P_6T_3T_4T_9$	34.90	6.90	1.10	5.80
$P_6T_2T_4T_{10}$	39.50	7.20	1.40	5.80	$P_6T_3T_4T_{10}$	42.40	7.30	1.60	5.70
$P_6T_2T_5T_7$	39.50	7.10	1.20	5.90	$P_6T_3T_5T_7$	40.90	7.20	1.40	5.80
$P_6T_2T_5T_8$	40.90	7.20	1.40	5.80	$P_6T_3T_5T_8$	42.40	7.30	1.50	5.70
$P_6T_2T_5T_9$	37.10	6.70	1.10	5.60	$P_6T_3T_5T_9$	39.50	7.10	1.20	5.80
$P_6T_2T_5T_{10}$	42.40	7.50	1.60	5.90	$P_6T_3T_5T_{10}$	45.60	7.60	1.80	5.80
$P_6T_2T_6T_7$	40.90	7.30	1.40	6.10	$P_6T_3T_6T_7$	42.40	7.60	1.60	6.00
$P_6T_2T_6T_8$	42.40	7.50	1.60	5.90	$P_6T_3T_6T_8$	45.60	7.70	1.80	5.90
$P_6T_2T_6T_9$	39.50	6.90	1.20	5.70	$P_6T_3T_6T_9$	40.90	7.50	1.40	6.10
$P_6T_2T_6T_{10}$	45.60	7.60	1.80	5.80	$P_6T_3T_6T_{10}$	47.50	7.80	2.00	5.80
SE	0.074	0.023	0.023	0.054	SE	0.074	0.023	0.023	0.054
CD	0.205	0.064	0.064	0.149	CD	0.205	0.064	0.064	0.149
F	168.493**	166.633**	26.319**	19.815**	F	168.493**	166.633**	26.319**	19.815**

** Significant at 1 per cent level

TSS, RS and NRS content also revealed significant variations among processed and cooked samples. However there was no significant variation between germinated, boiled samples ($P_6T_2T_4T_7$) and ground, pressure cooked samples ($P_6T_2T_6T_9$). A comparison between germinated, steamed samples ($P_6T_2T_4T_8$) and fermented and boiled samples ($P_6T_2T_5T_7$) and also between fermented, roasted ($P_6T_2T_5T_{10}$) and ground, steamed samples ($P_6T_2T_6T_8$) revealed similar results.

Samples soaked for three hours with $NaHCO_3$ also revealed similar results.

4.2. THE INHIBITORY CONSTITUENTS IN PULSES

The inhibitory constituents in pulses affecting starch digestibility are observed to be protein, fibre and phytin. The values are expressed as per 100g seed weight.

4.2.1. Inhibitory constituents in untreated pulses (Table 26)

In the untreated pulses analysed, protein content was found to be in the range of 22.23 g per cent to 42.70 g per cent with the lowest concentration in redgram, followed by cowpea, bengalgram, blackgram, greengram and soya bean. Fibre in the untreated pulses analysed was in the range of 1.60 g per cent to 13.29 g per cent on dry weight basis with the highest concentration in blackgram, followed by soyabean, cowpea, greengram, bengalgram and redgram. Phytate in the untreated pulses

Table 26. Inhibitory constituents in untreated uptake samples (100g) (mean values)

Pulses	Inhibitory constituents		
	Protein (g)	Fibre (g)	Phytate (mg)
1. Cowpea	22.41	4.78	377.94
2. Black gram	23.26	13.29	215.46
3. Red gram	22.23	1.60	170.00
4. Green gram	23.37	4.43	190.92
5. Soya bean	42.70	6.20	130.50
6. Bengal gram	22.58	3.80	158.03
SE	7.31	6.163	0.329
CD	0.202	0.171	0.914
F	14935.18**	3999.852**	88156.44**

** Significant at 1 per cent level

analysed was in the range of 130.50 mg per cent to 377.94 mg per cent with the highest concentration in cowpea followed by blackgram, greengram, redgram, bengalgram and soyabean.

No significant variation in protein content of the pulse samples analysed except in comparison with soyabean was observed. However there was significant variation in the fibre and phytate content in all the pulse samples.

4.2.2. Influence of pre-treatments, processing and cooking treatments on the inhibitory constituents of different pulses (Tables 27 to 35)

Table 27 details the protein content of different treated pulses. Significant variations in the protein content of different treated, processed and cooked pulses were observed.

Influence of processing techniques on the protein content of different pre-treated pulses irrespective of the kind revealed significant variations (Table 28). Grinding (T_6) was found to cause greater loss in protein followed by fermentation (T_5) and germination (T_4). These samples, when cooked, varied in their protein content significantly. Among the different cooking treatments administered protein loss was highest when pressure cooking (T_9) was administered followed by boiling (T_7), steaming (T_8) and roasting (T_{10}).

Table 27. Protein content of different treated pulses (mean values) (g/100g)

Pulses	Untreated	Pretreated samples			Pretreated and processed samples			Uncooked	Pre treated, processed and cooked samples			
	T_1	T_1	T_2	T_3	T_4	T_5	T_6	T_0	T_7	T_8	T_9	T_{10}
Cowpea	22.41	23.27	22.41	21.98	23.20	22.37	22.09	26.08	21.29	21.79	21.55	22.05
Blackgram	23.26	23.97	23.49	23.04	24.15	23.42	22.94	27.50	22.20	22.61	22.39	22.81
Greengram	23.37	23.52	22.96	22.60	23.91	22.80	22.38	24.53	22.34	22.76	22.55	22.97
Soyabean	42.70	43.42	42.87	42.29	43.55	42.75	42.29	46.51	41.60	42.08	41.83	42.27
Bengalgram	22.58	23.57	23.24	22.83	23.92	23.02	22.70	27.40	21.91	22.25	22.08	22.44
F	14935.18**		40.59**			25.98**				624.72**		
CD	0.202		0.052			0.052				0.067		
SE	7.31		0.019			0.019				0.024		

** Significant at 1 per cent level

Table 28. Influence of processing on the protein content of treated pulses (g/100g)

Pretreatments	Processing treatments			Uncooked	Cooking treatments			
	T_4	T_5	T_6	T_0	T_7	T_8	T_9	T_{10}
T_1	28.20	27.40	27.05	31.64	26.21	26.61	26.42	26.87
T_2	27.76	26.87	26.35	30.27	25.85	26.30	26.08	26.48
T_3	27.27	26.35	26.04	29.30	25.55	25.98	25.74	26.18
F		26.24**				406.17**		
CD		0.040				0.052		
SE		0.015				0.019		

** Significant at 1 per cent level

A comparison of different cooking treatments on the pre treated and processed pulse samples with reference to their protein content (Table 29) revealed significant fluctuations.

When the effect of cooking treatments alone on the protein content of the pulses were compared, this also indicated significant variations.

There was significant variation in the fibre content of the treated pulses, processed and cooked samples (Table 30)

Different processing techniques influenced significantly the fibre content of different pre treated pulses, irrespective of the kind (Table 31). Among the different processing treatments administered, fermentation (T_5) was found to have the maximum effect in reducing the fibre content in pulses, followed by grinding (T_6) and germination (T_4). Significant variation was observed in a comparison among the pre treated and cooked pulse samples on their fibre content. Among the different cooking treatments administered, fibre loss was highest in the pulses cooked under pressure (T_9) followed by boiled (T_7), steamed (T_8) and roasted (T_{10}) samples.

A comparison of different cooking treatments on the pre treated and processed pulse samples with reference to their fibre content (Table 32) revealed significant reductions in fibre content.

Table 29. Influence of different cooking treatments on the protein content of the pretreated and processed pulses (g/100g)

Processing treatments	Uncooked T_0	Cooking treatments			
		T_7	T_8	T_9	T_{10}
T_4	31.58	26.44	26.90	26.67	27.13
T_5	30.30	25.70	26.12	25.92	26.32
T_6	29.33	25.46	25.87	25.64	26.08
F	218.06**				
CD	0.052				
SE	0.019				

** Significant at 1 per cent level

Table 30. Fibre content of different treated pulses (mean values) (g/100g)

Pulses	Untreated	Pretreated samples			Pretreated and processed samples			Uncooked	Pre treated, processed and cooked samples			
	T_1	T_1	T_2	T_3	T_4	T_5	T_6	T_0	T_7	T_8	T_9	T_{10}
Cowpea	4.78	3.73	3.81	3.90	4.25	3.44	3.75	4.98	3.52	3.61	3.15	3.80
Blackgram	13.29	10.80	11.19	12.32	11.70	10.99	11.62	14.04	10.31	11.47	9.07	12.29
Greengram	4.43	4.11	4.23	4.42	4.50	3.98	4.28	5.27	3.76	4.20	3.47	4.56
Soyabean	6.20	4.18	4.31	4.43	4.42	4.17	4.31	6.99	3.56	3.65	3.50	3.82
Bengalgram	3.80	3.73	3.87	4.08	4.06	3.70	3.92	4.97	3.54	3.69	3.44	3.83
F	3 999.85**		346.54**			80.97**				1043.14**		
CD	0.171		0.044			0.044				0.057		
SE	6.163		0.016			0.016				0.021		

** Significant at 1 per cent level

Table 31. Influence of processing on the fibre content of treated pulses (g/100g)

Pretreatments	Processing treatments			Uncooked	Cooking treatments			
	T_4	T_5	T_6	T_0	T_7	T_8	T_9	T_{10}
T_1	5.58	5.02	5.32	7.05	4.75	5.13	4.19	5.41
T_2	5.78	5.18	5.49	7.26	4.86	5.24	4.55	5.50
T_3	5.99	5.58	5.92	7.44	5.21	5.60	4.84	6.06
F		28.80**				30.72**		
CD		0.034				0.044		
SE		0.012				0.016		

** Significant at 1 per cent level

Table 32. Influence of different cooking treatments on the fibre content of the pretreated and processed pulses (g/100g)

Processing treatments	Uncooked T_0	Cooking treatments			
		T_7	T_8	T_9	T_{10}
T_4	7.41	5.17	5.55	4.86	5.93
T_5	7.08	4.59	5.10	4.20	5.31
T_6	7.25	5.06	5.32	4.52	5.73
F	27.62**				
CD	0.044				
SE	0.016				

** Significant at 1 per cent level

When the effect of different cooking treatments alone on the fibre content of the pulse samples were compared this also revealed significant variations.

A significant variation in the phytate content of different treated, processed and cooked pulses, were observed (Table 33).

Influence of processing techniques on the phytate content of different pretreated pulses irrespective of the kind (Table 34) revealed significant variation. Among the different processing treatments administered, germination (T_4) was found to cause maximum reduction in the phytate content followed by fermentation (T_5) and grinding (T_6). Similar trend was observed in a comparison among the pre treated and cooked pulse samples on their phytate content. Among the different cooking treatments administered, cooking under pressure (T_9) was found to cause maximum phytate loss followed by boiling (T_7), steaming (T_8) and roasting (T_{10}).

A comparison of different cooking treatments on the pre treated and processed pulse samples revealed significant fluctuations in the phytate content (Table 35)

4.2.3. Effect of different processing and cooking techniques on the inhibitory constituents of cowpea (Tables 36 and 37)

Among the three processing techniques administered, germinated cowpea was observed to retain protein significantly followed by fermented and ground samples.

Table 33. Phytate content of different treated pulses (mean values) (mg/100g)

Pulses	Untreated	Pretreated samples			Pretreated and processed samples			Uncooked	Pre treated, processed and cooked samples			
	T_1	T_1	T_2	T_3	T_4	T_5	T_6	T_0	T_7	T_8	T_9	T_{10}
Cowpea	377.94	292.09	324.45	311.17	294.08	309.05	324.58	351.63	289.29	303.23	282.78	319.27
Blackgram	215.46	77.62	87.04	80.78	59.36	75.12	110.96	143.13	63.35	69.83	52.31	80.44
Greengram	190.92	93.73	140.39	103.74	105.07	112.24	120.55	158.00	85.70	112.39	73.92	133.11
Soyabean	130.50	88.82	96.69	93.05	85.36	93.47	99.72	113.34	85.19	90.49	80.12	95.12
Bengalgram	158.03	113.23	128.53	119.41	115.72	120.11	125.34	132.50	112.71	122.12	106.46	128.16
F	88156.44**		11689.37**			11315.73**				14483.83**		
CD	0.914		0.233			0.233				0.301		
SE	0.329		0.084			0.084				0.109		

** Significant at 1 per cent level

Table 34. Influence of processing on the phytate content of treated pulses (mg/100g)

Pretreatments	Processing treatments			Uncooked	Cooking treatments			
	T_4	T_5	T_6	T_0	T_7	T_8	T_9	T_{10}
T_1	122.70	132.10	144.50	170.66	114.81	131.41	105.77	142.85
T_2	143.45	155.02	167.79	188.24	142.27	150.16	136.32	160.11
T_3	129.61	138.88	156.41	180.26	124.66	137.26	115.26	150.70
F		639.97**				1693.91**		
CD		0.181				0.233		
SE		0.065				0.084		

** Significant at 1 per cent level

Table 35. Influence of different cooking treatments on the phytate content of the pretreated and processed pulses (mg/100g)

Processing treatments	Uncooked T_0	Cooking treatments			
		T_7	T_8	T_9	T_{10}
T_4	172.27	115.31	127.79	104.98	139.23
T_5	180.01	125.50	138.36	117.38	148.75
T_6	186.88	140.93	152.68	134.99	165.68
F	1291.29**				
CD	0.233				
SE	0.084				

** Significant at 1 per cent level

There was variation in the protein content of germinated cowpea, when different cooking treatments were applied (Table 36).

Among the cooking treatments, boiling and pressure cooking were found to hydrolyse more protein in the cowpea. While roasting as well as steaming methods were found to retain more protein.

Among the different samples also there was significant variation in protein retention except between samples fermented, boiled ($P_1T_1T_5T_7$) and ground, pressure cooked ($P_1T_1T_6T_9$) and also between fermented, pressure cooked ($P_1T_1T_5T_9$) and ground, steamed samples ($P_1T_1T_6T_8$).

Higher concentration of fibre was observed in germinated cowpea, followed by ground and fermented samples. There was significant variation in the fibre content of the untreated and treated pulse samples. Fermented ($P_1T_1T_5$) samples were observed to have the lowest fibre content.

There was variation in the fibre content of processed cowpea, when different cooking treatments were applied. Among the cooking treatments, pressure cooking and boiling were found to hydrolyse more fibre in the cowpea. While steaming as well as roasting methods were found to conserve more fibre.

Among the processed and cooked samples, there was significant variation in fibre retention except between fermented, steamed ($P_1T_1T_5T_8$)

Table 36. Effect of processing and cooking techniques on the inhibitory constituents of cowpea soaked for six hours

Pulses	Inhibitory constituents / 100 g		
	Protein (g)	Fibre (g)	Phytate (mg)
1. Untreated			
T_1	22.41	4.78	377.94
2. Processed			
$P_1T_1T_4$	28.75	5.10	332.11
$P_1T_1T_5$	28.30	4.80	340.60
$P_1T_1T_6$	27.50	4.90	347.24
3. Processed and cooked			
$P_1T_1T_4T_7$	22.06	4.00	261.36
$P_1T_1T_4T_8$	22.76	4.08	278.53
$P_1T_1T_4T_9$	22.50	3.48	258.52
$P_1T_1T_4T_{10}$	23.29	4.12	292.66
$P_1T_1T_5T_7$	21.50	3.05	264.57
$P_1T_1T_5T_8$	21.80	3.18	285.37
$P_1T_1T_5T_9$	21.70	2.59	259.79
$P_1T_1T_5T_{10}$	22.20	3.22	306.11
$P_1T_1T_6T_7$	21.40	3.25	271.34
$P_1T_1T_6T_8$	21.70	3.41	298.52
$P_1T_1T_6T_9$	21.50	3.12	269.34
$P_1T_1T_6T_{10}$	22.10	3.58	315.25
SE	0.073	0.028	0.146
CD	0.201	0.076	0.404
F	4.053**	14.955**	150.004**

** Significant at 1 per cent level

and ground, pressure cooked ($P_1T_1T_6T_9$) samples and also between ground, boiled ($P_1T_1T_6T_7$) and fermented, roasted ($P_1T_1T_5T_{10}$) samples.

Phytate content in the pulse samples was highest in ground samples followed by fermented, germinated samples. There was significant variation between treated and untreated samples. Germinated samples ($P_1T_1T_4$) had the lowest phytate content.

There was variation in the phytate content in germinated cowpea, when different cooking treatments were applied. Among the cooking treatments, pressure cooking and boiling were found to hydrolyse more phytate in the cowpea. While steaming and roasting methods were found to conserve more phytate. Among the processed and cooked samples there was significant variation in their phytate content.

Reduction in soaking duration had been found to conserve more fibre and phytate than protein (Table 37) irrespective of the cooking treatments administered. A comparison of samples soaked for three hours revealed significant variation in different inhibitory constituents in soaked cowpea samples. Samples soaked for three hours without $NaHCO_3$ and cooked by different methods were noted to retain more protein and phytate while findings related to fibre indicate that addition of $NaHCO_3$ resulted in retention of fibre. Among the processed samples, germinated ($P_1T_2T_4$) sample had been found to retain more protein and fibre. There was significant variation in the retention of inhibitory constituents among different treated and untreated samples.

Table 37. Effect of processing and cooking techniques on the inhibitory constituent of cowpea (100g) soaked for three hours

Pulses	Without $NaHCO_3$			Pulses	With $NaHCO_3$		
	Protein (g)	Fibre (g)	Phytate (mg)		Protein (g)	Fibre (g)	Phytate (mg)
1. Untreated				**1. Untreated**			
T_1	22.41	4.78	377.94	T_1	22.41	4.78	377.94
2. Processed				**2. Processed**			
$P_1T_2T_4$	26.60	5.10	350.51	$P_1T_3T_4$	25.75	5.20	345.07
$P_1T_2T_5$	25.30	4.80	364.72	$P_1T_3T_5$	24.30	4.90	353.12
$P_1T_2T_6$	24.57	4.90	370.43	$P_1T_3T_6$	23.76	5.10	360.76
3. Processeed and cooked				**3. Processed and cooked**			
$P_1T_2T_4T_7$	21.80	4.03	279.87	$P_1T_3T_4T_7$	21.50	4.13	279.59
$P_1T_2T_4T_8$	22.50	4.13	296.36	$P_1T_3T_4T_8$	21.80	4.18	282.34
$P_1T_2T_4T_9$	22.06	3.51	271.19	$P_1T_3T_4T_9$	21.70	3.56	261.36
$P_1T_2T_4T_{10}$	22.76	4.57	312.52	$P_1T_3T_4T_{10}$	22.06	4.62	309.23
$P_1T_2T_5T_7$	21.20	3.11	318.79	$P_1T_3T_5T_7$	21.00	3.18	281.56
$P_1T_2T_5T_8$	21.50	3.25	325.77	$P_1T_3T_5T_8$	21.40	3.31	301.59
$P_1T_2T_5T_9$	21.40	2.73	313.91	$P_1T_3T_5T_9$	21.20	2.81	271.81
$P_1T_2T_5T_{10}$	21.70	3.30	338.19	$P_1T_3T_5T_{10}$	21.50	3.34	309.76
$P_1T_2T_6T_7$	21.00	3.38	324.51	$P_1T_3T_6T_7$	20.80	3.54	321.99
$P_1T_2T_6T_8$	21.40	3.43	331.60	$P_1T_3T_6T_8$	21.20	3.56	328.97
$P_1T_2T_6T_9$	21.20	3.25	321.33	$P_1T_3T_6T_9$	21.00	3.29	317.73
$P_1T_2T_6T_{10}$	21.50	3.62	347.11	$P_1T_3T_6T_{10}$	21.40	3.85	342.64
SE	0.073	0.028	0.146	SE	0.073	0.028	0.146
CD	0.201	0.076	0.404	CD	0.201	0.076	0.404
F	4.053**	14.955**	150.004**	F	4.053**	14.955**	150.044**

** Significant at 1 per cent level

There was no significant variation in protein content between fermented, steamed ($P_1T_2T_5T_8$) and ground, roasted samples ($P_1T_2T_6T_{10}$) and also between fermented, pressure cooked ($P_1T_2T_5T_9$) and ground, steamed samples ($P_1T_2T_6T_8$). A comparison in fibre content between fermented, steamed ($P_1T_2T_5T_8$) and ground, pressure cooked ($P_1T_2T_6T_9$) samples and also between germinated, boiled ($P_1T_3T_4T_7$) and germinated, steamed samples ($P_1T_3T_4T_8$) also revealed similar findings. But in the case of phytate content there was significant variation among all the samples.

4.2.4. Effect of different processing and cooking treatments on the inhibitory constituents of blackgram (Tables 38 and 39)

Among the three processing techniques administered, germinated blackgram was observed to have more protein content followed by fermented and ground. There was significant variation between untreated and treated samples. Germinated sample ($P_2T_1T_4$) had the highest protein content.

As revealed in Table 38, by processing and cooking treatments, inhibitory constituents in blackgram was found to be significantly hydrolysed. There was variation in the protein content of germinated blackgram, when different cooking treatments were applied. Among the cooking treatments, boiling and pressure cooking were found to hydrolyse more protein in the blackgram. While steaming and roasting methods were found to conserve more protein.

Table 38. Effect of processing and cooking techniques on the inhibitory constituents of blackgram soaked for six hours

Pulses	Inhibitory constituents / 100 g		
	Protein (g)	Fibre (g)	Phytate (mg)
1. Untreated			
T_1	23.26	13.29	215.46
2. Processed			
$P_2T_1T_4$	29.40	13.80	120.40
$P_2T_1T_5$	28.74	13.50	130.70
$P_2T_1T_6$	27.50	13.70	140.20
3. Processed and cooked			
$P_2T_1T_4T_7$	22.90	9.97	35.11
$P_2T_1T_4T_8$	23.40	11.25	35.28
$P_2T_1T_4T_9$	23.30	9.27	20.39
$P_2T_1T_4T_{10}$	23.64	11.97	54.14
$P_2T_1T_5T_7$	22.40	9.34	61.50
$P_2T_1T_5T_8$	22.76	10.34	71.18
$P_2T_1T_5T_9$	22.60	6.49	38.57
$P_2T_1T_5T_{10}$	22.90	11.57	76.89
$P_2T_1T_6T_7$	22.20	9.76	88.62
$P_2T_1T_6T_8$	22.60	11.25	96.01
$P_2T_1T_6T_9$	22.40	7.98	85.67
$P_2T_1T_6T_{10}$	22.76	11.60	109.62
SE	0.073	0.028	0.146
CD	0.201	0.076	0.404
F	4.053**	14.955**	150.004**

** Significant at 1 per cent level

Among the processed and cooked samples, there was significant variation between the pulse samples, except between germinated, boiled ($P_2T_1T_4T_7$) and fermented, roasted ($P_2T_1T_5T_{10}$) samples, and also between fermented, boiled ($P_2T_1T_5T_7$) and ground, pressure cooked ($P_2T_1T_6T_9$) samples. A comparison between fermented, steamed ($P_2T_1T_5T_8$) and ground, roasted samples ($P_2T_1T_6T_{10}$) and also between fermented, pressure cooked ($P_2T_1T_5T_9$) and ground, steamed ($P_2T_1T_6T_8$) samples also revealed similar results.

Among the three processing techniques administered germinated blackgram had the highest value for fibre followed by ground and fermented blackgram samples. There was significant variation between treated and untreated samples.

Among the cooking treatments, pressure cooking and boiling were found to hydrolyse more fibre in the blackgram, while steaming as well as roasting methods were found to retain more fibre.

There was no significant variation between germinated, steamed ($P_2T_1T_4T_8$) and ground, steamed samples ($P_2T_1T_6T_8$) and also between germinated, pressure cooked ($P_2T_1T_4T_9$) and fermented boiled samples ($P_2T_1T_5T_7$). A comparison between fermented, roasted ($P_2T_1T_5T_{10}$) and ground, roasted samples ($P_2T_1T_6T_{10}$) also revealed similar results.

Phytate content in the processed samples was observed to retain more in ground blackgram followed by fermented, germinated blackgram.

There was significant variation in phytate content between untreated and treated samples.

There was variation in phytate content in germinated blackgram, when different cooking treatments were applied. Among the cooking treatments, pressure cooking and boiling were found to hydrolyse more phytate in the blackgram while steaming and roasting methods were found to retain more phytate.

There was significant variation in the phytate content among different cooked samples. However germinated, boiled ($P_2T_1T_4T_7$) and germinated, steamed ($P_2T_1T_4T_8$) samples revealed no significant variation.

Table 39 details the changes in inhibitory constituents in blackgram soaked for three hours with and without $NaHCO_3$. Reduction in soaking hours had been found to conserve more fibre and phytate than protein irrespective of the cooking treatments administered since higher values for the above two variables were observed in all the treatments when compared to the values obtained for the blackgram samples soaked for six hours. A comparison between the two samples ie., samples soaked for three hours revealed significant variation in different inhibitory constituents in soaked blackgram samples. Samples soaked without $NaHCO_3$ and cooked by different methods were noted to conserve more protein and phytate. Findings related to fibre indicate that addition of $NaHCO_3$ resulted in better conservation of fibre.

Table 39. Effect of processing and cooking techniques on the inhibitory constituent of black gram (100g) soaked for three hours

Pulses	Without $NaHCO_3$			Pulses	With $NaHCO_3$		
	Protein (g)	Fibre (g)	Phytate (mg)		Protein (g)	Fibre (g)	Phytate (mg)
1. Untreated				**1. Untreated**			
T_1	23.26	13.29	215.46	T_1	23.26	13.29	215.46
2. Processed				**2. Processed**			
$P_2T_2T_4$	28.60	14.20	144.30	$P_2T_3T_4$	27.50	14.40	134.50
$P_2T_2T_5$	27.40	14.00	156.40	$P_2T_3T_5$	26.70	14.20	145.80
$P_2T_2T_6$	26.20	14.10	163.30	$P_2T_3T_6$	25.50	14.30	152.60
3. Processeed and cooked				**3. Processed and cooked**			
$P_2T_2T_4T_7$	22.76	10.38	46.40	$P_2T_3T_4T_7$	22.40	10.54	37.93
$P_2T_2T_4T_8$	23.30	11.93	49.51	$P_2T_3T_4T_8$	22.80	12.11	43.09
$P_2T_2T_4T_9$	22.90	9.64	28.45	$P_2T_3T_4T_9$	22.60	10.28	21.44
$P_2T_2T_4T_{10}$	23.40	12.17	63.50	$P_2T_3T_4T_{10}$	23.29	13.50	55.98
$P_2T_2T_5T_7$	22.20	9.76	51.37	$P_2T_3T_5T_7$	21.70	10.59	51.06
$P_2T_2T_5T_8$	22.60	10.39	60.06	$P_2T_3T_5T_8$	22.06	12.51	59.50
$P_2T_2T_5T_9$	22.40	8.56	46.51	$P_2T_3T_5T_9$	21.80	10.44	42.43
$P_2T_2T_5T_{10}$	22.76	10.56	68.54	$P_2T_3T_5T_{10}$	22.20	12.56	66.23
$P_2T_2T_6T_7$	21.70	9.98	101.12	$P_2T_3T_6T_7$	21.50	12.48	97.08
$P_2T_2T_6T_8$	22.06	10.95	107.87	$P_2T_3T_6T_8$	21.80	12.51	105.93
$P_2T_2T_6T_9$	21.80	9.34	99.51	$P_2T_3T_6T_9$	21.70	9.64	87.83
$P_2T_2T_6T_{10}$	22.20	11.89	118.77	$P_2T_3T_6T_{10}$	22.06	14.78	110.25
SE	0.073	0.028	0.146	SE	0.073	0.028	0.146
CD	0.201	0.076	0.404	CD	0.201	0.076	0.404
F	4.053**	14.955**	150.004**	F	4.053**	14.955**	150.004**

** Significant at 1 per cent level

When the pulse samples were analysed, it was found that processing and cooking affected the inhibitory constituents. Among the processed samples, germinated ($P_2T_2T_4$) samples had been found to conserve more protein and fibre when compared to phytate content. Statistical treatment of the data revealed that there was significant variation in the inhibitory constituents between untreated (T_1), germinated ($P_2T_2T_4$), fermented ($P_2T_2T_5$) and ground ($P_2T_2T_6$) samples.

Variation in protein content was not significant between germinated, boiled ($P_2T_2T_4T_7$) and fermented, roasted ($P_2T_2T_5T_{10}$) and also between fermented, boiled ($P_2T_2T_5T_7$) and ground, roasted ($P_2T_2T_6T_{10}$) samples. A comparison between fermented, boiled ($P_2T_3T_5T_7$) and ground, pressure cooked ($P_2T_3T_6T_9$) and also between fermented, steamed ($P_2T_3T_5T_8$) and ground, roasted ($P_2T_3T_6T_{10}$) samples revealed similar results. Same trend was observed in a comparison between fermented, roasted ($P_2T_3T_5T_9$) and ground, steamed ($P_2T_3T_6T_8$) samples.

Fibre content was not significantly varying when germinated, boiled ($P_2T_2T_4T_7$) and fermented, steamed ($P_2T_2T_5T_8$) samples were compared. Similar findings were observed in the case of germinated, steamed ($P_2T_2T_4T_8$) and ground, roasted ($P_2T_2T_6T_{10}$) samples. A comparison between germinated, boiled ($P_2T_3T_4T_7$) and fermented, boiled ($P_2T_3T_5T_7$) samples and also between fermented, steamed ($P_2T_3T_5T_8$) and ground, steamed samples ($P_2T_3T_6T_8$) revealed similar results. Significant variation in phytate content was observed in samples exposed to $NaHCO_3$.

4.2.5. Effect of different processing and cooking treatments on the inhibitory constituents of redgram (Tables 40 and 41)

Germination was not administered on split redgram. Fermented samples conserved more protein than ground. There was significant variation between untreated and treated samples.

There was variation in the protein content of fermented redgram, when different cooking treatments were applied. Among the cooking treatments, boiling and pressure cooking were found to hydrolyse more protein in the redgram. While steaming and roasting methods were found to conserve more protein.

Significant variation in protein content was observed in all the samples except in comparison among fermented, boiled ($P_3T_1T_5T_7$), ground, boiled ($P_3T_1T_6T_7$) and ground, pressure cooked samples ($P_3T_1T_6T_9$); between fermented, steamed ($P_3T_1T_5T_8$) and ground, roasted ($P_3T_1T_6T_{10}$) and also between fermented, pressure cooked ($P_3T_1T_5T_9$) and ground, steamed ($P_3T_1T_6T_8$) samples.

Ground redgram samples had better retention of fibre and phytate than fermented redgram. There was significant variation between untreated and treated samples.

There was variation in the fibre content of processed redgram, when different cooking treatments were applied. Among the cooking

Table 40. Effect of processing and cooking techniques on the inhibitory constituents of red gram soaked for six hours

Pulses	Inhibitory constituents / 100g		
	Protein (g)	Fibre (g)	Phytate (mg)
1. Untreated			
T_1	22.23	1.60	170.00
2. Processed			
$P_3T_1T_5$	26.80	1.70	128.70
$P_3T_1T_6$	25.30	1.90	139.60
3. Processed and cooked			
$P_3T_1T_5T_7$	21.50	0.50	101.12
$P_3T_1T_5T_8$	21.80	0.60	105.93
$P_3T_1T_5T_9$	21.70	0.40	96.01
$P_3T_1T_5T_{10}$	22.06	0.70	110.25
$P_3T_1T_6T_7$	21.40	0.60	102.67
$P_3T_1T_6T_8$	21.70	0.70	107.36
$P_3T_1T_6T_9$	21.50	0.50	99.51
$P_3T_1T_6T_{10}$	21.80	0.80	118.77
SE	0.135	5.869	6.455
CD	0.381	0.166	0.183
F	146.561**	86.281**	85980.22**

** Significant at 1 per cent level

treatments, pressure cooking and boiling were found to hydrolyse more fibre and phytate in the redgram. While steaming and roasting were found to conserve more fibre and phytate.

There was no significant variation in the fibre content between fermented, boiled samples ($P_3T_1T_5T_7$) and ground, pressure cooked samples ($P_3T_1T_6T_9$); between fermented, steamed ($P_3T_1T_5T_8$) and ground, boiled ($P_3T_1T_6T_7$) samples; and also between fermented, roasted ($P_3T_1T_5T_{10}$) and ground, steamed samples ($P_3T_1T_6T_8$).

Variation was statistically significant in all the samples in their phytate content.

Table 41 details the inhibitory constituents in redgram soaked for three hours with and without $NaHCO_3$. Reduction in soaking hours had been found to conserve more fibre and phytate than protein in redgram irrespective of the cooking treatments administered. Samples cooked without $NaHCO_3$ and cooked by different methods were noted to conserve more protein and phytate. Findings related to fibre indicated that addition of $NaHCO_3$ resulted in conservation of fibre.

There was significant variation in the inhibitory constituents between untreated (T_1), fermented ($P_3T_2T_5$) and ground ($P_3T_2T_6$) samples. This was highly significant between untreated (T_1) and fermented ($P_3T_2T_5$) samples.

Table 41. Effect of processing and cooking techniques on the inhibitory constituent of red gram (100g) soaked for three hours

Pulses	Without $NaHCO_3$			Pulses	With $NaHCO_3$		
	Protein (g)	Fibre (g)	Phytate (mg)		Protein (g)	Fibre (g)	Phytate (mg)
1. Untreated				**1. Untreated**			
T_1	22.23	1.60	170.00	T_1	22.23	1.60	170.00
2. Processed				**2. Processed**			
$P_3T_2T_5$	25.70	2.00	147.60	$P_3T_3T_5$	24.70	2.20	137.60
$P_3T_2T_6$	24.30	2.10	160.30	$P_3T_3T_6$	23.30	2.40	150.30
3. Processeed and cooked				**3. Processed and cooked**			
$P_3T_2T_5T_7$	21.20	0.80	118.77	$P_3T_3T_5T_7$	20.80	1.00	105.93
$P_3T_2T_5T_8$	21.50	0.90	124.00	$P_3T_3T_5T_8$	21.20	1.10	110.25
$P_3T_2T_5T_9$	21.40	0.70	110.25	$P_3T_3T_5T_9$	21.00	0.90	101.12
$P_3T_2T_5T_{10}$	21.70	1.00	130.37	$P_3T_3T_5T_{10}$	21.40	1.20	111.83
$P_3T_2T_6T_7$	21.00	0.90	124.00	$P_3T_3T_6T_7$	20.60	1.00	110.25
$P_3T_2T_6T_8$	21.40	1.00	130.37	$P_3T_3T_6T_8$	21.00	1.20	118.77
$P_3T_2T_6T_9$	21.20	0.80	118.77	$P_3T_3T_6T_9$	20.80	1.10	105.93
$P_3T_2T_6T_{10}$	21.50	1.10	140.00	$P_3T_3T_6T_{10}$	21.20	1.30	124.00
SE	0.135	5.869	6.455	SE	0.135	5.869	6.455
CD	0.381	0.166	0.182	CD	0.381	0.166	0.183
F	146.561**	86.281**	85980.22**	F	146.561**	86.281**	85980.22**

** Significant at 1 per cent level

Among the processed and cooked samples there was significant variation among themselves and also in comparison with untreated and processed samples. However there was no significant variation in protein content between fermented, boiled ($P_3T_2T_5T_7$) and ground, pressure cooked ($P_3T_2T_6T_9$) and also between fermented, steamed ($P_3T_2T_5T_8$) and ground, roasted ($P_3T_2T_6T_{10}$) samples. A comparison of fermented, pressure cooked ($P_3T_2T_5T_9$) and ground, steamed samples ($P_3T_2T_6T_8$) also revealed similar results.

Fibre and phytate content was significantly varying between all the samples. However there was no significant variation between fermented, boiled ($P_3T_2T_5T_7$) and ground, pressure cooked samples ($P_3T_2T_6T_9$) and also between fermented, steamed ($P_3T_2T_5T_8$) and ground, boiled ($P_3T_2T_6T_7$) and also between fermented, roasted ($P_3T_2T_5T_{10}$) and ground, steamed ($P_3T_2T_6T_8$) samples.

4.2.6. Effect of different processing and cooking treatments on the inhibitory constituents of greengram (Tables 42 and 43)

Among the three processing techniques administered, germinated sample was found to retain more protein than fermented and ground greengram. As revealed in Table 42 by processing and cooking treatments, inhibitory constituents in greengram was found to be significantly hydrolysed.

Table 42. Effect of processing and cooking techniques on the inhibitory constituents of green gram soaked for six hours

Pulses	Inhibitory constituents / 100g		
	Protein (g)	Fibre (g)	Phytate (mg)
1. Untreated			
T_1	23.37	4.43	190.92
2. Processed			
$P_4T_1T_4$	27.52	5.20	139.80
$P_4T_1T_5$	25.34	5.00	148.60
$P_4T_1T_6$	23.96	5.10	157.90
3. Processed and cooked			
$P_4T_1T_4T_7$	23.29	4.10	56.42
$P_4T_1T_4T_8$	23.64	4.15	93.81
$P_4T_1T_4T_9$	23.40	3.40	41.76
$P_4T_1T_4T_{10}$	23.80	4.65	100.51
$P_4T_1T_5T_7$	22.59	3.13	58.26
$P_4T_1T_5T_8$	22.90	4.03	96.52
$P_4T_1T_5T_9$	22.70	3.11	43.65
$P_4T_1T_5T_{10}$	23.79	4.16	106.36
$P_4T_1T_6T_7$	22.40	4.07	70.61
$P_4T_1T_6T_8$	22.70	4.11	100.79
$P_4T_1T_6T_9$	22.59	3.20	52.11
$P_4T_1T_6T_{10}$	23.10	4.18	138.83
SE	0.073	0.028	0.146
CD	0.201	0.076	0.404
F	4.053**	14.955**	150.004**

** Significant at 1 per cent level

When fibre was analysed, it was seen that among the three processing techniques administered, germinated greengram had the highest value followed by ground and fermented greengram samples. There was significant variation in the fibre content between treated and untreated samples.

Phytate content in the processed samples was highest in ground samples, followed by fermented and germinated samples. There was significant variation in phytate content after processing and cooking. There was significant variation between untreated and treated samples.

There was significant variation in protein, fibre and phytate contents of the treated and untreated pulse samples.

There was variation in the protein content of germinated greengram, when different cooking treatments were applied. Among the cooking treatments, boiling and pressure cooking were found to hydrolyse more protein, fibre and phytate in the greengram. While steaming and roasting methods were found to conserve more protein, fibre and phytate.

Among the processed and cooked greengram samples, there was significant variation in protein content between the samples except between fermented, pressure cooked ($P_4T_1T_5T_9$) and ground, steamed samples ($P_4T_1T_6T_8$).

There was no significant variation in fibre content, between germinated, boiled ($P_4T_1T_4T_7$) and ground, steamed samples ($P_4T_1T_6T_8$) and also between germinated, steamed ($P_4T_1T_4T_8$) and fermented roasted ($P_4T_1T_5T_{10}$) samples. A comparison between fermented, boiled ($P_4T_1T_5T_7$) and fermented, pressure cooked ($P_4T_1T_5T_9$) samples also indicated similar results.

Table 43 details the inhibitory constituents in greengram soaked for three hours with and without $NaHCO_3$. Reduction in soaking hours had been found to conserve more fibre and phytate than protein in greengram irrespective of the cooking treatments administered. A comparison between the two samples revealed significant variation in different inhibitory constituents in soaked greengram samples. Samples soaked without $NaHCO_3$ and cooked by different methods were noted to conserve more protein and phytate. Findings related to fibre indicated that addition of $NaHCO_3$ resulted in the retention of fibre.

When the pulse samples were analysed, it was found that processing and cooking resulted in a reduction of inhibitory constituents. Among the processed samples, germinated samples ($P_4T_2T_4$) had been found to retain more protein and fibre and less phytate content.

Statistical treatment of the data revealed that there was significant variation in the inhibitory constituents between untreated and treated samples.

Table 43. Effect of processing and cooking techniques on the inhibitory constituent of green gram (100g) soaked for three hours

Pulses	Without $NaHCO_3$			Pulses	With $NaHCO_3$		
	Protein (g)	Fibre (g)	Phytate (mg)		Protein (g)	Fibre (g)	Phytate (mg)
1. Untreated				**1. Untreated**			
T_1	23.37	4.43	190.92	T_1	23.37	4.43	190.92
2. Processed				**2. Processed**			
$P_4T_2T_4$	26.53	5.40	158.30	$P_4T_3T_4$	25.30	5.60	149.40
$P_4T_2T_5$	24.31	5.10	166.40	$P_4T_3T_5$	23.20	5.30	156.30
$P_4T_2T_6$	23.80	5.30	176.90	$P_4T_3T_6$	23.00	5.40	168.40
3. Processeed and cooked				**3. Processed and cooked**			
$P_4T_2T_4T_7$	22.76	4.15	124.32	$P_4T_3T_4T_7$	22.59	4.16	61.39
$P_4T_2T_4T_8$	23.40	4.18	136.79	$P_4T_3T_4T_8$	23.29	4.57	99.32
$P_4T_2T_4T_9$	23.29	4.13	117.27	$P_4T_3T_4T_9$	22.76	3.97	45.32
$P_4T_2T_4T_{10}$	23.64	4.76	142.79	$P_4T_3T_4T_{10}$	23.40	5.01	108.91
$P_4T_2T_5T_7$	22.06	3.16	126.78	$P_4T_3T_5T_7$	21.80	3.19	71.97
$P_4T_2T_5T_8$	22.40	4.10	134.93	$P_4T_3T_5T_8$	22.20	4.26	104.39
$P_4T_2T_5T_9$	22.20	3.17	118.34	$P_4T_3T_5T_9$	22.06	3.19	59.37
$P_4T_2T_5T_{10}$	22.50	4.16	154.40	$P_4T_3T_5T_{10}$	22.40	4.70	137.34
$P_4T_2T_6T_7$	21.80	3.91	127.79	$P_4T_3T_6T_7$	21.70	3.98	73.72
$P_4T_2T_6T_8$	22.20	4.13	138.63	$P_4T_3T_6T_8$	22.06	4.28	106.34
$P_4T_2T_6T_9$	22.06	3.23	123.96	$P_4T_3T_6T_9$	21.80	3.86	63.49
$P_4T_2T_6T_{10}$	22.40	4.59	158.32	$P_4T_3T_6T_{10}$	22.20	4.81	150.51
SE	0.073	0.028	0.146	SE	0.073	0.028	0.146
CD	0.201	0.076	0.404	CD	0.201	0.076	0.404
F	4.053**	14.955**	150.004**	F	4.053**	14.955**	150.004**

** Significant at 1 per cent level

However there was no significant variation in protein content between fermented, boiled ($P_4T_2T_5T_7$) and ground, pressure cooked ($P_4T_2T_6T_9$) and also between fermented, steamed ($P_4T_2T_5T_8$) and ground, roasted ($P_4T_2T_6T_{10}$) samples.

Fibre content was also not significantly varying between germinated, boiled ($P_4T_2T_4T_7$) and fermented, steamed ($P_4T_2T_5T_8$) when compared and also between germinated, pressure cooked ($P_4T_2T_4T_9$) and ground, steamed ($P_4T_2T_6T_8$) samples. A comparison between fermented, boiled ($P_4T_2T_5T_7$) and fermented, pressure cooked ($P_4T_2T_5T_7$) samples also revealed similar results.

There was significant variation among the pulse samples in their phytate content.

4.2.7. Effect of different processing and cooking treatments on the inhibitory constituents of soyabean (Tables 44 and 45)

Among the three processing techniques administered, germinated sample was found to retain more protein than fermented, ground soyabean. As revealed in Table 44, by processing and cooking treatments, inhibitory constituents in soyabean was found to be significantly hydrolysed. There was variation in the protein content of germinated soyabean, when different cooking treatments were applied. Statistical treatment of the data revealed that there was significant variation in protein fibre and phytate content of untreated processed and processed, cooked soyabean.

Table 44. Effect of processing and cooking techniques on the inhibitory constituents of soyabean soaked for six hours

Pulses	Inhibitory constituents / 100g		
	Protein (g)	Fibre (g)	Phytate (mg)
1. Untreated			
T_1	42.70	6.20	130.50
2. Processed			
$P_5T_1T_4$	48.60	6.90	103.90
$P_5T_1T_5$	47.50	6.50	109.70
$P_5T_1T_6$	46.80	6.70	112.30
3. Processed and cooked			
$P_5T_1T_4T_7$	42.50	3.56	71.18
$P_5T_1T_4T_8$	42.87	3.62	76.89
$P_5T_1T_4T_9$	42.70	3.54	64.50
$P_5T_1T_4T_{10}$	43.10	3.84	87.63
$P_5T_1T_5T_7$	41.90	3.40	85.67
$P_5T_1T_5T_8$	42.39	3.43	87.63
$P_5T_1T_5T_9$	42.20	3.34	76.89
$P_5T_1T_5T_{10}$	42.55	3.56	88.62
$P_5T_1T_6T_7$	41.60	3.51	88.62
$P_5T_1T_6T_8$	42.20	3.54	96.01
$P_5T_1T_6T_9$	41.90	3.48	85.67
$P_5T_1T_6T_{10}$	42.40	3.80	97.08
SE	0.073	0.028	0.146
CD	0.201	0.076	0.404
F	4.053**	14.955**	150.004**

** Significant at 1 per cent level

Among the cooking treatments, boiling and pressure cooking were found to hydrolyse more protein, fibre and phytate in the soyabean, while steaming and roasting methods were found to retain more protein, fibre and phytate.

Among the processed and cooked soyabean samples, there was significant variation in protein content among the samples. However there was no significant variation between germinated, boiled ($P_5T_1T_4T_7$) and fermented, roasted ($P_5T_1T_5T_{10}$) and also between fermented, boiled ($P_5T_1T_5T_7$) and ground, pressure cooked ($P_5T_1T_6T_9$) soya bean samples. A comparison between fermented, pressure cooked ($P_5T_1T_5T_9$) and ground, steamed ($P_5T_1T_6T_8$) soyabean samples also revealed similar results.

When fibre was analysed, it was seen that among the three processing techniques administered, germinated soyabean had the highest value followed by ground and fermented soyabean.

Among the processed and cooked samples, there was significant variation between soyabean samples. However there was no significant variation between germinated, boiled ($P_5T_1T_4T_7$), pressure cooked ($P_5T_1T_4T_9$) and ground, steamed ($P_5T_1T_6T_8$) soyabean samples. A comparison between fermented, boiled ($P_5T_1T_5T_7$) and fermented steamed ($P_5T_1T_5T_8$) and also between fermented, roasted ($P_5T_1T_5T_{10}$) and ground, boiled ($P_5T_1T_6T_7$) soyabean samples revealed similar results.

Table 45. Effect of processing and cooking techniques on the inhibitory constituent of soyabean (100g) soaked for three hours

Pulses	Without $NaHCO_3$			Pulses	With $NaHCO_3$		
	Protein (g)	Fibre (g)	Phytate (mg)		Protein (g)	Fibre (g)	Phytate (mg)
1. Untreated				**1. Untreated**			
T_1	42.70	6.20	130.50	T_1	42.70	6.20	130.50
2. Processed				**2. Processed**			
$P_5T_2T_4$	47.40	7.20	114.30	$P_5T_3T_4$	46.50	7.40	108.70
$P_5T_2T_5$	46.30	6.90	119.40	$P_5T_3T_5$	45.20	7.10	110.90
$P_5T_2T_6$	45.60	7.00	122.80	$P_5T_3T_6$	44.50	7.20	118.40
3. Processeed and cooked				**3. Processed and cooked**			
$P_5T_2T_4T_7$	42.40	3.58	76.89	$P_5T_3T_4T_7$	41.90	3.83	75.00
$P_5T_2T_4T_8$	42.70	3.80	88.62	$P_5T_3T_4T_8$	42.40	3.86	84.00
$P_5T_2T_4T_9$	42.50	3.56	71.18	$P_5T_3T_4T_9$	42.20	3.62	68.54
$P_5T_2T_4T_{10}$	42.87	3.98	96.01	$P_5T_3T_4T_{10}$	42.50	4.00	93.00
$P_5T_2T_5T_7$	41.60	3.48	88.62	$P_5T_3T_5T_7$	40.90	3.51	87.63
$P_5T_2T_5T_8$	42.20	3.54	96.01	$P_5T_3T_5T_8$	41.40	3.62	88.62
$P_5T_2T_5T_9$	41.90	3.43	85.67	$P_5T_3T_5T_9$	41.10	3.48	84.00
$P_5T_2T_5T_{10}$	42.40	3.62	97.08	$P_5T_3T_5T_{10}$	41.60	3.80	96.01
$P_5T_2T_6T_7$	40.90	3.54	97.08	$P_5T_3T_6T_7$	40.70	3.62	96.01
$P_5T_2T_6T_8$	41.40	3.62	99.51	$P_5T_3T_6T_8$	41.10	3.80	97.08
$P_5T_2T_6T_9$	41.10	3.51	96.01	$P_5T_3T_6T_9$	40.90	3.56	88.62
$P_5T_2T_6T_{10}$	41.60	3.86	101.12	$P_5T_3T_6T_{10}$	41.40	3.98	99.51
SE	0.073	0.028	0.146	SE	0.073	0.028	0.146
CD	0.201	0.076	0.404	CD	0.201	0.076	0.404
F	4.053**	14.955**	150.004**	F	4.053**	14.955**	150.004**

** Significant at 1 per cent level

Phytate content of the processed soyabean samples was highest in ground, followed by fermented and germinated samples.

There was also significant variation between processed and cooked samples. A comparison between germinated, steamed ($P_5T_1T_4T_8$) and fermented, pressure cooked ($P_5T_1T_5T_9$) samples revealed that they were not significantly varied. There was no significant variation between germinated, roasted ($P_5T_1T_4T_{10}$) and fermented, steamed ($P_5T_1T_5T_8$) and also between fermented, roasted ($P_5T_1T_5T_{10}$) and ground, boiled ($P_5T_1T_6T_7$) soya bean samples.

Table 45 details the inhibitory constituents in soyabean soaked for three hours with and without $NaHCO_3$. Reduction in soaking hours had been found to conserve more fibre and phytate than protein irrespective of the cooking treatments administered since higher values for the above two variables were observed in all the treatments when compared to the values obtained for the soyabean samples soaked for six hours. A comparison between the two samples ie., samples soaked for three hours revealed significant variation in different inhibitory constituents in soaked soyabean samples. Samples soaked without $NaHCO_3$ and cooked by different methods were noted to conserve more protein and phytate. Findings related to fibre indicated that addition of $NaHCO_3$ resulted in conservation of fibre.

When the pulse samples were analysed, it was found that processing and cooking revealed a variation in the inhibitory constituents.

Among the processed samples, germinated ($P_5T_2T_4$) sample had been found to conserve more protein and fibre. There was variation in the inhibitory constituents in the pulse samples after processing and cooking.

Statistical treatment of the data revealed that there was significant variation in the inhibitory constituents between untreated (T_1), germinated ($P_5T_2T_4$), fermented ($P_5T_2T_5$) and ground ($P_5T_2T_6$) samples. This was more significant between untreated (T_1) and germinated ($P_5T_2T_4$) samples.

Among the processed and cooked samples, there was significant variation in the constituents and also in a comparison between fresh and processed samples. However there was no significant variation in protein between untreated (T_1) and germinated, steamed ($P_5T_2T_4T_8$) and also between fermented, boiled ($P_5T_2T_5T_7$) and ground, roasted ($P_5T_2T_6T_{10}$) samples.

Fibre content was not significantly varied between germinated, boiled ($P_5T_2T_4T_7$) and germinated, pressure cooked ($P_5T_2T_4T_9$) and also between fermented, steamed ($P_5T_2T_5T_8$) and ground, boiled ($P_5T_2T_6T_7$) samples. A comparison between germinated, steamed ($P_5T_2T_4T_8$) and ground, roasted samples ($P_5T_2T_6T_{10}$) and between fermented, roasted ($P_5T_2T_5T_{10}$) and ground, steamed samples ($P_5T_2T_6T_8$) also revealed similar results.

There was significant variation between the pulse samples when phytate content was analysed. However there was no significant variation

between germinated, steamed ($P_5T_2T_4T_8$) and fermented, boiled ($P_5T_2T_5T_7$) samples and also among germinated, roasted ($P_5T_2T_4T_{10}$), fermented, steamed ($P_5T_2T_5T_8$) and ground, pressure cooked ($P_5T_2T_6T_9$) samples. A comparison between fermented, roasted ($P_5T_2T_5T_{10}$) and ground, boiled ($P_5T_2T_6T_7$) samples also revealed similar results.

4.2.8. Effect of different processing and cooking treatments on the inhibitory constituents of bengalgram (Tables 46 and 47)

Among the three processing techniques administered, germinated sample was found to retain more protein than fermented and ground bengalgram. Statistical treatment of the data revealed that there was significant variation in the protein, fibre and phytate content between untreated and treated samples.

There was variation in the protein, fibre and phytate content of germinated bengalgram, when different cooking treatments were applied. Among the cooking treatments, boiling and pressure cooking were found to hydrolyse more protein, fibre and phytate in the bengalgram. While steaming and roasting methods were found to conserve more protein, fibre and phytate.

Among the processed and cooked samples, there was significant variation in protein content. However, there was no significant variation between fermented, boiled ($P_6T_1T_5T_7$) and ground, pressure cooked

($P_6T_1T_6T_9$) samples and also between fermented, steamed ($P_6T_1T_5T_8$) and ground, roasted ($P_6T_1T_6T_{10}$) samples.

Data on fibre indicated that among the three processing techniques administered, germinated bengalgram had the highest values followed by ground and fermented bengalgram. Statistical analysis of the data revealed that there was significant variation in fibre and phytate content of the pulse samples whether untreated, processed or processed, cooked. There was significant variation between untreated and treated samples.

Among the processed and cooked samples, there was significant variation among the samples. However, there was no significant variation between germinated, boiled ($P_6T_1T_4T_7$) and ground, steamed ($P_6T_1T_6T_8$) and also between germinated, steamed ($P_6T_1T_4T_8$) and ground, roasted samples ($P_6T_1T_6T_{10}$). A comparison between germinated, pressure cooked ($P_6T_1T_4T_9$) and fermented, steamed ($P_6T_1T_5T_8$) samples also revealed similar results.

Phytate content in the processed samples was highest in ground, followed by fermented and germinated samples.

Statistical treatment of the data revealed that there was significant variation between processed and cooked samples. A comparison between fermented, roasted ($P_6T_1T_5T_{10}$) and ground, steamed ($P_6T_1T_6T_8$) samples revealed that they are not significantly varied.

Table 46. Effect of processing and cooking techniques on the inhibitory constituents of bengal gram soaked for six hours

Pulses	Inhibitory constituents / 100g		
	Protein (g)	Fibre (g)	Phytate (mg)
1. Untreated			
T_1	22.58	3.80	158.03
2. Processed			
$P_6T_1T_4$	29.50	5.00	120.10
$P_6T_1T_5$	28.20	4.50	125.40
$P_6T_1T_6$	27.50	4.80	130.80
3. Processed and cooked			
$P_6T_1T_4T_7$	22.80	3.56	99.51
$P_6T_1T_4T_8$	23.10	3.62	111.83
$P_6T_1T_4T_9$	22.90	3.48	93.81
$P_6T_1T_4T_{10}$	23.30	3.81	117.27
$P_6T_1T_5T_7$	21.80	3.12	100.51
$P_6T_1T_5T_8$	22.20	3.48	118.77
$P_6T_1T_5T_9$	22.06	3.05	96.52
$P_6T_1T_5T_{10}$	22.40	3.58	123.96
$P_6T_1T_6T_7$	21.70	3.43	108.91
$P_6T_1T_6T_8$	22.06	3.51	123.96
$P_6T_1T_6T_9$	21.80	3.34	99.32
$P_6T_1T_6T_{10}$	22.20	3.62	127.79
SE	0.073	0.028	0.146
CD	0.201	0.076	0.404
F	4.053**	14.955**	150.004**

** Significant at 1 per cent level

Table 47 details the inhibitory constituents in bengalgram soaked for three hours with and without $NaHCO_3$. Reduction in soaking hours had been found to conserve more fibre and phytate than protein irrespective of the cooking treatments administered since higher values for the above two variables were observed in all the treatments when compared to the values obtained for the samples soaked for six hours. A comparison between the two samples revealed significant variation in different inhibitory constituents in soaked bengalgram samples. Statistical treatment of the data revealed that there was significant variation in the inhibitory constituents between untreated (T_1), germinated ($P_6T_2T_4$), fermented ($P_6T_2T_5$) and ground ($P_6T_2T_6$) samples. The variation was more significant between untreated (T_1) and germinated ($P_6T_2T_4$) samples.

Samples soaked without $NaHCO_3$ and cooked by different methods were noted to conserve more protein and phytate. Findings related to fibre indicated that addition of $NaHCO_3$ resulted in conservation of fibre.

When the pulse samples were analysed, it was found that processing and cooking showed a variation in the inhibitory constituents. Among the processed samples, germinated ($P_6T_2T_4$) sample had been found to conserve more protein and fibre and less phytate content. There was variation in the inhibitory constituents in the pulse samples after processing and cooking.

Among the processed and cooked samples, there was significant variation among themselves and also with untreated and processed

Table 47. Effect of processing and cooking techniques on the inhibitory constituent of bengalgram (100g) soaked for three hours

Pulses	Without $NaHCO_3$			Pulses	With $NaHCO_3$		
	Protein (g)	Fibre (g)	Phytate (mg)		Protein (g)	Fibre (g)	Phytate (mg)
1. Untreated				**1. Untreated**			
T_1	22.58	3.80	158.03	T_1	22.58	3.80	158.03
2. Processed				**2. Processed**			
$P_6T_2T_4$	28.40	5.20	133.90	$P_6T_3T_4$	27.40	5.40	128.80
$P_6T_2T_5$	27.70	4.70	139.70	$P_6T_3T_5$	26.10	4.90	132.50
$P_6T_2T_6$	26.30	5.00	142.30	$P_6T_3T_6$	25.50	5.20	138.80
3. Processeed and cooked				**3. Processed and cooked**			
$P_6T_2T_4T_7$	22.60	3.58	118.77	$P_6T_3T_4T_7$	22.20	3.97	105.93
$P_6T_2T_4T_8$	22.90	3.83	124.00	$P_6T_3T_4T_8$	22.60	4.00	111.83
$P_6T_2T_4T_9$	22.80	3.62	110.25	$P_6T_3T_4T_9$	22.40	3.83	100.79
$P_6T_2T_4T_{10}$	23.10	3.97	130.37	$P_6T_3T_4T_{10}$	22.80	4.03	124.00
$P_6T_2T_5T_7$	21.70	3.31	123.96	$P_6T_3T_5T_7$	21.50	3.54	110.25
$P_6T_2T_5T_8$	22.06	3.51	127.79	$P_6T_3T_5T_8$	21.80	3.62	117.27
$P_6T_2T_5T_9$	21.80	3.18	117.27	$P_6T_3T_5T_9$	21.70	3.40	105.93
$P_6T_2T_5T_{10}$	22.20	3.62	134.93	$P_6T_3T_5T_{10}$	22.06	3.97	126.78
$P_6T_2T_6T_7$	21.50	3.56	127.79	$P_6T_3T_6T_7$	21.40	3.83	118.77
$P_6T_2T_6T_8$	21.80	3.81	134.93	$P_6T_3T_6T_8$	21.70	3.86	124.00
$P_6T_2T_6T_9$	21.70	3.40	123.96	$P_6T_3T_6T_9$	21.50	3.62	110.25
$P_6T_2T_6T_{10}$	22.06	3.83	138.00	$P_6T_3T_6T_{10}$	21.80	4.00	130.37
SE	0.073	0.028	0.146	SE	0.073	0.028	0.146
CD	0.201	0.076	0.404	CD	0.201	0.076	0.404
F	4.053**	14.955**	150.044**	F	4.053**	14.955**	150.004**

** Significant at 1 per cent level

samples. However, there was no significant variation in protein content between fermented, boiled ($P_6T_2T_5T_7$) and ground, pressure cooked ($P_6T_2T_6T_9$) samples and also between fermented, steamed ($P_6T_2T_5T_8$) and ground, roasted ($P_6T_2T_6T_{10}$) samples. A comparison between fermented pressure cooked ($P_6T_2T_5T_9$) and ground, steamed ($P_6T_2T_6T_8$) samples also revealed similar results.

Fibre content was significantly varying in many samples except between germinated, boiled ($P_6T_2T_4T_7$) and ground, boiled ($P_6T_2T_6T_7$) and also among germinated, steamed ($P_6T_2T_4T_8$) ground, steamed ($P_6T_2T_6T_8$) and ground, roasted ($P_6T_2T_6T_{10}$) samples. A comparison between germinated, pressure cooked ($P_6T_2T_4T_9$) and fermented, roasted ($P_6T_2T_5T_{10}$) samples also revealed similar results.

There was significant variation among the pulse samples when phytate content was analysed except in the case of fermented, boiled ($P_6T_2T_5T_7$) and ground, pressure cooked ($P_6T_2T_6T_9$) samples; between fermented, roasted ($P_6T_2T_5T_{10}$) and ground, steamed ($P_6T_2T_6T_8$) samples.

4.3. The *in vitro* digestibility of carbohydrates in pulses (Table 48)

The *in vitro* digestibility of carbohydrates of six pulses was determined at different intervals and expressed as the quantity of reducing sugar released.

Table 48. *In vitro* digestibility of untreated pulse samples (100 g) (mean values)

Sl. No.	Pulses / Incubation time in min.	mg maltose released per unit enzyme 3	6	9	Rate of α amylolysis in units[1]
1.	Cowpea	23.80	44.60	83.60	50.66
2.	Blackgram	29.20	56.20	94.20	59.86
3.	Redgram	26.40	54.60	92.60	57.86
4.	Greengram	31.60	59.90	96.80	62.76
5.	Soyabean	5.10	18.80	20.90	14.93
6.	Bengalgram	29.50	58.20	96.20	61.30
	F	22.46*			
	CD	7.299			
	SE	2.633			

* Significant at 5 per cent level

1 - One unit of α-amylase activity = 1 mg maltose released / mg enzyme in 3 minutes

In the pulses analysed (Table 48), the *in vitro* digestibility of untreated pulse samples was found to be in the range of 14.93 to 62.76 mg maltose released per unit enzyme. Lowest digestibility was observed in soyabean (14.93 mg maltose) followed by cowpea (50.66 mg maltose), redgram (57.86 mg maltose), blackgram (59.86 mg maltose), bengalgram (61.30 mg maltose) and greengram (62.76 mg maltose).

Statistical treatment of the data revealed that there was significant variation in the *in vitro* digestibility of carbohydrates in the pulses. However there was no significant variation in the rate of alpha-amylolysis of blackgram with redgram, greengram and bengalgram. Similar association was noted in the case of redgram with greengram and bengalgram.

4.3.1. Influence of pretreatments, processing and cooking treatments on the *in vitro* digestibility of carbohydrates of different pulses (Tables 49-51)

Table 49 details the rate of alpha-amylolysis of different kinds of pulses on which different pretreatments, processing and cooking treatments were administered. A comparison of rate of alpha-amylolysis of the final products, after three types of pretreatments revealed that there was no significant variation among the pretreated samples. However lowest digestibility rate was observed in soyabean followed by bengalgram, cowpea, blackgram and greengram in the case of pulse samples soaked for six hours (T_1). In the case of pulse samples soaked for three hours, same trend was observed except in the case of cowpea and bengalgram. Similar results were observed in the pulse samples after processing and cooking treatments.

Influence of processing techniques on the rate of alpha-amylolysis of different pretreated pulses irrespective of the kind is presented in Table 50. This also revealed no significant variation in the

Table 49. Rate of α-amylolysis of different treated pulses (mean values) (mg maltose released per unit enzyme)

Pulses	Untreated	Pre treated samples			Pre treated and processed samples			Pre treated, processed and cooked samples			
	T_1	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_9
Cowpea	50.66	32.62	35.69	39.47	32.87	35.66	39.26	33.85	37.67	31.29	40.90
Blackgram	59.86	41.87	43.74	48.50	43.18	44.30	46.63	47.73	43.86	45.88	41.36
Greengram	62.76	45.00	45.47	51.38	47.48	45.86	48.51	44.73	50.63	45.89	47.89
Soyabean	14.93	22.67	12.10	12.94	23.30	12.01	12.39	16.57	16.34	18.71	11.99
Bengralgram	61.30	31.29	43.34	46.64	34.49	41.97	44.80	39.95	41.43	37.26	43.05
F	22.46^{*}		1.215^{NS}			0.918^{NS}				0.377^{NS}	
SE	2.633		4.561			4.561				5.267	
CD	7.299		12.643			12.643				14.599	

* Significant at 5 percent level

Table 50. Influence of processing on the rate of α-amylolysis of treated pulses (mg maltose released per unit enzyme)

Pretreatments	Processing treatments			Cooking treatments			
	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
T_1	35.63	33.11	35.32	35.38	36.34	34.38	32.66
T_2	34.48	35.41	38.32	35.51	37.09	34.45	37.22
T_3	38.68	39.36	41.32	38.80	40.54	38.58	41.24
F		0.113^{NS}			0.103^{NS}		
CD		9.793			11.308		
SE		3.533			4.080		

Table 51. Influence of different cooking treatments on the rate of α-amylolysis of the pretreated and processed pulses (mg maltose released per unit enzyme)

Processing treatments	Cooking treatments			
	T_7	T_8	T_9	T_{10}
T_4	37.46	38.03	35.72	33.86
T_5	34.92	36.79	34.75	37.38
T_6	37.32	39.15	36.94	39.87
F	0.144^{NS}			
CD	11.308			
SE	4.080			

rate of alpha-amylolysis. Among the different processing treatments administered, fermentation (T_5) was found to have the maximum effect on the starch digestibility followed by grinding (T_6) and germination (T_4), in the case of the pulse samples soaked for six hours. In the case of pulse samples soaked for three hours, germination was found to have the maximum effect followed by fermentation and grinding. Similar trend was observed in a comparison among pretreated and cooked pulse samples on their rate of alpha-amylolysis. Among the different cooking treatments, the roasted samples (T_{10}) had the minimum starch digestibility followed by pressure cooked, boiled and steamed samples while the starch digestibility of pulse samples soaked for less duration was minimum in pressure cooked sample (T_9) followed by boiled, steamed and roasted samples.

In Table 51, a comparison of different cooking treatments on pretreated and processed pulse samples with reference to the rate of alpha-amylolysis is made and the results revealed no significant variation. In the germinated samples, the minimum starch digestibility was observed in roasted samples followed by pressure cooked, boiled and steamed samples. Among the fermented and ground samples, minimum value was for samples cooked under pressure followed by boiled, steamed and roasted samples.

A comparison of cooking treatments alone also revealed no significant variation in the rate of alpha-amylolysis.

4.3.2. Influence of processing and cooking treatments on the *in vitro* digestibility of carbohydrates in cowpea (Tables 52 and 53)

As revealed in Table 52, by processing and cooking treatments, the rate of alpha-amylolysis in cowpea was found to be reduced considerably. There was variation in the rate of alpha-amylolysis in the processed and cooked samples. Among the cooking treatments, pressure cooking and boiling were found to hydrolyse more starch in the cowpea. While steaming as well as roasting methods were found to conserve more maltose.

Statistical analysis of the data revealed that there was no significant variation between the treatments in the rate of alpha-amylolysis.

Table 53 details the rate of alpha-amylolysis in cowpea soaked for three hours with and without $NaHCO_3$. Reduction in soaking duration had been found to conserve more maltose irrespective of the cooking treatments administered.

A comparison between the two samples (soaked for three hours with and without $NaHCO_3$) revealed that there was reduction in the rate of alpha-amylolysis in soaked cowpea samples. Samples soaked with $NaHCO_3$ and cooked by different methods were noted to conserve more maltose, since higher values were observed for all the samples.

Table 52. Effect of processing and cooking techniques on the rate of α-amylolysis of cowpea (100g) soaked for 6 hours

Sl. No.	Pulses / Incubation time in min.	mg maltose released per unit enzyme 3	6	9	Rate of α-amylolysis in units[1]
1. Untreated					
	T_1	23.80	44.60	83.60	50.66
2. Processed and cooked					
1.	$P_1T_1T_4T_7$	9.50	22.60	52.60	28.23
2.	$P_1T_1T_4T_8$	9.80	25.40	53.80	29.66
3.	$P_1T_1T_4T_9$	9.00	20.30	51.90	27.06
4.	$P_1T_1T_4T_{10}$	10.10	27.90	58.10	32.03
5.	$P_1T_1T_5T_7$	9.80	26.70	54.00	30.16
6.	$P_1T_1T_5T_8$	10.50	31.80	58.00	33.43
7.	$P_1T_1T_5T_9$	9.50	24.00	52.80	28.76
8.	$P_1T_1T_5T_{10}$	13.70	33.40	67.40	38.16
9.	$P_1T_1T_6T_7$	10.30	28.50	58.20	32.33
10.	$P_1T_1T_6T_8$	10.90	36.90	66.80	38.20
11.	$P_1T_1T_6T_9$	10.00	26.80	54.10	30.30
12.	$P_1T_1T_6T_{10}$	16.30	41.70	71.20	43.06
	F	0.090 NS			
	CD	19.586			
	SE	7.066			

1-One unit of α-amylase activity = 1 mg maltose released/mg enzyme in 3 minutes

Table 53. Effect of processing and cooking techniques on the rate of α-amylolysis of cowpea (100g) soaked for 3 hours

Without $NaHCO_3$					With $NaHCO_3$				
Pulses / Incubation time in min.	mg maltose released per unit enzyme 3	6	9	Rate of α-amylolysis in units[1]	Pulses / incubation time in min.	mg maltose released per unit enzyme 3	6	9	Rate of α-amylolysis in units[1]
1. Untreated					**1. Untreated**				
T_1	23.80	44.60	83.60	50.66	T_1	23.80	44.60	83.60	50.66
2. Processed and cooked					**2. Processed and cooked**				
$P_1T_2T_4T_7$	9.70	26.60	53.20	29.83	$P_1T_3T_4T_7$	10.30	29.40	65.80	35.16
$P_1T_2T_4T_8$	12.30	31.10	58.00	33.80	$P_1T_3T_4T_8$	13.40	33.80	70.60	39.26
$P_1T_2T_4T_9$	9.30	24.00	51.80	28.36	$P_1T_3T_4T_9$	10.00	28.00	57.50	31.83
$P_1T_2T_4T_{10}$	14.00	32.30	66.30	37.53	$P_1T_3T_4T_{10}$	17.50	35.20	72.20	41.63
$P_1T_2T_5T_7$	10.30	28.70	57.80	32.26	$P_1T_3T_5T_7$	10.80	30.40	70.80	37.33
$P_1T_2T_5T_8$	13.70	33.30	66.50	37.83	$P_1T_3T_5T_8$	14.00	35.00	73.10	40.70
$P_1T_2T_5T_9$	9.80	26.70	53.60	30.03	$P_1T_3T_5T_9$	10.30	29.70	66.40	34.46
$P_1T_2T_5T_{10}$	16.70	34.70	70.70	40.70	$P_1T_3T_5T_{10}$	18.10	36.80	74.20	43.03
$P_1T_2T_6T_7$	10.70	37.60	66.60	38.30	$P_1T_3T_6T_7$	11.20	39.30	72.60	41.03
$P_1T_2T_6T_8$	14.80	41.10	71.10	42.33	$P_1T_3T_6T_8$	15.20	42.20	74.10	43.83
$P_1T_2T_6T_9$	10.40	28.20	58.20	32.26	$P_1T_3T_6T_9$	10.60	31.60	70.20	37.46
$P_1T_2T_6T_{10}$	18.60	43.20	73.20	45.00	$P_1T_3T_6T_{10}$	20.20	44.20	76.40	46.93
F	0.091^{NS}				F	0.091^{NS}			
CD	19.586				CD	19.586			
SE	7.066				SE	7.066			

1 - One unit of α-amylase activity = 1 mg maltose released/mg enzyme in 3 minutes

However when the data was statistically analysed, the results revealed no significant variation among the treatments.

4.3.3. Influence of processing and cooking treatments on the *in vitro* digestibility of carbohydrates in blackgram (Tables 54 and 55)

As revealed in Table 54, by processing and cooking treatments, the rate of alpha-amylolysis in blackgram was found to be reduced considerably. There was variation in the rate of alpha-amylolysis in the processed and cooked samples. Among the cooking treatments, pressure cooking and boiling were found to hydrolyse more starch in the blackgram. While steaming as well as roasting methods were found to conserve more maltose.

Statistical analysis of the data revealed that there was no significant variation between the treatments in the rate of alpha-amylolysis.

Table 55 details the rate of alpha-amylolysis in blackgram soaked for three hours with and without $NaHCO_3$. Reduction in soaking duration had been found to conserve more maltose irrespective of the cooking treatments administered since higher values for the above two variables were observed in all the treatments when compared to the values obtained for the blackgram samples soaked for six hours.

Table 54. Effect of processing and cooking techniques on the rate of α-amylolysis of blackgram (100g) soaked for 6 hours

Sl. No.	Pulses / Incubation time in min.	mg maltose released per unit enzyme 3	6	9	Rate of α-amylolysis in units[1]
1. Untreated					
	T_1	29.20	56.20	94.20	59.86
2. Processed and cooked					
1.	$P_2T_1T_4T_7$	13.20	37.50	62.10	37.60
2.	$P_2T_1T_4T_8$	14.60	39.60	66.70	40.30
3.	$P_2T_1T_4T_9$	11.40	35.00	58.80	35.06
4.	$P_2T_1T_4T_{10}$	15.80	40.70	70.90	42.46
5.	$P_2T_1T_5T_7$	13.40	39.70	70.80	41.30
6.	$P_2T_1T_5T_8$	15.00	41.90	73.00	43.30
7.	$P_2T_1T_5T_9$	11.80	37.60	62.70	37.36
8.	$P_1T_1T_5T_{10}$	16.20	43.20	78.60	46.00
9.	$P_2T_1T_6T_7$	14.20	40.60	73.20	42.66
10.	$P_2T_1T_6T_8$	15.60	42.80	78.40	45.60
11.	$P_2T_1T_6T_9$	12.40	39.10	68.90	40.13
12.	$P_2T_1T_6T_{10}$	17.90	45.90	80.80	48.20
	F	0.091 NS			
	CD	19.586			
	SE	7.066			

1 - Unit of α-amylase activity = 1 mg maltose released/mg enzyme in 3 minutes

Table 55. Effect of processing and cooking techniques on the rate of α-amylolysis of black gram (100 g) soaked for 3 hours.

Without $NaHCO_3$					With $NaHCO_3$				
Pulses / Incubation time in min.	mg maltose released per unit enzyme 3	6	9	Rate of α-amylolysis in units[1]	Pulses / incubation time in min.	mg maltose released per unit enzyme 3	6	9	Rate of α-amylolysis in units[1]
1. Untreated					**1. Untreated**				
T_1	29.20	56.20	94.20	59.86	T_1	29.20	56.20	94.20	59.86
2. Processed and cooked					**2. Processed and cooked**				
$P_2T_2T_4T_7$	15.20	35.50	67.50	39.40	$P_2T_3T_4T_7$	16.10	45.60	77.90	46.53
$P_2T_2T_4T_8$	15.80	37.60	71.20	41.53	$P_2T_3T_4T_8$	16.60	46.40	80.50	47.83
$P_2T_2T_4T_9$	14.90	34.20	61.50	36.86	$P_2T_3T_4T_9$	15.20	43.60	73.10	43.96
$P_2T_2T_4T_{10}$	16.20	39.80	73.40	43.13	$P_2T_3T_4T_{10}$	17.50	48.30	84.10	49.96
$P_2T_2T_5T_7$	15.30	40.90	73.20	43.13	$P_2T_3T_5T_7$	16.60	46.20	81.20	48.00
$P_2T_2T_5T_8$	16.00	42.60	78.00	45.53	$P_2T_3T_5T_8$	17.40	47.50	83.90	49.60
$P_2T_2T_5T_9$	14.00	39.70	71.30	41.66	$P_2T_3T_5T_9$	15.50	45.00	78.00	46.16
$P_2T_2T_5T_{10}$	17.40	44.80	80.80	47.66	$P_2T_3T_5T_{10}$	18.60	49.50	85.50	51.20
$P_2T_2T_6T_7$	15.80	45.10	78.40	46.43	$P_2T_3T_6T_7$	17.50	49.10	82.50	49.70
$P_2T_2T_6T_8$	16.40	46.70	81.20	48.10	$P_2T_3T_6T_8$	18.40	50.20	84.80	51.13
$P_2T_2T_6T_9$	14.30	42.00	73.50	43.26	$P_2T_3T_6T_9$	16.20	46.30	80.60	47.70
$P_2T_2T_6T_{10}$	18.20	48.20	84.30	50.23	$P_2T_3T_6T_{10}$	20.50	52.60	88.70	53.93
F	0.091^{NS}				F	0.091^{NS}			
CD	19.586				CD	19.586			
SE	7.066				SE	7.066			

1-One unit of α-amylase activity = 1 mg maltose released/mg enzyme in 3 minutes

A comparison between the two samples, revealed that there was reduction in the rate of alpha-amylolysis in soaked blackgram samples. Samples soaked with $NaHCO_3$ and cooked by different methods were noted to conserve more maltose since higher values were observed for all the samples.

However when the data was statistically analysed, the results revealed no significant variation among the treatments.

4.3.4. Influence of processing and cooking treatments on the *in vitro* digestibility of carbohydrates in redgram (Tables 56 and 57)

As revealed in Table 56, by processing and cooking treatments, the rate of alpha-amylolysis in redgram was found to be reduced considerably from 57.86 mg maltose released per unit enzyme. Variation in the rate of alpha-amylolysis in the processed and cooked samples were similar to the findings observed in cowpea and blackgram samples.

Statistical analysis of the data revealed that there was no significant variation among the treatments in the rate of alpha-amylolysis.

Table 57 details the rate of alpha-amylolysis in redgram soaked for three hours with and without $NaHCO_3$. Reduction in soaking duration had been found to conserve more maltose irrespective of the cooking treatments administered.

Table 56. Effect of processing and cooking techniques on the rate of α-amylolysis of red gram (100 g) soaked for 6 hours.

Sl. No.	Pulses / Incubation time in min.	mg maltose released per unit enzyme 3	6	9	Rate of α-amylolysis in units[1]
1. Untreated					
	T_1	26.40	54.60	92.60	57.86
2. Processed and cooked					
1.	$P_3T_1T_5T_7$	12.40	37.70	71.20	40.43
2.	$P_3T_1T_5T_8$	12.90	39.80	73.40	42.03
3.	$P_3T_1T_5T_9$	12.00	37.20	63.30	37.50
4.	$P_3T_1T_5T_{10}$	14.80	42.80	78.50	45.36
5.	$P_3T_1T_6T_7$	14.60	40.20	73.70	42.83
6.	$P_3T_1T_6T_8$	16.40	42.40	78.60	45.80
7.	$P_3T_1T_6T_9$	14.20	38.60	69.20	40.66
8.	$P_3T_1T_6T_{10}$	16.9	44.7	80.7	47.43
	F	5.905 NS			
	CD	51.79			
	SE	18.22			

1-One unit of α-amylase activity = 1 mg maltose released/mg enzyme in 3 minutes.

Table 57. Effect of processing and cooking techniques on the rate of α-amylolysis of red gram (100 g) soaked for 3 hours.

Without $NaHCO_3$					With $NaHCO_3$				
Pulses / Incubation time in min.	mg maltose released per unit enzyme 3	6	9	Rate of α-amylolysis in units[1]	Pulses / incubation time in min.	mg maltose released per unit enzyme 3	6	9	Rate of α-amylolysis in units[1]
1. Untreated					**1. Untreated**				
T_1	26.40	54.60	92.60	57.86	T_1	26.40	54.60	92.60	57.86
2. Processed and cooked					**2. Processed and cooked**				
$P_3T_2T_5T_7$	16.60	41.30	73.00	43.63	$P_3T_3T_5T_7$	18.00	45.90	80.70	48.20
$P_3T_2T_5T_8$	17.10	42.60	78.20	45.96	$P_3T_3T_5T_8$	18.40	46.80	82.80	49.33
$P_3T_2T_5T_9$	16.00	39.40	71.20	42.20	$P_3T_3T_5T_9$	17.20	43.30	77.90	46.13
$P_3T_2T_5T_{10}$	17.60	45.10	81.60	48.10	$P_3T_3T_5T_{10}$	18.90	48.20	84.40	50.50
$P_3T_2T_6T_7$	16.20	42.20	78.10	45.50	$P_3T_3T_6T_7$	18.20	46.50	82.60	49.10
$P_3T_2T_6T_8$	17.00	44.50	81.50	47.66	$P_3T_3T_6T_8$	18.70	47.40	84.20	50.10
$P_3T_2T_6T_9$	15.70	41.60	73.20	43.50	$P_3T_3T_6T_9$	17.60	44.20	80.50	47.43
$P_3T_2T_6T_{10}$	18.50	46.90	83.80	49.73	$P_3T_3T_6T_{10}$	20.60	50.20	86.70	52.50
F	5.905^{NS}				F	5.905^{NS}			
CD	51.79				CD	51.79			
SE	18.22				SE	18.22			

1-One unit of α-amylase activity = 1 mg maltose released/mg enzyme in 3 minutes.

However, when the data was statistically analysed, the results revealed no significant variation between the treatments.

4.3.5. Influence of processing and cooking treatments on the *in vitro* digestibility of carbohydrates in greengram (Tables 58 and 59)

As revealed in Table 58, by processing and cooking treatments, the rate of alpha-amylolysis in greengram was found to be reduced considerably from 62.76 mg maltose released per unit enzyme. Variation in the rate of alpha-amylolysis in the processed and cooked samples were similar to the findings observed in cowpea, blackgram and redgram.

Statistical analysis of the data revealed that there was no significant variation between the treatments in the rate of alpha-amylolysis.

Table 59 details the rate of alpha-amylolysis in greengram soaked for three hours with and without $NaHCO_3$. Reduction in soaking duration had been found to conserve more maltose irrespective of the cooking treatments administered.

Samples soaked with $NaHCO_3$ and cooked by different methods were also noted to conserve more maltose. However when the data was statistically analysed, the results revealed no significant variation between the treatments.

Table 58. Effect of processing and cooking techniques on the rate of α-amylolysis of green gram (100 g) soaked for 6 hours

Sl. No.	Pulses / Incubation time in min.	mg maltose released per unit enzyme 3	6	9	Rate of α-amylolysis in units[1]
1. Untreated					
	T_1	31.60	59.90	96.80	62.76
2. Processed and cooked					
1.	$P_4T_1T_4T_7$	10.60	36.50	73.80	40.30
2.	$P_4T_1T_4T_8$	10.90	37.10	76.20	41.40
3.	$P_4T_1T_4T_9$	10.40	36.00	70.40	38.93
4.	$P_4T_1T_4T_{10}$	15.00	38.40	77.60	43.66
5.	$P_4T_1T_5T_7$	11.00	38.00	76.80	41.93
6.	$P_41T_5T_8$	11.30	38.20	78.20	42.56
7.	$P_4T_1T_5T_9$	10.80	39.70	75.50	42.00
8.	$P_4T_1T_5T_{10}$	15.50	40.10	80.40	45.33
9.	$P_4T_1T_6T_7$	14.8	38.7	80.00	44.50
10.	$P_4T_1T_6T_8$	15.30	40.30	81.20	45.60
11.	$P_4T_1T_6T_9$	11.70	36.20	79.10	42.33
12.	$P_4T_1T_6T_{10}$	16.40	42.50	83.00	47.30
	F	0.091^{NS}			
	CD	19.586			
	SE	7.066			

1-One unit of α-amylase activity - 1mg maltose released/mg enzyme in 3 minutes.

Table 59. Effect of processing and cooking techniques on the rate of α-amylolysis of green gram (100 g) soaked for 3 hours.

Without $NaHCO_3$					With $NaHCO_3$				
Pulses / Incubation time in min.	mg maltose released per unit enzyme 3	6	9	Rate of α-amylolysis in units[1]	Pulses / incubation time in min.	mg maltose released per unit enzyme 3	6	9	Rate of α-amylolysis in units[1]
1. Untreated					**1. Untreated**				
T_1	31.60	59.90	96.80	62.76	T_1	31.60	59.90	96.80	62.76
2. Processed and cooked					**2. Processed and cooked**				
$P_4T_2T_4T_7$	11.20	36.30	76.50	41.33	$P_4T_3T_4T_7$	17.50	47.00	84.60	49.70
$P_4T_2T_4T_8$	11.50	38.80	78.20	42.83	$P_4T_3T_4T_8$	22.30	48.40	86.20	52.30
$P_4T_2T_4T_9$	11.00	36.90	76.20	41.36	$P_4T_3T_4T_9$	13.70	45.20	81.20	46.70
$P_4T_2T_4T_{10}$	17.20	45.60	82.50	48.43	$P_4T_3T_4T_{10}$	20.80	48.80	87.10	52.23
$P_4T_2T_5T_7$	11.40	40.50	80.50	44.13	$P_4T_3T_5T_7$	19.00	47.50	86.70	51.06
$P_4T_2T_5T_8$	11.80	42.00	81.30	45.03	$P_4T_3T_5T_8$	22.80	51.00	89.00	54.26
$P_4T_2T_5T_9$	11.10	39.20	79.20	43.16	$P_4T_3T_5T_9$	17.20	44.50	84.90	48.86
$P_4T_2T_5T_{10}$	17.50	47.30	86.80	50.53	$P_4T_3T_5T_{10}$	22.90	52.20	90.10	55.06
$P_4T_2T_6T_7$	16.20	44.90	83.50	48.20	$P_4T_3T_6T_7$	19.30	49.00	87.30	51.86
$P_4T_2T_6T_8$	18.70	47.80	86.50	51.00	$P_4T_3T_6T_8$	24.90	52.30	90.90	56.03
$P_4T_2T_6T_9$	12.00	42.40	81.30	45.23	$P_4T_3T_6T_9$	17.60	47.50	85.20	50.10
$P_4T_2T_6T_{10}$	20.30	50.30	89.20	53.26	$P_4T_3T_6T_{10}$	25.50	53.50	91.70	56.90
F	0.091^{NS}				F	0.091^{NS}			
CD	19.586				CD	19.586			
SE	7.066				SE	7.066			

1-One unit of α-amylase activity = 1mg maltose released/mg enzyme in 3 minutes

4.3.6. Influence of processing and cooking treatments on the *in vitro* digestibility of carbohydrates in soyabean (Tables 60 and 61)

As revealed in Table 60, by processing and cooking treatments, the rate of alpha-amylolysis in soyabean was found to be reduced considerably from 14.93 mg maltose released per unit enzyme. Variation in the rate of alpha-amylolysis in the processed and cooked samples were similar to the findings observed in the other pulses.

Statistical analysis of the data revealed that there was no significant variation between the treatments in the rate of alpha-amylolysis.

Table 61 details the rate of alpha-amylolysis in soyabean soaked for three hours with and without $NaHCO_3$. Reduction in soaking duration had been found to conserve more maltose irrespective of the cooking treatments administered. Samples soaked with $NaHCO_3$ and cooked by different methods were noted to conserve more maltose. However when the data was statistically analysed, the results revealed no significant variation between the treatments.

4.3.7. Influence of processing and cooking treatments on the *in vitro* digestibility of carbohydrates in bengalgram (Tables 62 and 63)

As revealed in Table 62, by processing and cooking treatments, the rate of alpha-amylolysis in bengalgram was found to be reduced

Table 60. Effect of processing and cooking techniques on the rate of α-amylolysis of soya bean (100 g) soaked for 6 hours.

Sl. No.	Pulses / Incubation time in min.	mg maltose released per unit enzyme 3	6	9	Rate of α-amylolysis in units[1]
1. Untreated					
	T_1	5.10	18.80	20.90	14.93
2. Processed and cooked					
1.	$P_5T_1T_4T_7$	1.60	14.60	16.10	10.76
2.	$P_5T_1T_4T_8$	1.80	15.40	17.50	11.56
3.	$P_5T_1T_4T_9$	1.40	13.80	15.20	10.13
4.	$P_5T_1T_4T_{10}$	2.00	16.20	18.10	12.10
5.	$P_5T_1T_5T_7$	3.30	14.00	15.90	11.06
6.	$P_5T_1T_5T_8$	3.50	14.80	16.70	11.66
7.	$P_5T_1T_5T_9$	2.80	13.50	14.30	10.20
8.	$P_5T_1T_5T_{10}$	4.00	16.60	18.50	13.03
9.	$P_5T_1T_6T_7$	3.60	15.20	16.30	11.70
10.	$P_5T_1T_6T_8$	3.80	16.50	17.20	12.50
11.	$P_5T_1T_6T_9$	3.00	14.00	15.30	10.76
12.	$P_5T_1T_6T_{10}$	4.20	17.40	19.00	13.53
	F	0.091^{NS}			
	CD	19.586			
	SE	7.066			

1-One unit of α-amylase activity = 1mg maltose released/mg enzyme in 3 minutes.

Table 61. Effect of processing and cooking techniques on the rate of α-amylolysis of soyabean (100 g) soaked for 3 hours.

Without $NaHCO_3$					With $NaHCO_3$				
Pulses / Incubation time in min.	mg maltose released per unit enzyme 3	6	9	Rate of α-amylolysis in units[1]	Pulses / incubation time in min.	mg maltose released per unit enzyme 3	6	9	Rate of α-amylolysis in units[1]
1. Untreated					**1. Untreated**				
T_1	5.10	18.80	20.90	14.93	T_1	5.10	18.80	20.90	14.93
2. Processed and cooked					**2. Processed and cooked**				
$P_5T_2T_4T_7$	2.40	15.30	16.20	11.30	$P_5T_3T_4T_7$	3.80	15.90	18.10	12.60
$P_5T_2T_4T_8$	2.80	16.10	17.60	12.16	$P_5T_3T_4T_8$	4.10	16.20	18.50	12.93
$P_5T_2T_4T_9$	2.10	15.00	15.80	10.96	$P_5T_3T_4T_9$	3.40	15.60	17.80	12.26
$P_5T_2T_4T_{10}$	3.90	16.60	18.50	13.00	$P_5T_3T_4T_{10}$	4.30	16.50	18.90	13.23
$P_5T_2T_5T_7$	2.80	15.80	16.70	11.76	$P_5T_3T_5T_7$	3.90	16.40	18.50	12.93
$P_5T_2T_5T_8$	3.10	16.30	17.00	12.13	$P_5T_3T_5T_8$	4.20	16.80	18.80	13.26
$P_5T_2T_5T_9$	2.40	15.40	16.10	11.30	$P_5T_3T_5T_9$	3.70	16.10	18.20	12.66
$P_5T_2T_5T_{10}$	4.20	17.00	19.00	13.40	$P_5T_3T_5T_{10}$	4.50	17.00	19.20	13.56
$P_5T_2T_6T_7$	3.90	16.20	16.90	12.33	$P_5T_3T_6T_7$	4.20	17.10	19.00	13.43
$P_5T_2T_6T_8$	4.20	16.80	17.40	12.80	$P_5T_3T_6T_8$	4.60	17.50	19.50	13.86
$P_5T_2T_6T_9$	3.40	15.90	16.30	11.86	$P_5T_3T_6T_9$	4.00	16.80	18.40	13.06
$P_5T_2T_6T_{10}$	4.50	17.40	19.30	13.73	$P_5T_3T_6T_{10}$	4.80	18.00	19.70	14.16
F	0.091^{NS}				F	0.091^{NS}			
CD	19.586				CD	19.586			
SE	7.066				SE	7.066			

1-One unit of α-amylase activity = 1mg maltose released/mg enzyme in 3 minutes

Table 62. Effect of processing and cooking techniques on the rate of α-amylolysis of bengal gram (100 g) soaked for 6 hours.

Sl. No.	Pulses / Incubation time in min.	mg maltose released per unit enzyme 3	6	9	Rate of α-amylolysis in units[1]
1. Untreated					
	T_1	29.50	58.20	96.20	61.30
2.	**Processed and cooked**				
1.	$P_6T_1T_4T_7$	12.80	34.00	68.80	38.53
2.	$P_6T_1T_4T_8$	13.20	35.40	71.40	40.00
3.	$P_6T_1T_4T_9$	12.20	32.20	60.90	35.10
4.	$P_6T_1T_4T_{10}$	13.70	37.70	73.80	41.73
5.	$P_6T_1T_5T_7$	13.10	36.40	71.30	40.26
6.	$P_6T_1T_5T_8$	13.50	38.20	77.40	43.03
7.	$P_6T_1T_5T_9$	12.60	34.20	62.80	36.53
8.	$P_6T_1T_5T_{10}$	14.00	40.50	78.20	44.23
9.	$P_6T_1T_6T_7$	13.60	39.70	76.40	43.23
10.	$P_6T_1T_6T_8$	13.90	40.10	78.10	44.03
11.	$P_6T_1T_6T_9$	12.60	35.40	69.20	39.06
12.	$P_6T_1T_6T_{10}$	14.20	41.30	82.20	45.90
	F	0.091 NS			
	CD	19.586			
	SE	7.066			

1-One unit of α-amylolysis activity = 1mg maltose released/mg enzyme in 3 minutes.

Table 63. Effect of processing and cooking techniques on the rate of α-amylolysis of bengalgram (100g) soaked for 3 hours

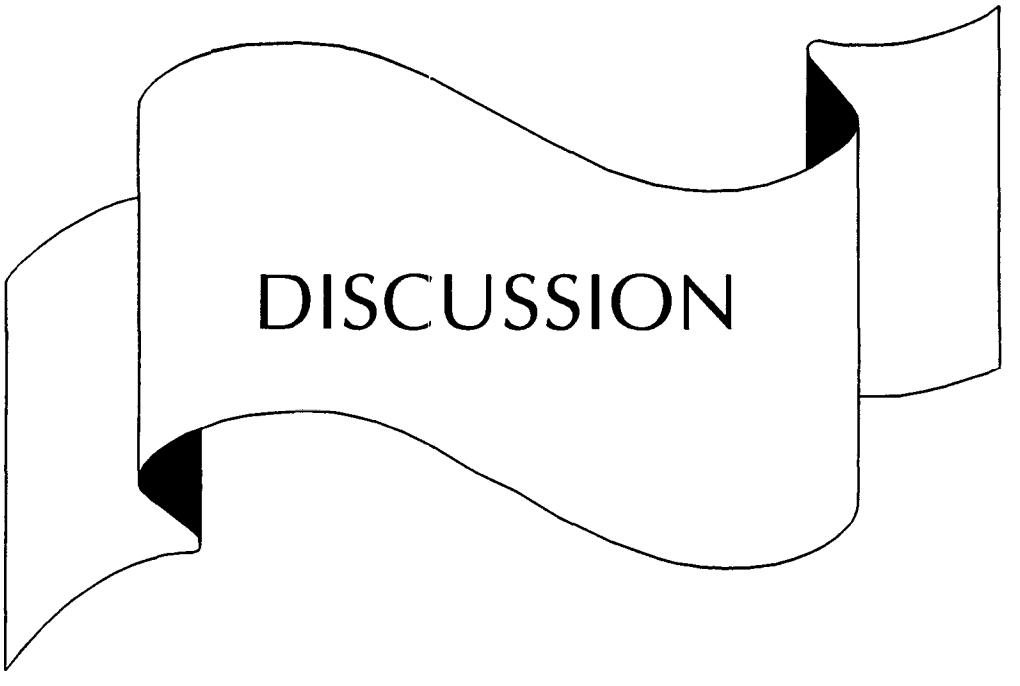
Without $NaHCO_3$					With $NaHCO_3$				
Pulses / Incubation time in min.	mg maltose released per unit enzyme 3	6	9	Rate of α-amylolysis in units[1]	Pulses / incubation time in min.	mg maltose released per unit enzyme 3	6	9	Rate of α-amylolysis in units[1]
1. Untreated					**1. Untreated**				
T_1	29.50	58.20	96.20	61.30	T_1	29.50	58.20	96.20	61.30
2. Processed and cooked					**2. Processed and cooked**				
$P_6T_2T_4T_7$	15.40	39.40	71.20	42.00	$P_6T_3T_4T_7$	16.00	43.60	73.20	44.26
$P_6T_2T_4T_8$	16.00	41.90	72.60	43.50	$P_6T_3T_4T_8$	16.50	44.20	78.10	46.26
$P_6T_2T_4T_9$	15.00	29.90	62.80	35.90	$P_6T_3T_4T_9$	15.70	41.50	69.20	42.13
$P_6T_2T_4T_{10}$	16.10	42.10	78.60	45.60	$P_6T_3T_4T_{10}$	16.80	44.80	84.30	48.63
$P_6T_2T_5T_7$	15.70	39.70	77.80	44.40	$P_6T_3T_5T_7$	17.00	44.00	81.40	47.46
$P_6T_2T_5T_8$	16.00	42.40	81.50	46.63	$P_6T_3T_5T_8$	17.40	46.20	84.20	49.26
$P_6T_2T_5T_9$	15.20	39.20	72.80	42.40	$P_6T_3T_5T_9$	16.60	42.10	78.50	45.73
$P_6T_2T_5T_{10}$	16.40	42.80	83.20	47.46	$P_6T_3T_5T_{10}$	17.80	46.70	86.10	50.20
$P_6T_2T_6T_7$	16.10	40.10	80.30	45.50	$P_6T_3T_6T_7$	17.30	44.40	84.30	48.66
$P_6T_2T_6T_8$	16.50	42.20	82.60	47.10	$P_6T_3T_6T_8$	17.70	46.50	86.00	50.06
$P_6T_2T_6T_9$	15.70	39.20	78.10	44.33	$P_6T_3T_6T_9$	16.90	42.50	81.40	46.93
$P_6T_2T_6T_{10}$	16.80	44.60	84.80	48.73	$P_6T_3T_6T_{10}$	18.00	47.90	87.50	51.13
F	0.091^{NS}				F	0.091^{NS}			
CD	19.586				CD	19.586			
SE	7.066				SE	7.066			

1-One unit of α-amylase activity = 1mg maltose released/mg enzyme in 3 minutes.

considerably from 61.30 mg maltose released per unit enzyme. Variation in the rate of alpha-amylolysis in the processed and cooked samples were similar to the findings observed in other pulses.

Statistical analysis of the data revealed that there was no significant variation between the treatments in the rate of alpha-amylolysis.

Table 63 details the rate of alpha-amylolysis in bengalgram soaked for three hours with and without $NaHCO_3$. Reduction in soaking duration had been found to conserve more maltose irrespective of the cooking treatments administered. Samples soaked with $NaHCO_3$ and cooked by different methods were noted to conserve more maltose. However when the data was statistically analysed, the results revealed no significant variation between the treatments.


DISCUSSION

5. DISCUSSION

The study entitled "Digestibility of carbohydrates in selected pulses" is conducted with the purpose of enlightening the rate of digestibility of starch in pulses as influenced by the nature of starch itself and the interaction of starch with inhibitory constituents like fibre, phytin and protein. Salient findings of the study are discussed under.

5.1. Influence of different processing and cooking treatments on the carbohydrate constituents of pulses

5.2. Influence of different processing and cooking treatments on the inhibitory constituents of pulses

5.3. Influence of different processing and cooking treatments on the *in vitro* digestibility of pulses

5.1. Influence of different processing and cooking treatments on the carbohydrate constituents of pulses (Figures 1 and 2)

In this study, among the pulses analysed, the readily available carbohydrates in the form of sugars were found to be very low as reported earlier by Bhatty and Christison (1984) and Jood *et al.* (1986). Pulses

were also observed to be either poor source of starch or rich in TSS. Greengram and bengalgram were found to have major portion of carbohydrate in the form of starch while it was present mainly as TSS, in cowpea, soyabean, blackgram, and red gram.

Pre treatments like soaking of pulses help to enhance their cooking quality and hydrolyse the starch content.

After soaking for six hours and soaking for three hours with and without $NaHCO_3$, a salient factor related to carbohydrate, observed was reduction in starch and sugar. Among the pulses, the lowest value for starch loss after soaking was observed in soyabean, probably because of low concentration and nature of starch.

Processing such as germination, fermentation, grinding and also cooking caused loss of starch in the pulses (Fig. 1). In this respect, among pulses, the lowest value for starch after processing was observed in soyabean. After cooking, pulses became more viscous resisting swell and rupture.

Among the different cooking treatments, cooking under pressure revealed the greatest effect on the reduction of starch. Processing pulses brought about favourable nutritional changes including hydrolysis of starch.

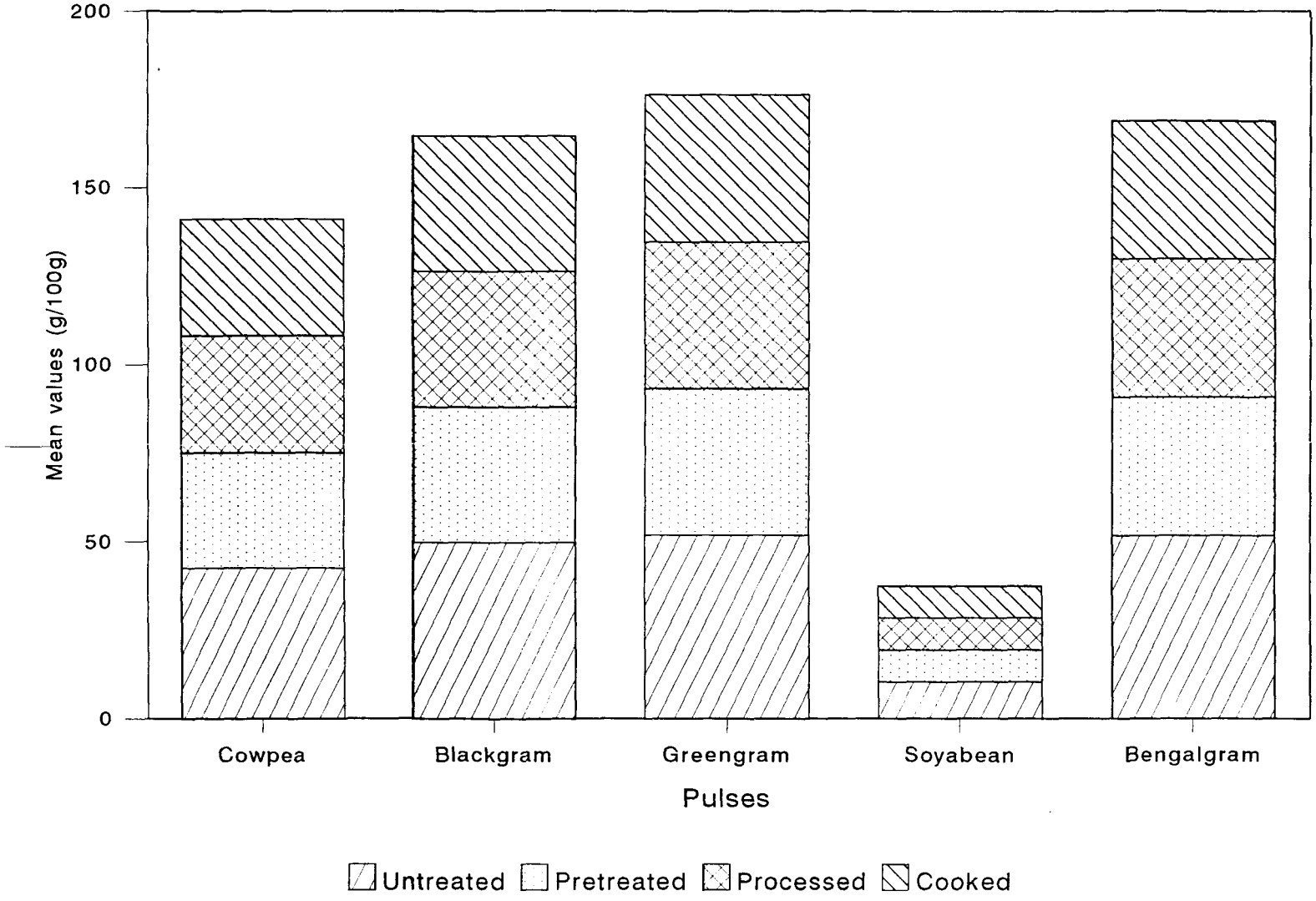


Fig. 1. Starch content of different treated pulses

The highest reduction in starch level was observed in germinated samples after cooking, while retention of starch content of the ground samples after different cooking treatments were comparatively higher.

Duration of soaking is found to have an influence on processing also. Pulse samples soaked for six hours revealed percentage degradation of starch in the order of germination, fermentation and grinding. Probably, because that duration for soaking has a direct effect on the leaching of carbohydrate constituents in pulses. As a result, pulses soaked for three hours had higher values for carbohydrate constituents. Addition of $NaHCO_3$ to the soaking medium also indicated leaching of carbohydrate constituents. Similar findings were reported earlier by Kailasapathy and Koneshan (1986), Srivastava *et al.* (1988) and Valverde *et al.* (1992).

Pulse samples soaked for three hours without $NaHCO_3$ when processed resulted in leaching of starch during germination, fermentation and grinding, but to a lesser concentration.

But rate of leaching of starch during grinding was at a higher rate in cowpea and redgram soaked with $NaHCO_3$ for three hours and processed followed by fermentation and germination (only cowpea). But in blackgram, greengram and soyabean, the order was germination, grinding and fermentation. But in bengalgram, the highest percentage reduction in starch was observed in fermentation followed by grinding and

germination. These variations may be due to the difference in the nature of the starch constituents and type of sugars present in different pulses.

A comparison of TSS, RS and NRS contents of different pulses after three types of soaking showed reduction when compared to that of the untreated ones probably soaking caused leaching of soluble sugars except in cowpea and bengalgram. In cowpea, there was a slight increase in TSS after soaking for six hours and three hours without $NaHCO_3$. In bengalgram, after soaking for six hours there was a slight increase in the TSS content. The lowest value for TSS in this context was seen in blackgram. Soaking duration was found to have negligible effect in TSS content of the samples. Presence of $NaHCO_3$ in soaking medium resulted in greater loss of TSS except in blackgram. In blackgram, the lowest value for TSS was for the sample soaked for six hours.

According to Silva and Braga (1982), leaching cannot be the only factor, causing carbohydrate reduction, and the rate of decrease was not commensurate with the duration of soaking. Decrease in oligosaccharides after soaking was observed by Sosulski *et al.* (1982), Jood *et al.* (1985), Kosson and Bakowski (1986) and Richard and Esther (1992).

Processing administered on different pulses were found to enhance their sugar content (Fig. 2). Only in blackgram, reduction in the sugar content was observed. Percentage increase in TSS content was highest in samples germinated followed by fermented and ground samples in all

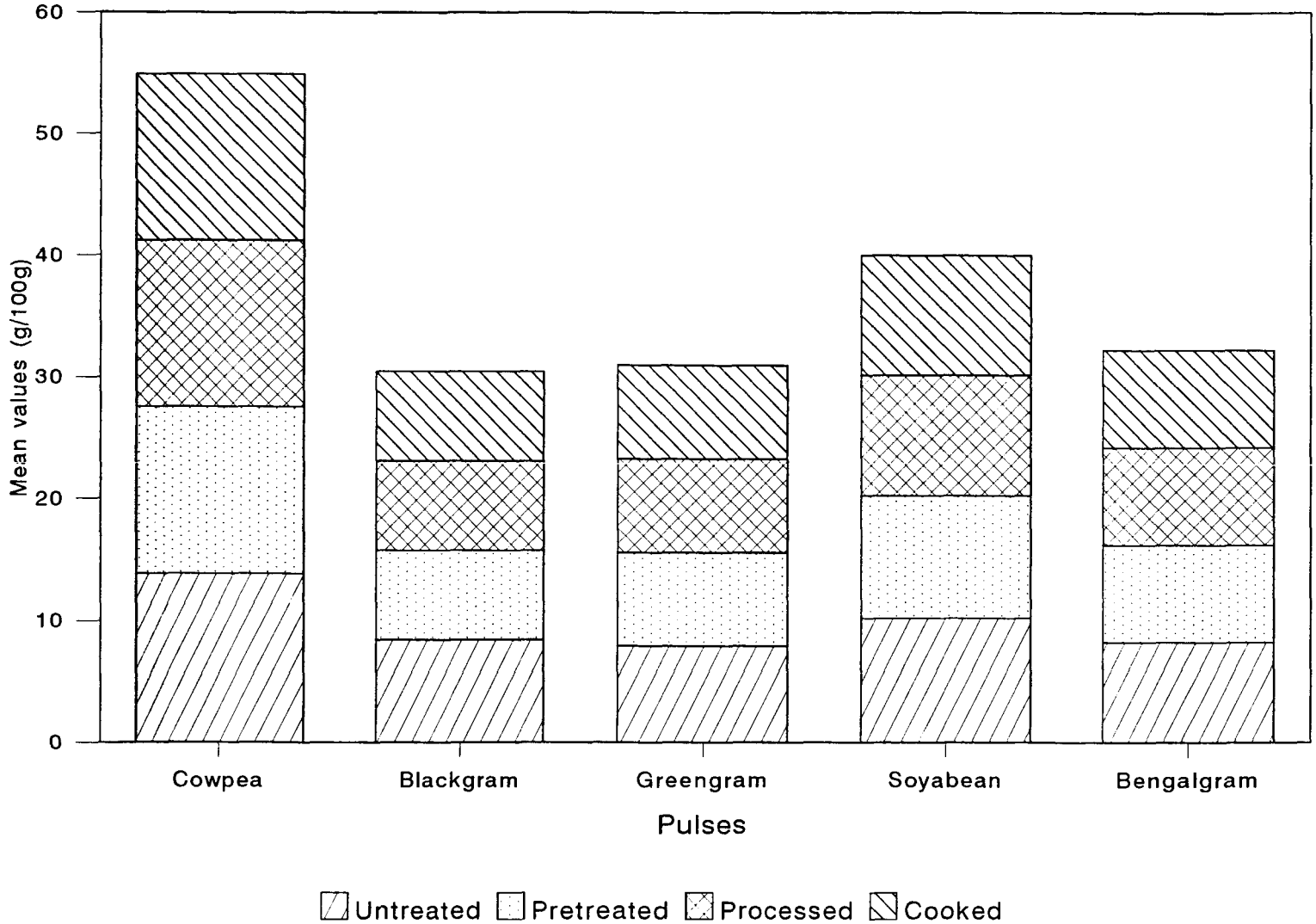


Fig. 2. Total soluble sugar content of different treated pulses

the pulses. While in blackgram, the highest percentage reduction was in the order of grinding followed by fermentation and germination. Similar reduction in carbohydrates has been reported by King and Puwastein (1987), Ejiofar and Oti (1987), Ninanna (1988), Chang *et al.* (1989) and Ninanna and Phillips (1990)

Pulse samples soaked for three hours without $NaHCO_3$ when processed also resulted in enhancement of TSS content. Highest percentage increase in TSS, RS and NRS was observed in germination followed by fermentation and grinding in all the pulses except blackgram and redgram. In blackgram the highest percentage increase was in the order of germination followed by grinding and fermentation. In redgram, the highest percentage increase in TSS was in the order of grinding followed by fermentation.

In bengalgram, the highest percentage increase in RS was in the order of fermentation followed by germination and grinding.

In blackgram, the highest reduction in NRS content was observed in fermented sample followed by ground and germinated samples. In redgram, the highest percentage increase in NRS content was observed in fermented sample followed by ground sample.

Pulse samples soaked for three hours with $NaHCO_3$ when processed also resulted in enhancement of TSS content. Highest percentage increase in TSS was observed in germination followed by

grinding and fermentation in all the pulses except soyabean and bengalgram. In soyabean and bengalgram, the highest percentage increase was observed in the order of germination followed by fermentation and grinding.

According to Jood *et al.* (1986) duration of germination has a direct effect on the TSS losses.

While Sathe *et al.* (1983) and Puwastein and King (1984) and Jood *et al.* (1985) had observed complete disappearance of oligosaccharides in different legumes at two to six days after germination.

In soyabean, germination was observed to be helpful to reduce the objectionable flavour by Vanderstoep (1981).

When pulse samples were soaked for three hours with $NaHCO_3$, reduction in RS content was highest in fermentation followed by germination and grinding in cowpea and greengram except bengalgram, soyabean, redgram, there was increase in RS content after grinding. In redgram, there was increase in RS content after fermentation and grinding. In soyabean, there was reduction in the RS content after processing in the order of grinding, followed by fermentation and germination. In bengalgram when RS content was compared, it was found that there was increase in RS content after grinding followed by fermentation but reduction after germination.

In all the samples soaked for six hours and processed, the lowest value for RS was found for the ground sample. RS content was more in fermented followed by germinated, ground samples in all the pulses except bengalgram. In bengalgram, more RS was found in germinated followed by fermented, ground samples.

According to Jood *et al.* (1986), duration of germination has a direct effect on the losses in the amount of RS in pulses.

The released sugars during germination are observed to be hydrolysed by galactosidase (Reddy and Salunkhe, 1980).

When the samples soaked for six hours were processed the NRS content was of highest percentage in germinated, followed by ground, fermented samples except in redgram, greengram and bengalgram. In greengram and bengalgram, the highest percentage increase in NRS content was observed in germinated samples followed by fermented, ground samples. In redgram, the highest percentage increase in NRS content was observed in fermented samples followed by ground samples.

When the samples were soaked with $NaHCO_3$ for three hours it was found that the highest percentage increase was during germination followed by grinding and fermentation the pulses except blackgram, redgram, soyabean and bengalgram. In blackgram, soyabean and bengalgram, the highest percentage increase was in the order of germination followed by fermentation and grinding. In redgram, NRS

content after processing was reduced in the order of fermentation and then grinding.

A comparison of cooking treatments administered on all the samples of processed pulses revealed the advantages of steaming and roasting methods in retaining the carbohydrate constituents in all the pulses.

TSS, RS, NRS and starch were lowered considerably when the pulse samples were pressure cooked. Goyal and Mathews (1985) had also reported similar findings. Studies of Kosson and Bakowski (1986), Ogun *et al.* (1989) and Richard and Esther (1992) strengthen these findings indicating the profound influence of temperature on the rate of losses of carbohydrate constituents.

As stated by Jacorzynski *et al.* (1981) decomposition of complex carbohydrate during cooking may be responsible for the appearance of new sugar compounds. Findings of Onigbinde and Akinyele (1983) had indicated that a mean decrease of 46 per cent and 50 per cent in stachyose and raffinose content of 20 cowpea varieties after 45 minutes cooking supports this hypothesis. O'Dea and Wong (1983) had reported that grinding the lentils before cooking resulted in a five - fold increase in the rate of starch hydrolysis during cooking. However Price *et al.* (1988) had observed that cooking alone will not be sufficient to bring about any significant reduction in the flatulence inducing activity of cowpea.

5. 2. Influence of different processing and cooking treatments on the inhibitory constituents of pulses

5.2.1. Inhibitory constituents in untreated pulses

Before ascertaining the influence of different processing and cooking treatments on the inhibitory constituents of pulses, the distribution of inhibitory constituents in untreated pulse samples were ascertained. Pulses are considered to be good sources of protein eventhough along with fibre and phytate, it inhibits the digestion of pulses. In the pulses analysed, the constituents like protein (22.23 g per cent to 42.70 g per cent), fibre (1.60 g per cent to 13.29 g per cent) and phytate (130.50 mg per cent to 377.94 mg per cent) were found high.

Kochar and Sharma (1991) had reported the per cent concentration of total dietary fibre in whole legumes as ranging from 12.50 to 12.83 g per cent. Goonerathne *et al.* (1994) had found the fibre content of mungbean flour and blackgram flour as 12.20 and 14.20 per cent respectively. Adeyeye *et al.* (1994) had observed that the fibre content of three different coloured African yambeans 6.00 per cent.

Phytic acid accounts for about 80 per cent of the total phosphorus in most legumes seeds (Chitra and Vimala, 1996).

In the present study, among the different pulses analysed, soyabean was found to have the highest protein content followed by greengram,

blackgram, bengalgram, cowpea and redgram. While fibre content was higher in blackgram followed by soyabean, cowpea, greengram, bengalgram and redgram. Phytate content was highest in cowpea followed by blackgram, greengram, redgram, bengalgram and soyabean.

5.2.2. **Influence of processing and cooking techniques on the inhibitory constituents of different pulses** (Figures 3, 4 and 5)

Different processing and cooking treatments had an influence on the inhibitory constituents of pulses. The protein content of the pulses in general were found to enhance after pretreatments (Fig. 3).

Processing is observed to improve the protein quality of legumes significantly (Usha *et al.*, 1981). According to Goyal and Mathews (1985), there was significant decrease in protein content in pulses after processing. Singh (1986) had reported that in pulses, the proteins are presented in the cotyledons and thus are not much wasted during processing.

In this experiment, soaking with $NaHCO_3$ resulted in a reduction in protein. Probably because of leaching of protein while soaking without $NaHCO_3$ had no such effect.

A comparison among the three processing methods revealed protein enhancement was in high order in germinated samples followed by fermented and ground samples.

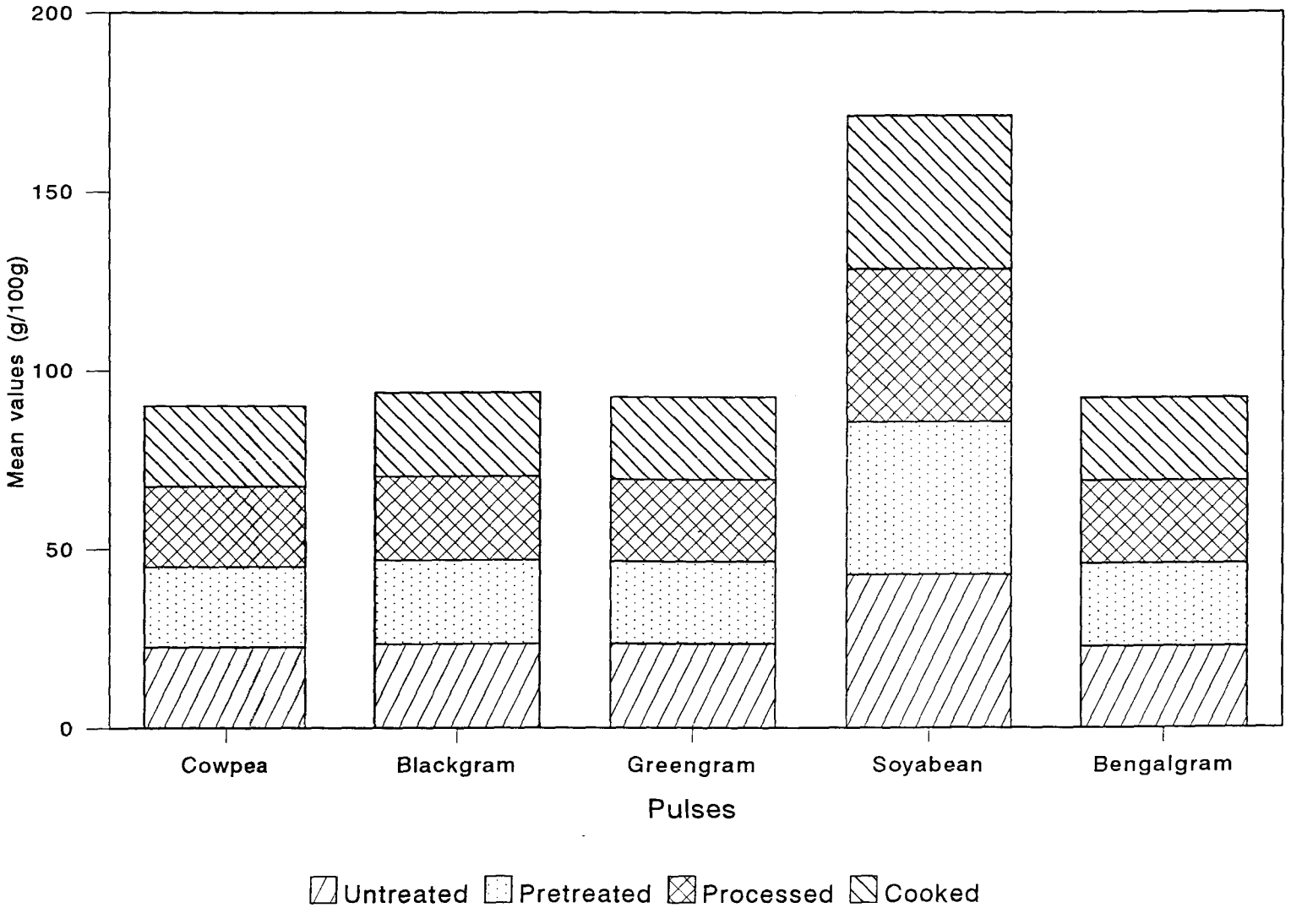


Fig. 3. Protein content of different treated pulses

Germination was found to have no advantage over moist heat methods in improving biological quality of protein as reported by Geervani and Theophilus (1980). However germination is reported to cause an increase in the protein content of legumes as reported by Fordham *et al.* (1975), Hsu *et al.* (1980) and Khaleque *et al.* (1985). According to Lee (1986), the average relative nutritive value of protein increased by 11 per cent during fermentation.

A comparison of cooking treatments administered on all the samples revealed the advantages of steaming and roasting methods in retaining the protein. However boiling caused reduction in protein followed by pressure cooking probably because of the vigorous shaking of the pulse samples during cooking. This was contradictory to Burns's (1987) results that the nutritive value of phaseolus bean protein is enhanced by thermal processing by moist heat treatments.

While Pushpamma and Rao (1983) had reported a negative correlation between cooking time and protein content. Boiling of soaked pulses is observed to cause maximum reduction in protein content (Ku, 1973; Meiners *et al.*, 1976 ..; Phillip, 1996).

While Tuan and Phillips (1992) reported that boiling cowpea seeds improved both overall and protein quality when compared to raw seeds.

Among the pretreated and boiled samples, the lowest protein content was observed for the samples soaked with $NaHCO_3$ for three hours

and the highest for the samples soaked for six hours. Ground and boiled samples showed the lowest protein content and the highest protein content was observed for the germinated samples.

During germination, percentage of protein in raw seeds was found to increase as reported by Moron *et al.* (1985). Arulmozhi and Janardhan (1995) had reported that during germination of the seed, stored proteins are degraded to simpler constituents and mobilized. Phillip (1996) had also reported that germination caused an increase in availability of protein in cowpea and greengram.

The increased nutritional value after germination may be the result of an increased accessibility of bean proteins to enzymatic attack (Romero and Ryan, 1978). In general, processing improved the protein quality of legumes significantly (Usha *et al.*, 1981).

Among the cooking treatments, roasting was found to conserve more protein, the highest in germinated samples and the lowest in the ground samples. The findings related to cooking treatments also indicated that high temperature has resulted in leaching of protein which dissolved in the medium. Probably this may be due to certain chemical changes in the protein content of pulses.

Phrike and Jadhav (1982) studied about the various agents employed to solubilize the bean proteins and had found that NaOH extracted the maximum protein. It may possibly be the reason for

obtaining the lowest value for samples soaked with $NaHCO_3$. Bakr and Gawish (1990) had also reported that soaking slightly increased protein content of mungbean.

Reduction in protein solubility at a temperature greater than or equal to 90°C was observed by Phillip *et al.* (1988) also.

According to Geervani and Theophilus (1980) processing improved the protein quality of the legumes significantly. Dehulling increased protein content of peas as reported by Igbasan and Guenter (1996).

Different pre treatments processing and cooking treatments were found to have an influence on the fibre content in all the pulses (Fig. 4).

Among the pulse samples, the highest fibre content was observed in blackgram. There was reduction in fibre after pre treatments, processing and cooking. The lowest fibre content was observed in bengalgram. This also indicated a reduction after soaking for six hours. Soaking for three hours with and without $NaHCO_3$ increased the availability of fibre. Fermentation caused reduction of fibre in bengalgram while germination and grinding increased its availability. Among the cooking treatments, roasting slightly increased the fibre content while the other methods brought about its reduction.

After three types of processing, germination of the pre treated samples was found to have the highest fibre content. Among the

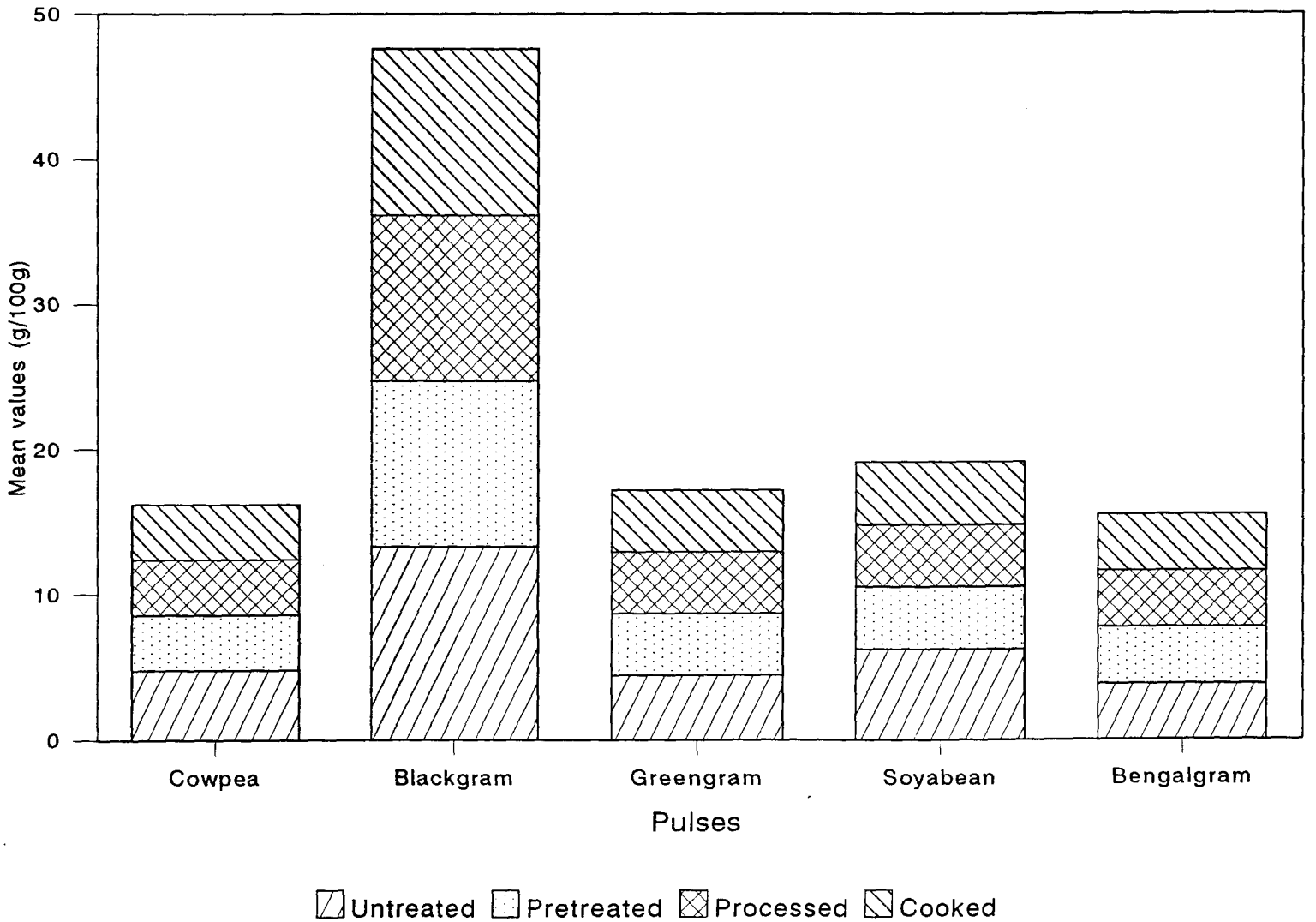


Fig. 4. Fibre content of different treated pulses

germinated samples, the samples soaked with $NaHCO_3$ for three hours revealed to retain fibre most and the lowest was observed for the samples germinated after soaking for six hours.

Among the pre treated samples, cooking under pressure caused maximum reduction of fibre. Samples soaked with $NaHCO_3$ for three hours and cooked had the highest fibre content and the samples soaked for six hours had the lowest fibre after cooking under pressure.

Among the pre treated and processed samples also, cooking under pressure caused maximum reduction in fibre content. Germinated and pressure cooked sample was observed to have the maximum fibre content and fermented and pressure cooked samples was indicated to have the lowest fibre content among the pressure cooked samples.

Effects of different processes were studied on Neutral Detergent Fibre (NDF) and Acid Detergent Fibre (ADF), Cellulose and lignin content of pulses by Valverde and Frias (1991). Raw legumes are known to have a fairly high NDF content and were found influenced by the type of the legumes but also on the processing involved. Igbedioh *et al.* (1994) had also reported similar results.

Analysis of data on pulses revealed that germination, fermentation and grinding were found to enhance the fibre content in all the pulses. Duration for soaking has a direct effect on the leaching of fibre from pulses. Pulses soaked for three hours had higher values for fibre.

A comparison among the three processing methods revealed that in the processed pulse samples, pre soaked for six hours as well as for three hours, the highest percentage retention in fibre was observed in germinated followed by ground and fermented samples in all the pulses.

According to Arti *et al.* (1989), soaking the seeds for 12 hours reduced significantly fibre content in chickpea. According to Kaur and Kapoor (1990) fibre content in greengram decreased with increase in soaking and sprouting time.

A comparison of cooking treatments administered on all the pulses revealed the advantages of steaming and roasting methods in retaining the fibre. Pressure cooking brought about the maximum reduction in the fibre content followed by boiling in all the pulses.

Goonerathne *et al.* (1994) had also reported that processing and cooking of legume seeds resulted in significant degradation of fibre.

The phytate content in the pulses were found to be influenced by different pre treatments, processing and cooking treatments (Fig. 5). Among the pulse samples, the highest phytate content was observed in cowpea. The lowest phytate content was observed in soyabean. Phytate content was observed to a reduce after pre treatments, processing and cooking.

Germinated samples had the lowest phytate content. Among the germinated samples, the samples germinated after soaking for six hours

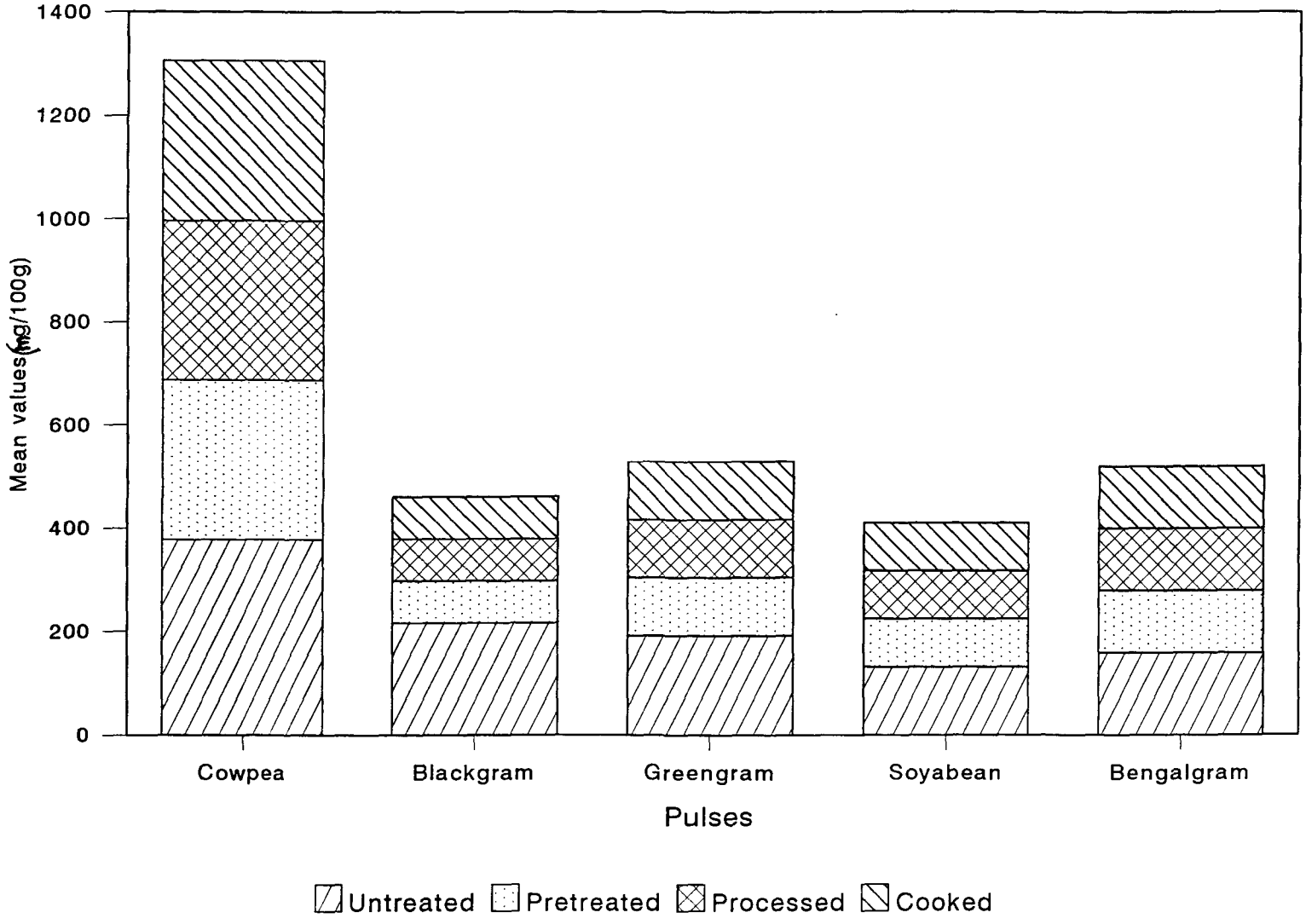


Fig. 5. Phytate content of different treated pulses

were found to have the lowest phytate content and the sample soaked for three hours without $NaHCO_3$ was found to have the highest phytate content. This may be due to the presence of water soluble sodium or potassium phytate in pulses.

Similar results for reduction in phytic acid in the soaked legumes have been reported earlier by Deshpande and Cheryan (1983), Ologhobo and Fetuga (1984) and Khokhar and Chauhan (1986).

During soaking, cowpea requiring long cooking time had decreased phytate (Akinyele *et al.*, 1986). Bishnoi *et al.* (1993) and Igbedioh *et al.* (1994) had reported that soaking lowers the phytic acid content in pulses.

Among the pretreated samples, after cooking the maximum reduction in phytate content was observed in sample cooked under pressure after soaking for six hours and the lowest reduction in phytate was observed in samples cooked under pressure after soaking for three hours without $NaHCO_3$.

Like germination, fermentation and grinding were also found to cause a reduction in phytate content in all the pulses.

A comparison among the three processing techniques in all the pulses samples soaked for six hours revealed the highest percentage reduction in phytate content in the order of germination followed by

fermentation and grinding. Pulses soaked for three hours had higher values for phytate without variation in the order of processing methods.

An important phenomenon in the fermentation of oil seeds and legumes is the break down of phytates, as a result of microbial activity (Parker, 1986). Fermentation of soyabeans into tempeh brought about favourable nutritional changes including reduction in the concentration of phytic acid as reported by Riet *et al.* (1987).

Tongnual (1983) had also observed that whole soyabean fermentation resulted in decrease in phytic acid. Yadav and Khetarpaul (1995) have also noted indigenous fermentation of 35°C for 18 h reduced the level of phytic acid to approximately half. In order to bring significant improvement in the nutritional value and effective utilization of plant foods, it is essential to reduce the concentration of antinutrients (Goyal and Khetarpaul, 1995).

Goyal and Khetarpaul (1995) had found that indigenous fermentation at 35°C for 24 h reduced the phytic acid level to almost half in all the pulse cereal blends. Higher temperature and longer period of fermentation, reduced the phytic acid content further.

A comparison of cooking treatments administered on all the samples revealed the advantages of steaming and roasting methods in retaining the phytate content. The maximum reduction was caused by cooking under pressure followed by boiling.

Among the samples pre treated and processed, germinated sample after cooking under pressure was found to have the least phytate content while the ground sample cooked under pressure had the highest phytate content.

According to Reddy *et al.* (1988), soaking, conventional cooking, quick-cooking, dehulling and germination removed phytate from great Northern Beans.

Bishnoi *et al.* (1994) had reported the loss of 6.00 to 8.00 per cent phytic acid occurred during 12 hours of germination of cowpea which was enhanced with the increase in the period of germination.

Study conducted by Bishnoi *et al.* (1993) revealed that germination (48 h) is the best method followed by pressure cooking and ordinary cooking of soaked dehulled seeds, dehulling and soaking for lowering the levels of phytic acid in vegetable pea. Igbedioh *et al.* (1994) had reported that soaking, soaking, dehulling and boiling, roasting and autoclaving and germination reduced phytic acid in legumes to various extent.

Phytic acid content was found significantly and positively correlated with protein content in chickpea and pigeonpea by Chitra *et al.* (1995).

Attia *et al.* (1994) reported that significant changes in phytic acid were observed due to cooking and decortication in pigeon pea.

According to Beal and Mehta (1985) cooking cowpea resulted in 13 per cent phytate reduction, the major loss appeared to be caused by germination.

5.3. Influence of processing and cooking treatments on the *in vitro* digestibility of carbohydrates in pulses

5.3.1. *In vitro* digestibility of untreated pulses

Enzymes responsible for the breakdown of starch are widely distributed in nature. Among these are the amylases, which act on starch, glycogen and derived polysaccharides to hydrolyse the alpha-1,4-glycosidic linkage (Robyt and Whelan, 1968).

In the present study, pulses untreated as well as treated in different forms were subjected to *in vitro* digestion with alpha-amylase. This enzyme hydrolyses starch to yield maltose.

Among the untreated pulses analysed, the rate of alpha-amylolysis was highest in greengram. These variations among the pulse samples may be due to the presence of amylase inhibitors which is lowest in soyabean. This may be a possible reason for lower rate of starch digestibility in soyabean. Moreover, this quality indirectly indicates, the cooking quality of pulses. Rate of alpha-amylolysis was found to be lower in all the treated and cooked pulses, when compared to untreated and cooked ones, probably because of the partial hydrolysis of starch during processing viz., germination, fermentation and grinding.

5.3.2. Influence of pretreatments, processing and cooking treatments on the *in vitro* digestibility of carbohydrates of different pulses (Fig. 6)

Among the pretreated samples also, the rate of starch digestibility was lowest in soyabean. Duration of soaking may have an influence on rate of starch digestibility. During soaking the grains swell in cold water and in a way increases the rate of digestibility. In this context also, lowest digestibility was seen in soyabean probably because of the thicker outer covering (Fig. 6).

Among the pretreated and processed samples the maximum effect on digestibility was caused by fermentation , followed by grinding and germination in the case of samples soaked for six hours. When the samples soaked for three hours without $NaHCO_3$ was compared, the maximum effect was caused by fermentation followed by germination and grinding. Among the samples soaked for three hours with $NaHCO_3$, the maximum effect was caused by germination followed by fermentation and grinding. $NaHCO_3$ might have influenced the rate of fermentation, probably in a way inhibiting the growth of organisms responsible for fermentation. During grinding starch granules in pulses may be rendered more susceptible to amylases due to the mechanical action (American Association of Cereal Chemists, 1962). As per the findings of this experiment, $NaHCO_3$ is observed to have no effect on the grinding while soaking duration do affect the effect of grinding on digestibility.

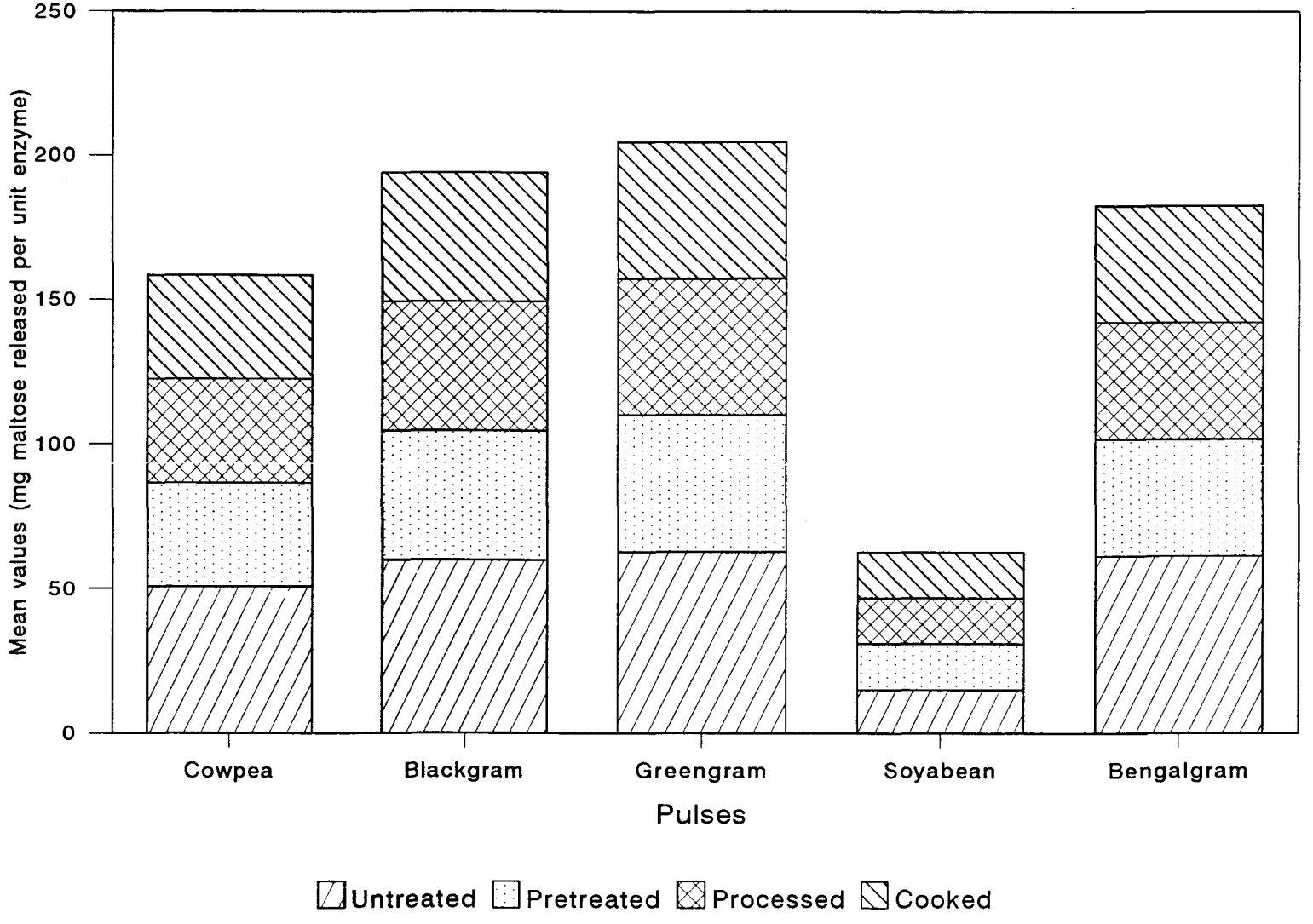


Fig. 6. Rate of alpha-amylolysis of different treated pulses

Among the cooking treatments applied, the rate of starch digestibility during cooking was found to be influenced by the duration of soaking. Soaking duration, if lower, the starch hydrolysis was also observed to be lower. Samples when cooked without water (roasting) were found to have lower rate of starch digestibility. Similarly cooking under pressure also resulted a similar situation. Again among the samples soaked for three hours with and without $NaHCO_3$, the minimum rate of starch digestibility was observed in samples cooked under pressure. In this regard, roasted, boiled as well as steamed samples were found to have higher rates in starch digestibility.

The digestibility of bean starch rapidly is observed to increase with cooking time (Hellendoorn, 1975). As he had observed, after one hour of normal cooking, the starch digestibility is observed to rise to about 85 per cent and after one hour of pressure cooking, the digestibility of beans with good cooking properties went upto about 95 per cent. However the digestibility of starch of beans of poor cooking quality never reaches a high value, not even after pressure cooking.

As stated by Guilbot and Mercier (1985) and Bornet *et al.* (1990) amylose content in the pulses may influence starch digestibility. As the concentration of amylose content increased, starch molecules are observed to be dispersed with greater difficulty thus lowering the availability of starch.

A close relationship had been reported to exist between the degree of gelatinization and rate of starch hydrolysis *in vitro* (Ross *et al.*, 1987). As stated by Ross *et al.* (1987), the greater the starch gelatinization, the easier is the access of alpha-amylase to the starch and rate of digestion and the subsequent, glycemic response.

The slight reduction of viscosity with higher alpha-amylase concentration might indicate increased starch hydrolysis with increased enzyme (Likimani *et al.*, 1991). This may probably be the reason for higher rate of alpha-amylolysis in green gram and bengal gram.

Fermentation is reported to improve the starch digestibility (*in vitro*) in rice-bengal gram dhal mixtures (Sharma and Khetarpaul, 1995). Similar findings were observed in this study also.

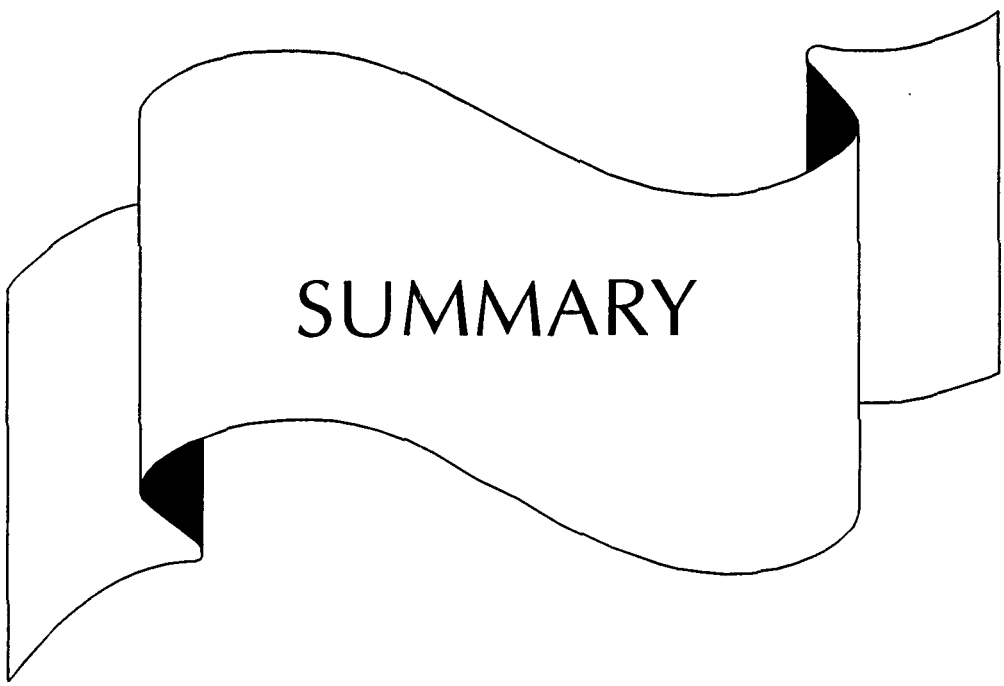
These findings indicated an existence of direct relationship between the cookability of beans and their digestibility.

A comparison of cooking treatments revealed the advantages of steaming and roasting methods. When the rate of alpha-amylolysis in different processed and cooked pulses were compared, it revealed reduction when cooked.

Duration for soaking has a direct effect on the rate of alpha-amylolysis in pulses since pulses soaked for five hours had higher values

for rate of alpha-amylolysis. A comparison of processed and cooked pulse samples revealed reduction when cooked.

The information thus generated on the factors influencing the nature and digestibility of starch in pulses, may help to utilise these food articles in a better way in the daily dietaries if the same is disseminated effectively to the target population.


SUMMARY

SUMMARY

1. The study entitled "Digestibility of carbohydrates in selected pulses" is an assessment of the digestibility of carbohydrates of selected pulses, processed and cooked in different forms. The influence of different processing and cooking techniques on the carbohydrate constituents and inhibitory constituents were also studied.

2. The pulses selected were cowpea, blackgram, redgram, greengram, soyabean and bengalgram. There were untreated samples (T_1), samples soaked for six hours (T_1), soaked for three hours (T_2) and soaked with $NaHCO_3$ for three hours (T_3). Processing techniques administered on the untreated samples as well as pretreated samples were germination (T_4), fermentation (T_5) and grinding (T_6). Cooking treatments administered were boiling (T_7), steaming (T_8), cooking under pressure (T_9) and roasting (T_{10}).

3. Pulses studied were observed to contain carbohydrate constitutes such as starch, Total Soluble Sugars (TSS), Reducing sugars (RS), and Non Reducing sugars(NRS).

4. In the untreated pulses, starch content was found to be in the range of 10.30 g per cent to 51.60 g per cent with the lowest concentration

in soyabean followed by cowpea, blackgram, redgram, bengalgram and greengram. TSS in the untreated pulses were in the range of 7.00 g per cent to 13.86 g per cent on dry weight basis, with the highest concentration in cowpea followed by soyabean, bengalgram, blackgram, greengram and redgram. In all the untreated pulses, the concentration of NRS was higher when compared to RS.

5. A comparison between the untreated and treated pulses revealed significant variation in starch and sugar contents. Among the three processing techniques administered, germinated pulses were observed to retain more starch content, followed by fermented and ground samples. Among the different cooking treatments, cooking under pressure and boiling were found to hydrolyse more carbohydrate constituents. While roasting as well as steaming methods were found to conserve more starch. A comparison of TSS, NRS and RS content of cooked samples also revealed similar trends.

6. Among the processed pulse samples and between processed and cooked samples, there was significant variation in their carbohydrate constituents. However the variations between the pulse samples were not uniformly significant. The TSS, RS and NRS contents of the processed samples were found to be significantly lower, when compared to untreated ones.

7. Reduction in soaking duration had been found to conserve TSS and other carbohydrate constituents irrespective of the cooking

treatments administered. Samples soaked with $NaHCO_3$ were noted to conserve the total carbohydrate constituents more. Addition of $NaHCO_3$ had enhanced the rate of hydrolysis of TSS and RS.

8. Retention of carbohydrate constituents were highest for the ground and roasted samples with significant effect of soaking and addition of $NaHCO_3$.

9. Retention of starch content was high in untreated greengram but TSS content highest in untreated cowpea. But RS content was found highest in pretreated and processed soyabean and NRS content in pretreated and processed cowpea.

10. Proteins along with fibre and phytate are known to inhibit the digestion of pulses.

11. In the untreated pulses analysed, protein content was found to be in the range of 22.23 g per cent to 42.70 g per cent with the lowest concentration in redgram followed by cowpea, bengalgram, blackgram, greengram and soyabean. Fibre in the untreated pulses was in the range of 1.60 g per cent to 13.29 g per cent on dry weight basis with the highest concentration in blackgram, followed by soyabean, cowpea, greengram, bengalgram and redgram. Phytate in the untreated pulses was in the range of 130.50 mg per cent to 377.94 mg per cent with the highest concentration in cowpea followed by blackgram, greengram, redgram, bengalgram and soyabean.

No significant variation in protein content of the pulse samples analysed except in comparison with soyabean was observed. However there was significant variation in the fibre and phytate content in all the pulse samples.

12. Different pretreatments, processing and cooking treatments were found to have an influence on the protein, fibre and phytate content of pulses. The highest protein content was found in pretreated and processed soyabean, and fibre in pretreated, processed and cooked blackgram. But phytate content was highest in untreated cowpea.

13. Among the three processing techniques administered, germinated samples were found to retain more protein than fermented and ground pulses. When fibre was analysed, it was seen that among the three processing techniques administered, germinated sample had the highest value followed by ground and fermented samples. But phytate content was highest in ground sample followed by fermented and germinated samples.

14. There was significant variation in protein, fibre and phytate content of the untreated and treated pulse samples.

15. There was variation in the inhibitory constituents when different cooking treatments were applied. Among the cooking treatments, boiling and pressure cooking were found to hydrolyse more protein, fibre and phytate in the pulses. While steaming and roasting methods were found to conserve more protein, fibre and phytate.

16. Reduction in soaking hours had been found to conserve more fibre and phytate than protein in the pulses irrespective of the cooking treatments administered. A comparison between the samples soaked for three hours with and without $NaHCO_3$ revealed significant variation. Samples soaked without $NaHCO_3$ and cooked by different methods were noted to conserve more protein and phytate while addition of $NaHCO_3$ resulted in the retention of fibre.

17. The *in vitro* digestibility of carbohydrates was determined at different intervals and expressed as the quantity of reducing sugar released.

18. In the untreated pulses, the *in vitro* digestibility was found to be in the range of 14.93 to 62.76 mg maltose released per unit enzyme with the lowest digestibility in soyabean followed by cowpea, redgram, blackgram, bengalgram and greengram.

19. There was significant variation in the *in vitro* digestibility of carbohydrates in pulses. However there was no significant variation in the rate of alpha-amylolysis of blackgram with redgram, greengram, and bengalgram. Similar association was noted in the case of redgram with greengram and bengalgram.

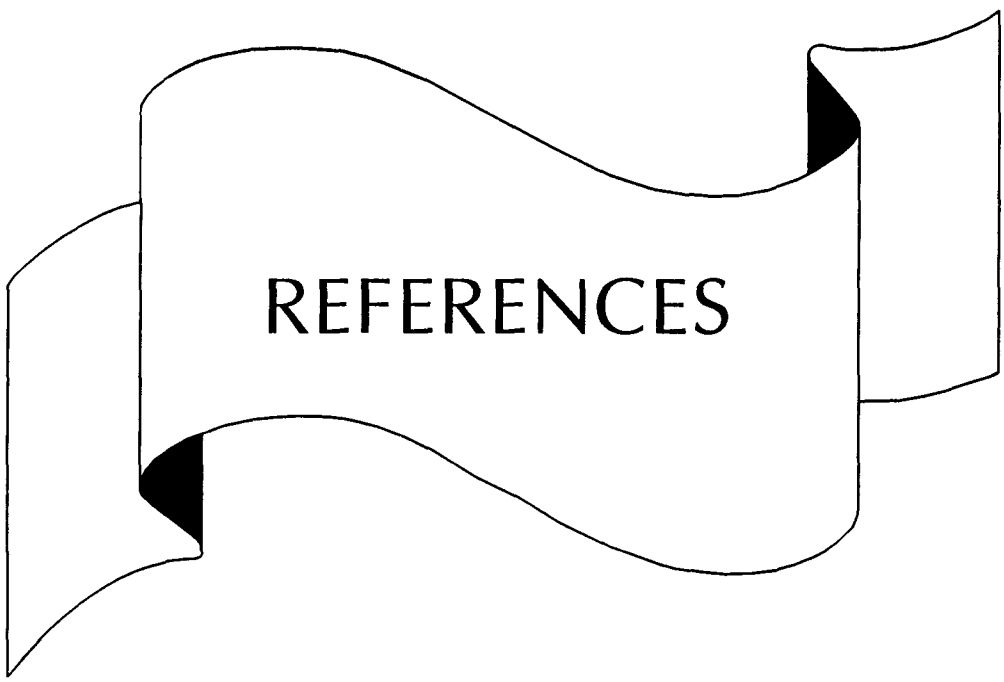
20. Among the three different processing techniques administered, fermentation was found to have the maximum effect followed by grinding and germination on the starch digestibility, in the case of

the pulse samples soaked for six hours. In the case of pulse samples soaked for three hours with $NaHCO_3$, germination was found to have the maximum effect followed by fermentation and grinding. While in the case of samples soaked for three hours without $NaHCO_3$, the maximum effect was caused by fermentation followed by germination and grinding.

21. There was variation in the rate of alpha-amylolysis in the processed and cooked samples.

22. Reduction in soaking duration had been found to conserve more maltose irrespective of the cooking treatments administered. A comparison between the samples soaked with and without $NaHCO_3$ revealed that there was reduction in the rate of alpha-amylolysis in soaked pulse samples. Samples soaked with $NaHCO_3$ and cooked by different methods were noted to conserve more maltose.

23. Among the cooking treatments, pressure cooking and boiling were found to hydrolyse more starch while steaming as well as roasting methods were found to conserve more starch in the pulses.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* Original not seen

DIGESTIBILITY OF CARBOHYDRATES IN SELECTED PULSES

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ABSTRACT OF THE THESIS
SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENT FOR THE DEGREE OF
MASTER OF SCIENCE IN HOME SCIENCE
(FOOD SCIENCE AND NUTRITION)
FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF HOME SCIENCE
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM

1999

ABSTRACT

The study entitled "Digestibility of carbohydrates in selected pulses" is an assessment of the digestibility of carbohydrates of selected pulses, processed and cooked in different forms. The influence of different processing and cooking techniques on the carbohydrate constituents and inhibitory constituents were also ascertained.

The pulses selected were cowpea, blackgram, redgram, greengram, soyabean and bengalgram. The pretreatments administered on the fresh samples were soaking in plain water for six hours (T_1), soaking in plain water for three hours (T_2) and soaking in water with $NaHCO_3$ for three hours (T_3). Processing techniques administered on fresh samples as well as pretreated samples were germination (T_4), fermentation (T_5) and grinding (T_6). Cooking treatments administered were boiling (T_7), steaming (T_8), cooking under pressure (T_9) and roasting (T_{10}).

Among the untreated pulses analysed, the readily available carbohydrates in the form of sugars were found to be very low (7.00 to 13.86 g per cent). Starch content of pulses were ranging from 10.30 g to 51.60 g per cent.

Pretreatments (soaking)were found to influence the starch content. In this study, processing and cooking treatments had a negative influence on the starch content of pretreated pulses. Among the different cooking treatments, cooking under pressure revealed the greatest effect on the reduction of starch.

Pulses soaked for three hours had higher values for carbohydrate constituents.

Processing administered on different pulses were found to enhance their sugar content.

A comparison of cooking treatments administered on all the samples of processed pulses revealed the advantages of steaming and roasting methods in retaining the carbohydrate constituents in all the pulses. TSS, RS, NRS and starch were lowered considerably when the pulse samples were pressure cooked.

In the untreated pulses analysed, the constituents like protein (22.23 g per cent to 42.70 g per cent), fibre (1.60 g per cent to 13.29 g per cent) and phytate (130.50 mg per cent to 377.94 mg per cent) were found high.

Different processing and cooking treatments had an influence on the inhibitory constituents of pulses. The protein content of the pulses in general were found to enhance after pretreatments. However, soaking with $NaHCO_3$ resulted in a reduction in protein.

A comparison among the three processing methods in the pulse samples soaked by all the three methods revealed protein enhancement in the order of germination followed by fermentation and grinding.

A comparison of the cooking treatments revealed the advantages of steaming and roasting methods in retaining the protein. However, boiling caused reduction in protein followed by cooking under pressure probably because of the vigorous shaking of the pulse samples during cooking.

Different pretreatments, processing and cooking treatments were found to have an influence on the fibre content in all the pulses. There was reduction in fibre after pretreatments, processing and cooking. Samples soaked with $NaHCO_3$ for three hours and cooked had the highest fibre content and the samples soaked for six hours had the lowest fibre after cooking under pressure.

The phytate content in the pulses were found to be influenced by pretreatments, processing and cooking treatments. Germinated samples had the lowest phytate content. Among the germinated samples, the samples germinated after soaking for six hours indicated to have the lowest phytate content and the sample soaked for three hours without $NaHCO_3$ was found to have the highest phytate content.

Cooking under pressure brought the maximum reduction in phytate content in all the pulses.

In the present study, pulses untreated as well as treated in different forms were subjected to *in vitro* digestion with alpha-amylase. This enzyme hydrolysis starch to yield maltose.

Among the untreated pulses analysed, the rate of alpha-amylolysis was highest in greengram and lowest in soyabean.

Among the pretreated samples also, the rate of starch digestibility was lowest in soyabean.

Among the pretreated and processed samples, the maximum effect on digestibility was caused by fermentation in the case of samples soaked for six hours. When the samples soaked for three hours without $NaHCO_3$ was compared, the maximum effect was caused by fermentation followed by germination and grinding. Among the samples soaked for three hours with $NaHCO_3$, the maximum effect was caused by germination followed by fermentation and grinding.

Cooking brought about a reduction in the *in vitro* digestibility of starch the maximum after cooking under pressure. Rate of alpha-amylolysis was found to be lower in all the treated and cooked pulses, when compared to untreated and cooked ones, probably because of the partial hydrolysis of starch during processing *viz.*, germination, fermentation and grinding.