

**EFFECT OF DOMESTIC PROCESSING AND COOKING METHODS ON
NUTRITIONAL VALUE OF PEAS (Pisum sativum)**

**By
SAROJ BISHNOI**

**Thesis submitted to the Haryana Agricultural University in
partial fulfilment of the requirements for the degree of :**

MASTER OF SCIENCE

in

FOODS AND NUTRITION

**College of Home Science
Haryana Agricultural University
Hisar
1991**

**DEDICATED
TO MY
VENERABLE
PARENTS**

ACKNOWLEDGEMENTS

I take this opportunity to express my deep sense of gratitude and heart-felt thanks to my esteemed advisor Dr. (Mrs.) Neelam Khetarpaul, Associate Professor, Department of Foods and Nutrition under whose benevolent and sustained guidance and close supervision I have been able to complete this study. I am also extremely grateful for her sublime suggestions, hearted support, pleasant discussion, incessant forbearance, stimulation, inspiration, constant encouragement, keen interest, constructive criticism and magnanimous help during the course of this investigation and preparation of this manuscript.

The author is indebted to Dr. A.C.Kapoor, Professor and Head, Department of Foods and Nutrition, for his valuable suggestions, timely guidance and constructive criticism at various stages of my study.

My heartfelt and fervent thanks are also due to other advisory committee members Dr. B.M.Chauhan, Dr. R.S.Thakur, Dr.K.S.Dhindsa, for their continuous interest, advice, healthy criticism, constructive comments and lofty suggestions for the improvement of the manuscript and kind help from time to time.

I am immensely indebted to the teaching, research as well as office staff of the Departments of Animal Nutrition and Foods and Nutrition, for their valuable co-operation.

I am also thankful to Dr.N.P.Singh for his help rendered during computer analysis. I also take this opportunity to extend my sincere thanks to Dr.S.S.Khirwar, Dr.K.C.Bishnoi and Dr.G.C.George for their valuable guidance and kind help.

My sincere thanks are due to my dear friends Anju, Binita, Kamlesh, Poonam, Neelam, Usha, Sandeepa, Rakhi and Chetna for their uncountable help, constant inspiration, moral support and encouragement during the entire period of my study.

I am also grateful to my beloved parents, brothers, uncles, aunts, bhabhi, nephew for the moral support and encouragement provided during the entire course of study.

Lastly I want to thank my husband, Dr.H.S.Panwar, Deputy District Attorney, Ambala for the patience shown by him and encouragement rendered and daughter Surbhi for the tremendous understanding exhibited by her for fulfilling this endeavour.

Appreciation is also due to Mr. & Mrs. K.K.Khurana for typing this manuscript.

Saroj Bishnoi

(SAROJ BISHNOI)

CERTIFICATE-I

This is to certify that this thesis entitled, " Effect of domestic processing and cooking methods on nutritional value of peas (Pisum sativum)" submitted for the degree of Master of Science, in the subject of Foods and Nutrition, of the Haryana Agricultural University, is a bonafide research work carried out by Mrs. Saroj Bishnoi under my supervision and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of investigation has been duly acknowledged.

N. Khetarpaul

Dr.(Mrs.) N. Khetarpaul
Assoc. Professor
Deptt. of Foods & Nutrition
I.C.College of Home Science
H.A.U., Hisar

CERTIFICATE -II

This is to certify that this thesis entitled, " Effect of domestic processing and cooking methods on nutritional value of peas (Pisum sativum)" submitted by Mrs. Saroj Bishnoi to the Haryana Agricultural University in partial fulfilment of the requirement for the degree of Master of Science in the subject of Foods and Nutrition, has been approved by the Student's Advisory Committee after an oral examination on the same, in collaboration with an External Examiner.

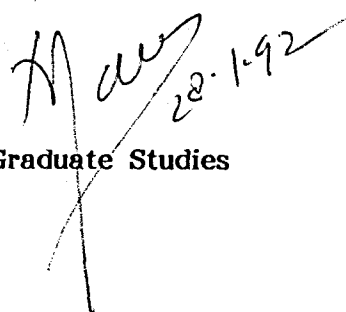
N. Khetarpaul
20.1.92

Major Advisor

an Bhat
20.1.92

External Examiner


Head of the Department


Dean, Post-Graduate Studies

CONTENTS

<u>Chapter</u>		<u>Pages</u>
I	INTRODUCTION	1 - 3
II	REVIEW OF LITERATURE	4 - 47
III	MATERIALS AND METHODS	48 - 71
IV	RESULTS AND DISCUSSION	72 - 178
V	SUMMARY AND CONCLUSION	179 -184
	BIBLIOGRAPHY	i - xxxv

LIST OF TABLES

<u>Table No.</u>	<u>Title</u>	<u>Page</u>
1.	Physico-chemical properties of peas	73
2.	Proximate composition of peas (g/100 g, on dry matter basis)	76
3.	Total soluble sugars (g/100 g), reducing sugars (mg/100 g), non-reducing sugars (g/100 g), starch (g/100 g) and total available carbohydrates content (g/100 g) of peas (on dry matter basis)	78
4.	Effect of soaking and dehulling on phytic acid content of peas (mg/100 g, on dry matter basis)	80
5.	Effect of ordinary cooking on phytic acid content of peas (mg/100 g, on dry matter basis)	82
6.	Effect of autoclaving on phytic acid content of peas (mg/100 g, on dry matter basis)	84
7.	Effect of germination on phytic acid content of peas (mg/100 g, on dry matter basis)	86
8.	Effect of soaking and dehulling on polyphenolic content of peas (mg/100 g, on dry matter basis)	91
9.	Effect of ordinary cooking on polyphenolic content of peas (mg/100 g, on dry matter basis)	94
10.	Effect of autoclaving on polyphenolic content of peas (mg/100 g, on dry matter basis)	95
11.	Effect of germination on polyphenolic content of peas (mg/100 g, on dry matter basis)	97
12.	Effect of soaking and dehulling on saponin of peas (mg/100 g, on dry matter basis)	103
13.	Effect of ordinary cooking on saponin content of peas (mg/100 g, on dry matter basis)	105
14.	Effect of autoclaving on saponin content of peas (mg/100 g, on dry matter basis)	106

<u>Table No.</u>	<u>Title</u>	<u>Page</u>
15.	Effect of germination on saponin content of peas (mg/100 g, on dry matter basis)	108
16.	Effect of soaking and dehulling on trypsin inhibitor activity in peas (TIU/g, on dry matter basis)	114
17.	Effect of ordinary cooking on trypsin inhibitor activity in peas (TIU/g, on dry matter basis)	116
18.	Effect of autoclaving on trypsin inhibitor activity in peas (TIU/g, on dry matter basis)	117
19.	Effect of germination on trypsin inhibitor activity in peas (TIU/g, on dry matter basis)	119
20.	Effect of soaking and dehulling on <u>in vitro</u> starch digestibility of peas (mg maltose released/g meal, on dry matter basis)	125
21.	Effect of ordinary cooking on <u>in vitro</u> starch digestibility of peas (mg maltose released/g meal, on dry matter basis)	126
22.	Effect of autoclaving on <u>in vitro</u> starch digestibility on peas (mg maltose released/g meal, on dry matter basis)	128
23.	Effect of germination on <u>in vitro</u> starch digestibility of peas (mg maltose released/g meal, on dry matter basis) ✓	130
24.	Correlation co-efficients of antinutritional factors with <u>in vitro</u> digestibility of starch	131
25.	Effect of soaking and dehulling on <u>in vitro</u> protein digestibility (%) of peas (on dry matter basis)	137
26.	Effect of ordinary cooking on <u>in vitro</u> protein digestibility (%) of peas (on dry matter basis)	139
27.	Effect of autoclaving on <u>in vitro</u> protein digestibility (%) of peas (on dry matter basis)	140
28.	Effect of germination on <u>in vitro</u> protein digestibility (%) of peas (on dry matter basis) ✓	142
29.	Correlation co-efficients of antinutritional factors with <u>in vitro</u> digestibility of protein	143

<u>Table No.</u>	<u>Title</u>	<u>Page</u>
30.	Effect of soaking on total calcium content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis) ✓	151
31.	Effect of soaking and dehulling on total calcium and phosphorus contents (mg/100 g) and their HCl-extractability (%) in peas (on dry matter basis)	152
32.	Effect of ordinary cooking on total calcium content(mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis)	153
33.	Effect of autoclaving on total calcium content (mg/100 g) and its extractability (%) in peas (on dry matter basis)	154
34.	Effect of germination on total calcium content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis) ✓	155
35.	Effect of soaking on total phosphorus content (mg/100 g) and its HCl-extractability(%) in peas (on dry matter basis)	156
36.	Effect of ordinary cooking on total phosphorus content (mg/100 g) and its HCl-extractability(%) in peas (on dry matter basis)	157
37.	Effect of autoclaving on total phosphorus content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis)	158
38.	Effect of germination on total phosphorus content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis)	159
39.	Effect of soaking on total iron content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis) ✓	160
40.	Effect of soaking and dehulling on total iron and zinc contents (mg/100 g) and their HCl-extractability (%) in peas (on dry matter basis)	161

<u>Table No.</u>	<u>Title</u>	<u>Page</u>
41.	Effect of ordinary cooking on total iron content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis)	162
42.	Effect of autoclaving on total iron content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis)	163
43.	Effect of germination on total iron content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis) ✓	164
44.	Effect of soaking on total zinc content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis)	165
45.	Effect of ordinary cooking on total zinc content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis)	166
46.	Effect of autoclaving on total zinc content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis)	167
47.	Effect of germination of total zinc content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis)	168
48.	Effect of soaking on total copper content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis)	169
49.	Effect of soaking and dehulling on total copper content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis)	170
50.	Effect of ordinary cooking on total copper content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis)	171
51.	Effect of autoclaving on total copper content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis)	172
52.	Effect of germination on total copper content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis)	173

LIST OF ILLUSTRATIONS

<u>No.</u>	<u>Title</u>	<u>Page No.</u>
1.	Effect of soaking (SO) and dehulling (DHL) of peas on phytic acid content.	87
2.	Effect of cooking (CO) of unsoaked, soaked and soaked+dehulled peas on phytic acid content.	88
3.	Effect of autoclaving (Aut) of unsoaked, soaked and soaked+dehulled peas on phytic acid content.	89
4.	Effect of germination (GER) of peas on phytic acid content.	90
5.	Effect of soaking (SO) and dehulling (DHL) of peas on polyphenolic content.	98
6.	Effect of cooking (CO) of unsoaked, soaked and soaked+dehulled peas on polyphenolic content.	99
7.	Effect of autoclaving (Aut) of unsoaked, soaked and soaked+dehulled peas on polyphenolic content.	100
8.	Effect of germination (GER) of peas on polyphenolic content.	101
9.	Effect of soaking (SO) and dehulling (DHL) of peas on saponin content.	109
10.	Effect of cooking (CO) of unsoaked, soaked and soaked+dehulled peas on saponin content	110
11.	Effect of autoclaving (Aut) of unsoaked, soaked and soaked+dehulled peas on saponin content	111
12.	Effect of germination (GER) of peas on saponin content	112
13.	Effect of soaking (SO) and dehulling (DHL) of peas on trypsin inhibitor activity	120
14.	Effect of cooking (CO) of unsoaked, soaked and soaked+dehulled peas on trypsin inhibitor activity	121

<u>No.</u>	<u>Title</u>	<u>Page No.</u>
15.	Effect of autoclaving (Aut) of unsoaked, soaked and soaked+dehulled peas on trypsin inhibitor activity.	122
16.	Effect of germination (GER) of peas on trypsin inhibitor activity	123
17.	Effect of soaking (SO) and dehulling (DHL) of peas on <u>in vitro</u> starch digestibility	132
18.	Effect of cooking (CO) of unsoaked, soaked and soaked+dehulled peas on <u>in vitro</u> starch digestibility	133
19.	Effect of autoclaving (Aut) of unsoaked, soaked and soaked+dehulled peas on <u>in vitro</u> starch digestibility	134
20.	Effect of germination (GER) of peas on <u>in vitro</u> starch digestibility	135
21.	Effect of soaking (SO) and dehulling (DHL) of peas on protein digestibility.	144
22.	Effect of cooking (CO) of unsoaked (UN), soaked and soaked+dehulled peas on protein digestibility	145
23.	Effect of autoclaving (Aut) of unsoaked, soaked and soaked+dehulled peas on protein digestibility	146
24.	Effect of germination (GER) of peas on protein digestibility	147

INTRODUCTION

Food legumes are rich and potential suppliers of several important nutrients. They not only add to the variety in the human diet but also serve as an economical source of supplementary protein for a large chunk of human population, especially in under developed and developing third world countries. In general, grain legumes are rich in lysine, the most limiting amino acid, but are deficient in methionine, thereby complementing the protein quality of the cereals. Legume grains are also recognized as a major source of complex carbohydrates including dietary fibre which is said to lower cholesterol level in blood serum (Anderson and Bridges, 1988). Moreover, legumes have an important place in the diets of Indians as the latter are mostly vegetarian.

In India, the land under pulses was about 22 to 24 million hectares with an annual production of about 11 million tonnes (Deosthale, 1984; Satyapriya, 1989). Traditional pulses like chick pea, pigeon pea, black gram, green gram, lentil etc. are being grown continuously but their yield has been almost static during the last 25 years (Malhotra et al., 1988). Consequently, with increasing population, the per capita availability of pulses has declined sharply.

The daily recommended allowance of pulses in a balanced diet is around 50 g (Gopalan et al., 1984). Diet surveys reveal that in economically poor sections of population, the consumption of food legumes is far below the recommended levels. Thus, there is a growing need for making more of grain legumes available to meet the protein requirements of people (Janoria et al., 1984).

One of the methods of increasing the pulse production to meet the food requirements of growing population is through evolving high yielding

varieties suitable to different environments. Hence, time to time, the Department of Plant Breeding, H.A.U., Hisar, introduces high yielding varieties of legumes. Recently, this Department has released two varieties each of field (HFP4 or Aparna and Rachna) and vegetable (Bonneville and Arkel) peas. The seeds of field peas are round, yellow and smooth whereas these of vegetable peas are green and wrinkled. Field and vegetable peas contain 5 to 6 and 10 to 12 per cent sugar content, respectively; field peas are more starchy and have higher content of antinutritional factors too.

The introduction of pea into primitive agriculture must have taken place rapidly as, alongside cereals, they had become widely used by Greek and Roman times (Cole, 1961). Pea was called 'Pisos' by the Greeks and 'Pisum' by the Romans. When the plant passed on to English it became ' Peason' then 'Pease' or 'Peasse' and finally ' Pea ' (Savage and Deo, 1989). Pea (Pisum sativum) is released for general cultivation in irrigated areas. It grows and matures quickly and is resistant to powdery mildew. Pea offers a bulk source of seed protein for man and his animals from a relatively short growing season when compared with other legumes.

The utilization of food legumes including peas for human nutrition is constrained due to the inherent antinutritional factors like haemagglutinins, trypsin inhibitors, chymotrypsin inhibitors, amylase inhibitors, oxalate content, phytic acid, phenolic compounds, lipo-oxygenase activity, volatile constituents, saponins etc. (Savage and Deo, 1989). Phytic acid, widely distributed in food grains, lowers the bioavailability of minerals (Ali and Harland, 1991) and inhibits proteases and amylases (Deshpande and Cheryan, 1984). Saponins, present in significant amounts in legume grains (Khokhar and Chauhan, 1986;

Jood et al., 1986) impart a bitter taste to the plant foods and cause physiological disturbances and toxicity to the human system (George, 1965; Oakenfull et al., 1979). Polyphenols may lower digestibility of dietary protein (Bressani and Elias, 1980; Hernández et al., 1991) and starch (Thompson and Yoon, 1984) in plant foods. Removal of these antinutrients is, therefore, necessary for effective utilization of food legumes for human nutrition.

In India, legume grains are processed and consumed in a variety of forms, depending on cultural and taste preferences. The most common domestic methods of processing of legumes include soaking, ordinary cooking, pressure cooking, sprouting and fermentation etc., which may bring about changes in the contents of antinutritional factors, digestibility of protein and carbohydrates and bioavailability of minerals which needs to be investigated for considering the ultimate contribution of dry peas in human nutrition.

With this perspective in mind, the present investigation was planned and carried out with the following objectives :

- (i) To assess the nutrient composition of pea varieties
- (ii) To determine the level of antinutritional factors
- (iii) To study the effect of domestic processing and cooking on digestibility and the level of antinutritional factors.

REVIEW OF LITERATURE

Seed legumes are major source of protein and other nutrients in the diets of many developing countries. Pea (Pisum sativum L.) offers a bulk source of seed protein for man and animals from a relatively short growing season when compared with other legumes.

The proximate composition of peas is similar to that of other grain legumes. The seeds contain high levels of protein and digestible carbohydrates and low concentrations of fibre and fat. Peas contain a number of antinutritive factors which may be controlled by suitable processing and breeding programmes. Antinutritive factors are less important in human diets as cooking and processing are normally carried out prior to consumption. Peas have a potential as a protein concentrate and can be processed to produce high protein containing products (Savage and Deo, 1989).

The literature related to nutritive value and effect of domestic cooking and processing on the antinutrients and in vitro digestibility of starch and protein of peas and other legumes has been reviewed under the following headings:

- 2.1 Physico-chemical properties
- 2.2 Nutritive value
 - 2.2.1 Proximate principles
 - 2.2.2 Carbohydrates
- 2.3 Effect of domestic processing and cooking
 - 2.3.1 Antinutritional factors
 - 2.3.1.1 Phytic acid
 - 2.3.1.2 Polyphenols

- 2.3.1.3 Saponin
- 2.3.1.4 Trypsin inhibitor activity
- 2.3.2 In vitro digestibility
 - 2.3.2.1 Starch
 - 2.3.2.2 Protein
- 2.3.3 Minerals
 - 2.3.3.1 Total
 - 2.3.3.2 HCl extractable

2.1 Physico - chemical properties

Physico - chemical parameters such as density, hydration capacity, swelling capacity and cooking time are important parameters which ultimately play an important role in its behaviour for cooking and processing. Williams et al. (1982) evaluated the above properties of chick pea (Cicer arietinum L.) and observed that hydration capacity was highly correlated with seed size. Seed volume and swelling capacity per seed were related to cooking time. Dry seed volume of Kabuli type chick pea was 0.247 ml whereas density 1.29 g/ml. Swelling capacity and hydration capacity were 0.344 ml and 0.356 g, respectively (Williams et al., 1982). According to Ahmad and Shehata (1982) both consumers and processors prefer beans that have high hydration and swelling coefficients. They analysed 93 faba bean samples and observed that hydration coefficient ranged between 161 to 195 and swelling coefficient from 172 to 219. Mubarak et al. (1988) observed that faba beans grown in two different areas of Sudan had 187.2 to 202.6 hydration coefficients.

Soaking grain legumes before cooking can provide many beneficial attributes to the final cooked products. Soaking serves to remove foreign

material, facilitates cleaning of beans, aids in can filling through uniform expansion, ensure product tenderness and improves colour (Cain, 1950; Hoff and Nelson, 1966).

Cooking time is also an important property as most of the legumes require hours for cooking, if not soaked. Cooking time is defined as the time from commencement of boiling until 90 to 100 per cent of seeds are cooked. Muneta (1964) cooked faba beans in boiling water for five different cooking times with 10 minute interval. Cooked seeds were drained and seed coat removed before testing by judges who determined the degree of cooking. Cooking time (CT 50) was calculated as the time when half of the judges considered that beans were cooked or overcooked. Quest and de Silva (1977) employed Kramer press to determine the degree of cooking in faba beans. Singh et al. (1988) observed that soaking reduced the cooking time in faba beans. Cooking time of dry and soaked seeds was highly correlated in faba beans.

Latunde - Dada (1991) reported that swelling capacity and seed density of ten Nigerian soybean varieties ranged from 99.3 to 197.7 per cent and 1.82 to 2.36 g/cm³, respectively.

2.2 Nutritive value

2.2.1 Proximate principles

Legumes have been studied intensively for their nutritional composition and marked variations for total protein, ether extract, crude fibre, iron, total phosphorus and phytin phosphorus etc. as reported in different pulses by earlier workers (Martson and de Omana, 1979; Fleming, 1981; Khokhar, 1984; Kataria, 1986; Kaur, 1986).

Legumes are nutritionally important and good sources of protein which is normally well above twice the level found in cereal grains. The protein content varies from 20 per cent in chick pea to 35 to 40 per cent in soybean (Rao and Subramanian, 1970; Yannai and Zimmermann, 1970; Kadwe et al., 1974).

The proximate composition of pea is similar to that of other grain legumes. The seeds contain high levels of protein and digestible carbohydrates and low concentrations of fibre and fat (Savage and Deo, 1989). The pea protein content ranges from 15.6 to 32.5 per cent (Evans and Boulter, 1980; Deo, 1987; Johns, 1987; Gueguen and Barbot, 1988; and Savage and Deo, 1989).

Meiners et al. (1976) reported 21 per cent protein in raw green split peas which decreased to 7.4 per cent on cooking (boiling). Reichert and Mackenzie (1982) showed a wide variation in the protein content of field peas ranging from 14.5 to 28.5 per cent. Khalil et al. (1986) studied the effect of experimental cooking on the yield and proximate composition of field peas, moth beans and pigeon peas. They observed that crude protein content was 24.5 per cent for field peas (8.5 per cent moisture basis), 27.7 per cent for moth bean (10 per cent moisture basis) and 21.3 per cent for pigeon peas (10 per cent moisture basis).

Renu and Bhattacharya (1989) studied the proximate composition of improved genotype of peas and reported that crude protein content of peas varied from 15.0 to 29.3 per cent. On the whole seed basis, the crude protein content of peas is comparable to other legumes such as lentils and beans (Vicia faba). The wide range of crude protein is the reflection of variation among pea cultivars which is affected by both genetic and environmental factors (Savage and Deo, 1989). Pesola (1955) was unable to correlate the protein content

with the size, weight or the colour of some 30 varieties of peas grown over a series of 6 seasons in Finland. He did note, however that varieties sown later in the season did tend to contain higher levels of crude protein in the seed. Wrinkled seeds contained as much as 3 per cent more protein than smooth seeded peas (Shia and Slinkard, 1977).

The environmental factors responsible for the very wide range in pea protein content are not fully understood. For instance, Ali Khan and Youngs (1973) showed a range of 22 to 32 per cent protein content in field peas. Such information may provide useful germplasm for broadening the genetic base in breeding for high protein cultivars. In addition, McLean et al. (1974) reported that pea protein contents were increased from 20 to 30 per cent by application of nitrogen fertilizer.

According to Pandey and Gritton (1975) crude protein content varied considerably between 9 cultivars of peas. Each cultivar's crude protein content varied between years and between stages of maturity. The crude protein contents of mature peas reported by them are exceptionally high, for instance, cultivar Tiny had a crude protein content of 38.3 per cent in the first experiment and 32.6 per cent in the second. They also reported that the crude protein concentration decreased with increasing pea seed maturity.

Koreleski et al. (1977) confirmed that cooking for 30 minute at 170°C (dry heating) significantly improved the nutritive value of field peas (P. arvense) when compared with same variety given raw. Savage and Deo (1989) found that cooked peas had slightly lower crude protein contents.

Ei - Refai et al. (1987) showed that blanching had very little effect on the protein content of peas; bottling or canning resulted in a 7 to 8 per cent

loss of protein content.

A wide variation in the quantity of protein present in different pulses i.e. lentil, green gram, black gram, pigeon peas, cowpeas, horse gram, moth, lathyrus, french peas, soybean, rice bean and peas etc. has been reported to range from 16.1 per cent in bean (*Phaseolus*) seed to a maximum of 45.2 per cent in soybean (Kapoor, 1972; Bressani, 1973; Evans et al., 1978; Shrivastava and Bajpai, 1981; Ekfenyong and Brochers, 1982; Ologhobo and Fetuga, 1982; Malhotra et al., 1988).

According to Kataria (1986) the crude protein, fat, ash, crude fibre and nitrogen free extract varied from 22.3 to 24.8; 1.7 to 3.3; 2.3 to 3.5; 2.2 to 2.9 and 67.3 to 69.3, respectively, in amphidiploids of green gram and black gram.

Like many other legume seeds, the fat content (ether extract) in pea seed is low ranging from 0.8 to 6.1 per cent (Savage and Deo, 1989). The crude fibre content of pea seeds is also low and ranges from 1.1 to 9.9 per cent. Bramsnaes and Olsen, (1979) reported that Trapper, a field pea variety contained 8.2 per cent testa while Valdebouze et al. (1980) showed that French - grown peas contained between 8.2 and 11.6 per cent testa. According to Savage and Deo (1989) the ash content of raw seeds ranged from 2.4 to 4.1 per cent. A reduction in total ash content occurred on cooking.

2.2.2 Carbohydrates

Carbohydrate concentrations in whole peas ranged from 56.6 to 74.0 per cent and in kernel from 62.8 to 78.6 per cent. Slightly lower levels were found in the cooked samples suggesting small losses in cooking water (Savage and Deo, 1989). They reported that the polysaccharide concentration of peas

was high ranging from 214 to 486 g/kg while amylose content varied from 163 to 658 g/kg in whole raw seed. Higher concentrations of starch (392 to 598 g/kg) were found in the kernel. Kooistra (1962) found that smooth peas contained considerable higher starch contents (440 to 463 g/kg) than wrinkled peas (280 to 337 g/kg). The amylose content of starch of smooth peas was relatively low ranging from 20 to 38 per cent in contrast to wrinkled peas which contained considerably higher levels of amylose ranging from 60 to 75 per cent.

Peas have relatively high concentrations of insoluble carbohydrates. Reichert (1981) reported high concentrations of insoluble carbohydrates (hemicellulose 75.0; lignin 14.0; cellulose 688.0 and crude fibre 584 g/kg) in pea testas. A deficiency of dietary fibre has been implicated in several diseases including diverticular disease of the large bowel and carcinoma of the colon (Burkitt, 1973). Therefore, increased consumption of peas should be further encouraged in the developed countries.

Biliaderis et al. (1981) reported that chain length of amylopectin isolated from smooth peas was (22) which was similar to that found in many other legume starches, while the chain length of amylopectin isolated from wrinkled pea starch was appreciably longer (34). This strongly suggested that the amylopection fraction of wrinkled pea had its own unique structure. In contrast, the mean chain length of amylose isolated from wrinkled peas was shorter than that isolated from smooth peas.

Pea, in common with many other legumes contain high concentrations of alpha - galactosides i.e. raffinose, stachyose and verbascose. The intestinal discomfort of flatulence which follows the consumption of beans has been

associated with these oligosaccharides (Eskin et al., 1980). Various studies indicated that most of the legumes contain 60 per cent carbohydrates which include the raffinose family and are well known for the production of flatus in man and animals (Calloway et al., 1971; Reddy and Salunkhe, 1980). They further reported that carbohydrates from raffinose family such as verbascose, stachyose and raffinose escape digestion due to lack of alpha galactosidase activity in mammalian intestinal mucosa. They are not digested or absorbed in the small intestine. Consequently, bacteria in the large intestine metabolize them to form large amounts of carbondioxide, hydrogen and small amounts of methane.

Fleming (1981) used rats to show that hydrogen produced following ingestion of wrinkled field peas (25 u mol/h) was 1.5 times higher than that produced following consumption of smooth field pea (15.8 u mol/h). Wrinkled field peas contained higher concentrations of raffinose, stachyose and verbascose. Pea seeds contained small concentrations (1.7 g/kg) of galactinal (Sosulski et al., 1982.).

Total soluble sugars, non reducing and reducing sugars varied from 62.5 to 91.3, 38.0 to 72.7 and 10.0 to 24.0 mg/g flour, respectively among amphidiploids and the black gram and green gram parents (Gupta and Wagle, 1980).

Kataria (1986) reported that total soluble, reducing and non-reducing sugars and starch ranged from 7.6 to 9.5; 0.311 to 0.516; 7.2 to 8.9 and 44.0 to 49.0 g/100 g, respectively among amphidiploids and the parents (green gram and black gram).

According to Kaur (1986) the total soluble, reducing, non reducing

sugars, starch and the available carbohydrates content in different varieties of rice bean varied from 3.5 to 5.6; 0.159 to 0.517; 3.4 to 5.3; 52.4 to 55.1 and 57.4 to 60.1 g/100 g, respectively.

Naivikal (1978) analysed the carbohydrates present in flour obtained from navy bean, pinto bean, faba bean and lentil. Starch (50.9 to 52.9 per cent) contents were almost similar for all the five flours. Total sugar contents ranged from 4.99 to 7.22 per cent, reducing sugar from 0.75 to 1.81 per cent, non-reducing sugars from 2.53 to 3.08 per cent and amylose from 15.3 to 19.5 per cent.

Sharma and Pant (1979) found starch to vary from 53 to 59 per cent and soluble sugars from 2 to 4 per cent on dry weight basis in six varieties of pigeon pea (Cajanus cajan).

A small decrease in oligosaccharide content of beans was noticed after soaking them in water and the relative amount was not proportional to the solubility of sugars in water (Silva and Braga, 1982). According to Jacorzynski et al. (1981) soaking and cooking decreased soluble sugars by 16 per cent in peas, 43 per cent in white beans and 80 per cent in soybeans. During soaking and cooking, oligosaccharides were partly decomposed and new sugar compounds appeared. Losses of sugars during soaking could be due to simple diffusion of sugars after getting solubilized. Structure of seed coat may determine the passing out of sugars from seed to the soaking medium. Harder the seed coat, lesser may be the losses of the sugars. The greater losses of sugars during longer period of soaking may be because of enhanced solubility of sugars (Silva and Braga, 1982; Jood et al., 1985; Jood et al., 1988 and Kataria et al., 1990).

Cooking has been reported to cause a significant increase in the oligosaccharide content of all pulses (Rao and Belavady, 1978). However, the increase was the highest in bengal gram and least in green gram. Total sugars were reduced from 78.5 to 52.6 per cent during 40 minute cooking of black gram (Reddy and Salunkhe, 1980). Hydrolysis of starch to oligosaccharides and that of oligosaccharide to monosaccharides, resulting from cooking may be responsible for increased concentration of sugars in the pulses. Hydrolysis of starch as well as oligosaccharides to monosaccharides may perhaps be more effective, thus, accounting for higher concentration of reducing sugars in the seeds (Rao and Belavady, 1978; Kataria et al., 1990). Amylolysis during pressure cooking, just like ordinary cooking, may perhaps be the reason for increased level of sugars of the pulses.

Total soluble carbohydrates and non reducing sugars increased with the progress of germination in chick pea and green gram (Jaya and Venkataraman, 1980). In black gram, total sugar content during 5 days germination period gradually decreased during first 48 h of germination and increased thereafter up to 120 h of germination (Reddy and Salunkhe, 1980). Germination of Phaseolus mungo, Phaseolus mungoreous and Phaseolus aureus for 4 days decreased the soluble and reducing sugars (Gupta and Wagle, 1980). Jood et al. (1985) observed a decrease in non reducing sugars of black gram, bengal gram, red gram and P. vulgaris when these were sprouted for 24 h.

Germination may cause mobilisation and hydrolysis of seed polysaccharides, leading to more available non reducing as well as reducing sugars. Rapid mobilisation might yield significant amount of maltose, a reducing sugar. The longer the period of germination the more may be hydrolysis of starch , thereby

resulting in more release and concentration of soluble sugars. Various workers (Kumar and Venkataraman, 1976; Subbulakshmi et al., 1976; Sharma and Pant 1979; Jood et al., 1985 and Kataria et al., 1990) had reported this phenomenon in different pulses and legumes including chick pea, cowpea, green gram, red gram, kidney bean, black gram, broad bean and bengal gram.

2.3 Effect of domestic processing and cooking

2.3.1 Antinutritional factors

2.3.1.1 Phytic acid

The phytic acid content of peas ranges from 4.7 to 8.2 g/kg (Elkowicz and Sosulski, 1982; Kumar and Kapoor, 1983; Manan et al., 1987). Phytates are widely distributed in plant seeds (de Boland et al., 1975 and Cain, 1950) and significantly influence the functional and nutritional properties of foods. Phytic acid is also considered to be an antinutritional factor in peas (Savage and Deo, 1989). Barre (1965) demonstrated some in vitro inhibition of proteolytic activity by phytic acid.

Phytate (inositol hexaphosphate) is a compound which occurs naturally in many plant foods (Maga, 1982; Reddy et al., 1982) and it binds various essential metals and reduces their availability for absorption from the diet (Cheryan, 1980; Maga, 1982; Reddy et al., 1982; Wise, 1983) and reabsorption after their secretion in digestive juices (Davies and Nightingale, 1975).

The mixed Ca - Mg salt of phytic acid is known as phytin, which reduces the bioavailability of dietary minerals (Davies and Nightingale, 1975; Erdman, 1979), especially zinc (O'Dell, 1969; Cummings, 1978; Davies and Reid, 1979; Daniels and Fisher, 1981). An insoluble Zn-Ca phytate complex is formed in the presence of Ca and Zn at pH 6 (Reddy et al., 1978).

It is thought that this complex which is formed in vitro in the upper gastrointestinal tract of single stomached animals reduces the zinc availability.

Phytic acid also forms insoluble complexes with iron, calcium and copper (Oberleas et al., 1966 and Griffiths and Thomas, 1981). Wise (1983) reported that phytate forms more stable complex with zinc followed by copper, cobalt, manganese and calcium. The effect of phytate on the bioavailability of zinc and some other cations is well established (Maga, 1982).

Phytic acid is a powerful chelating agent for divalent cations such as Ca^{++} , Mg^{++} , Zn^{++} , Fe^{++} , and Fe^{+++} to interfere with mineral availability by the formation of insoluble phytates (Erdman and Forbes, 1977; Reddy and Salunkhe, 1981). Phytic acid can also affect digestibility by chelating with calcium or by binding with substrate or proteolytic enzymes. (Erdman, 1981; Ologhobo and Fetuga, 1982).

Phytic acid is also known to react with proteins forming complex products which have inhibitory effects on the peptic digestion on ovalbumin and elastin. Phytic acid binds to protonated basic residues of protein at acidic pH forming a binary protein - phytate complex. At alkaline pH, in the presence of cations, phytic acid forms a ternary protein mineral - phytate complex (Cheryan, 1980). Such a complex formation is believed to obstruct or inhibit the enzymatic degradation of protein (Ranhotra, 1972; O'Dell and de Boland, 1976; Singh and Krikorian, 1982; Serraino et al., 1985).

Phytates inhibiting action on the activity of digestive proteinases, pepsin (Barre, 1965; Canus and Laporte, 1976; Knuckles et al., 1985) and trypsin (Singh and Krikorian, 1982) was also reported. Phytic acid inhibits proteases and amylases (Singh and Krikorian, 1982; Deshpande and Cheryan, 1984).

The hydrolysis of phytate is catalysed by the enzyme phytase (myo inositol hexaphosphate phosphorylase) to inositol and free orthophosphate. The enzyme has been reported in soybeans, cornseeds, faba beans, mung beans, triticale and wheat (Gibbins and Norris, 1963; Chang, 1967; Sartirana and Bianchetti, 1967; Mandal et al., 1972; Singh and Sedeh, 1979; Michael Eskin and Wiebe, 1983).

Boulter (1982) emphasized the role of phytate in bean hardening. This author demonstrated that hard-to-cook peas contained much less (over 50 per cent) phytate than normal and that removal of this compound by soaking or enzymatic action induced the textural defect. This adverse attribute increases cooking time and is important to people in developing countries where energy sources including fuel wood are becoming increasingly scarce and expensive.

Phytates have been found in cereal grains and legumes upto a level of 5 per cent by weight (de Boland et al., 1975). Fifty cultivated varieties and lines of mature dry beans (P. vulgaris) were analysed for phytic acid content which varied from 0.54 to 2.93 per cent (Lolas and Markakis, 1975; Deshpande and Cheryan, 1983). In dry legumes it has been reported to vary from 0.44 to 1.46 per cent (Reddy et al., 1982). Winged beans contained 0.6 to 0.7 per cent phytate (Tan et al., 1983).

According to Khokhar and Chauhan (1986) the phytic acid among varieties of moth bean ranged from 852.49 to 899.16 mg/100 g. Kaur and Kapoor (1990) reported 1875.4 to 2270.7 mg/100 g phytic acid in rice bean varieties. The phytic acid content of amphidiploids (green gram x black gram) was in range of 697 to 750 mg/100 g as reported by Kataria

et al. (1988). A wide variation in phytic acid exists among different varieties of faba bean. Throw MS variety of faba bean contained 9.6 g/kg phytic acid whereas in variety Dylan it was as high as 12.0 g/kg (Griffiths and Thomas, 1981). Carnovale et al. (1988) observed a variation of 0.71 to 1.15 per cent in faba beans.

Soaking of dry beans in water for 12 h at 24°C resulted in slight decrease in phytate (Tabekhia and Luh, 1980). The greater losses were observed when they were soaked in sodium bicarbonate and mixed salt solutions. These chemicals may affect the seed coat permeability thus allowing higher losses (Deshpande and Cheryan, 1983). Cowpea and lima beans when soaked in deionized water for 3 days at 27°C lost phytic acid content from 1.45 to 1.04 per cent and 1.07 to 0.96 per cent, respectively (Ologhobo and Fetuga, 1984).

The average losses in phytic acid content of moth bean varieties on soaking in tap water were 46 to 50 per cent, respectively and for those when soaked in a solution of four salts (Sodium chloride, sodium tripolyphosphate, sodium bicarbonate and sodium carbonate), the losses were 47 to 50 per cent, respectively. Soaking in sodium bicarbonate and mixed salt solutions has even shown to reduce the cooking times of beans (Iyer et al., 1980).

Henderson and Ankrah (1985) observed that soaking of broad beans at 20-35°C increased phytase activity and hence reduced phytate contents. Kataria et al. (1989) reported that phytic acid decreased by 2 to 13 per cent when the seeds of the amphidiploids were soaked in water for 6 h. The loss was higher when the period of soaking was increased to 12 and 18 h. Kaur and Kapoor (1990) stated that the phytic acid content reduced by 6.2 to 26.2 per cent,

17.5 to 32.1 per cent and 28.6 to 51 per cent when the seeds of the rice bean varieties were soaked in water for 6, 12 and 18 h, respectively.

Soaking and dehulling reduced phytate content by 3 to 4 per cent only in faba bean varieties (Sharma, 1989). According to Abdus Sattar et al. (1989), soaking of mung bean seeds for 3 to 12 h at 22 to 25 or 55°C slightly increased protein content and reduced phytate and trypsin inhibitor content. Reductions were greater at 55°C than at 22 to 25°C.

Soaking usually forms an integral part of pulses processing methods such as cooking, germination, fermentation and roasting. Thus, soaking may offer the dual advantage of saving energy costs as well as rendering grains nutritionally superior. According to Mattson (1946), loss of solids during soaking may be influenced by the concentration gradient (difference in chemical potential), which governs the rate of diffusion and by the physical barriers in cotyledon cell walls and seed coat, which limit the diffusion of water or the soaking medium. The greater losses observed in phytic acid, when the seeds were soaked in mixed salt solutions, may be due to the effects of these chemicals in creating an ionic environment. Under such conditions, changes in the seed coat permeability may be much greater and rapid, thus allowing higher solid losses.

Tabekhia and Luh (1980) observed a little effect of cooking (100°C for 3 h) on the level of phytate in dry beans. Khokhar and Chauhan (1986) reported that ordinary cooking as well as pressure cooking followed by soaking in plain water or mineral salt solution decreased the phytic acid contents of moth bean varieties. The losses varied from 1 to 2 per cent in ordinary cooking; 1 to 4 per cent in pressure cooking of seeds soaked in plain water and

4 to 7 per cent by pressure cooking of seeds presoaked in mineral salt solution. Kataria et al. (1989) stated that cooking of soaked and unsoaked seeds of the amphidiploids decreased phytic acid by 15 to 22 per cent. Kaur and Kapoor (1990) studied the effect of ordinary cooking of unsoaked and soaked seeds of rice bean. They noted that the reduction was about 21.1 to 28.1 per cent and 28 to 41.3 per cent in unsoaked and soaked seeds, respectively.

Cooking resulted in a considerable reduction (82 per cent) in the phytic acid content of Pakistani varieties of peas without any loss of total phosphorus (Manan et al., 1987). They went on to show that the nutritive value of the cooked peas was considerably improved when compared with the raw peas. Akinyele (1989) observed a decrease of 21 and 46 per cent in phytic acid on cooking two varieties of cowpea. Cooking of soaked as well as soaked and dehulled seeds caused a loss of 32 to 34 per cent phytic acid in varieties of faba bean (Sharma, 1989).

According to Rackis (1974) autoclaving for 4 h at 115°C is required to destroy most of the phytic acid in case of soy isolate. It was also reported that after 2 h of autoclaving, approximately 70 per cent of soy phytate was lost (de Boland et al., 1975). It was also reported that autoclaving of unsoaked and soaked seeds of rice bean reduced the phytic acid by 23.0 to 40.8 per cent and 41.0 to 52.2 per cent, respectively (Kaur and Kapoor, 1990). Only 16 to 18 per cent of reduction in soaked seeds and 39 per cent reduction in soaked and dehulled seeds was observed in faba bean varieties Sharma (1989). However, autoclaving of soaked and dehulled seeds for 25 minute destroyed 53 to 55 per cent of phytate in faba beans.

The differences in the loss of phytic acid contents during cooking could probably be explained on the basis that phytase active at a temperature of 40 to 55°C may degrade inositol hexaphosphate to the pentaphosphate or lower molecule weight forms (de Boland et al., 1975). Kumar et al. (1978) observed that the phytic acid content decreased because insoluble complexes between phytate and other components were formed during cooking.

Germination, soaking, fermentation and cooking reduce the effect of phytate in legumes (Reddy and Salunkhe, 1980) because of degradation of phytic acid during cooking, germination, soaking and fermentation (Savage and Deo, 1989). The overall reduction up to 71 to 77 per cent in phytate at the end of 10 days germination period was observed by Michael Eskin and Wiebe (1983). Sprouting of the seeds for 60 h at 25°C lowered phytic acid content in moth bean varieties by 48 to 55 per cent and loss was observed in the contents of phytic acid exclusively by cooking of sprouts in all the varieties of moth bean from 1 to 3 per cent (Khokhar and Chauhan, 1986). Germination of seeds caused a reduction in phytic acid upto 28 to 55 per cent in various legumes (Duhan et al., 1989). After 36 h and 48 h of sprouting 46 to 48 per cent and 66 to 69 per cent loss of phytates was noticed, respectively (Sharma, 1989).

Phytase activity during germination resulted in hydrolysis of phytate phosphorus down to inositol monophosphate (Sobolev, 1963) which contributed to decrease in phytic acid (Mandal et al., 1972; Michael Eskin and Wiebe, 1983; Lee and Karunanithy, 1990). The liberated phosphorus is possibly transported to the embryo for further synthesis of organic phosphates (Sartirana and Bianchetti, 1967; Reddy et al., 1978).

2.3.1.2 Polyphenols

Polyphenols are also called 'tannins' by various investigators (Maxson and Rooney, 1972; Griffiths and Moseley, 1980; Singh and Jambunathan, 1981; Deshpande and Salunkhe, 1982). They are powerful reducing agents that are widely distributed in higher plants used as human food. Polyphenols can complex with dietary proteins, reducing their digestibility and thus protein quality (Mabry et al., 1970; Haslam, 1974; Bond, 1976; Marquardt et al., 1978a; Monties and Rambourgh, 1978; Bressani and Elias, 1980; Metche, 1980; Aw and Swanson, 1985). The phenolic groups of tannins bind to enzymes and other proteins by hydrogen bonding to amide groups to form insoluble complexes (Oh et al., 1980; Pierpoint, 1983). Polyphenols and tannins react with the alpha amino group of lysine and polymerise into tannin protein complexes, which will make large blocks of amino acids resistant to the digestive enzymes of monogastric animals (Sosulski, 1979).

Tannins individually have been shown to have direct inhibitory effects on digestive enzymes such as salivary and pancreatic alpha-amylases (Tamir and Alumot, 1969; Monties and Rambourgh, 1978; Griffiths, 1979; Thompson and Yoon, 1984; Singh, 1984; Rea et al., 1985; Thompson and Gabon, 1987) and also to interact with intestinal epithelial cells disrupting absorption of nutrients (Jaffe, 1980; King et al., 1982; Nakata and Kimura, 1985; Welch et al., 1989), explaining some of their effects. Food containing such antinutrients have recently received much attention as they result in only gradual increases in blood glucose after digestion and appear useful in the management of diabetes (Crapo, 1984; Jenkins et al., 1986; Thompson, 1988) and hyperlipidaemia (Jenkins and Jepson, 1982; Jenkins et al., 1983), thus it has been suggested

that consumption of low levels of certain antinutrients may produce health benefits (Thompson, 1988).

A study was conducted to find out the effects of polyphenol compounds present in the seed coat on the nutritional quality of protein by Elias et al. (1979) who concluded that the pigments present in the seed coat contained high levels of polyphenols and other related tannins. As a result there was a decrease in protein digestibility and protein quality. Gorski (1985) showed that seed coat of coloured varieties of faba bean contained up to 6 to 8 per cent tannins. Elias et al. (1979) and Papadopoulos et al. (1985) stated that varieties of faba beans with coloured coat contained more tannins as compared to lighter coloured beans. Seed with white testa contained traces of polyphenols while coloured seeds contained 1.69 to 3.13 per cent polyphenols. Singh and Jambunathan (1981) reported that the mean values of polyphenolic compounds (mg/g meal) in seed samples of Desi chick pea (4.7 mg) were more than twice the amount that was present in Desi dhal and Kabuli (2.1 mg). These differences disappeared in dehusked dhal samples indicating the distribution of these compounds mainly in the seed coat. In the winged beans, tannin levels ranged from 6.3 to 7.5 mg/g of bean (Tan et al., 1983). Tannin content of dry beans ranged from 0.0 to 2.0 per cent depending on the bean species and colour of the seed coat (Reddy et al., 1985).

Janardanan and Lakshmanan (1985) have reported the presence of high level of tannins (7.25 per cent) in dry beans. Kaur and Kapoor (1990) reported that the polyphenolic contents of the rice bean varieties ranged from 1287 to 1442 per cent. Polyphenol content in peas has been reported to be 26 mg/kg (Savage and Deo, 1989).

Soaking of pigeon pea and chick pea for overnight resulted in 50 per cent losses of tannin whereas in black gram and green gram the losses were 25 per cent (Rao and Deosthale, 1982; Udayasekhara and Deosthale, 1982). As reported by Deshpande and Cheryan (1983) losses of tannin averaged 17, 41 and 49 per cent when beans were soaked in water for 6, 12 and 18 h, respectively. The losses of tannins on soaking the beans in distilled water increased with the time of soaking (Reddy et al., 1985). Kaur and Kapoor (1990) reported 27.2 to 36.8, 35 to 46.3 and 42.8 to 52.3 per cent reduction in polyphenol content after soaking of rice bean seeds for 6, 12 and 18 h, respectively.

Drum et al. (1990) observed that processing contributed to a decrease in the total phenolic acid contents of the dry beans, with significant ($P < 0.05$) differences between the raw beans and soaked and canned beans. These decreases may be attributed to oxidation and decarboxylation of the phenolic acids to their respective phenols, hydrolysis of the esterified and insoluble phenolic acid to the free acids and solubilisation and leaching of the free phenolic acids from the tissue (Steinke and Paulson, 1964; Tressl, et al., 1977). Since polyphenolic compounds are present on the periphery of the grain, their passing out in the soaking medium through seed coat is possible (Kataria et al., 1989).

Since most of the tannins are contained on the testa, dehusking is a practical way to reduce the total tannin content (Rao and Prabhavathi, 1982; Sharma, 1989). Sharma (1989) stated that after dehulling of soaked seeds, 70 to 73 per cent of the total tannin content was reduced in faba beans.

Cooking has been shown to have little effect on destroying tannins. However, they are partially removed with the cooking broth. Polyphenols,

expressed as tannic acid, decreased 30 to 49 per cent on cooking (de Espana, 1977). The losses of tannin in pigeon pea on cooking were about 59 per cent whereas in chick pea, black gram and green gram losses were 70 per cent (Rao and Deosthale, 1982). Udayasekhara and Deosthale, (1982) also reported a significant decrease in tannin content in pulses on cooking. Cooking of raw pulses brought about a 70 per cent decrease in their tannin content (Udayasekhara and Deosthale, 1982). Cooking reduced the total polyphenolic compounds of black, white and red coloured beans to 60.4, 66.7 and 37.4 per cent (Reddy et al., 1985). Cooking of soaked as well as unsoaked seeds resulted in significant reduction of polyphenol contents of the amphidiploids (green gram x black gram) and rice bean (Kataria et al., 1989; Kaur and Kapoor, 1990).

Autoclaving resulted in losses of tannins to the extent of 53.4 to 56.7 per cent (Ekfenyong, 1985). A loss varying from 21 to 25 per cent in the polyphenolic contents of the amphidiploid and the parent grains was noticed when they were pressure cooked for 15 minute (Kataria et al., 1989).

Jood et al. (1987) stated that loss of polyphenols during cooking and germination may be due to presence of polyphenol oxidase and enzymatic hydrolysis. Decrease in tannin content of the legume grains during cooking may be ascribed to binding of polyphenol with other organic substances and proteins or to alterations in the chemical structure of polyphenols which can not be extracted and determined by available methods. Ordinary cooking and autoclaving involve moist heating. Polyphenols may be destroyed during these methods of processing (Kataria et al., 1989).

Udayasekhara and Deosthale (1982) observed that germination too had pronounced effect on tannin content of various beans. On germination for 48 h, loss of 60 per cent of tannin in pigeon pea and chick pea and 50 per cent in black gram and green gram was observed. Rao and Prabhavathi (1982) observed that the tannin contents of seeds could be substantially reduced by germination with a subsequent increase in the availability. As a result of overnight soaking in water and subsequent germination for 40 h, more than 50 per cent tannins were lost in pigeon pea, chick pea, green gram and black gram (Reddy et al., 1985). Rahma et al. (1987) observed a significant decrease in polyphenols of faba beans on germination. Sprouting for 36 and 48 h resulted in 80 to 83 and 90 to 91 per cent destruction of tannins in faba beans, respectively (Sharma, 1989).

The loss of polyphenols during germination may be attributed to the presence of polyphenol oxidase and enzymatic hydrolysis (Rao and Deosthale, 1982; Jood et al., 1987). Kruger (1976) has demonstrated increasing activity of the enzymes polyphenol oxidase with increasing period of germination in wheat.

2.3.1.3 Saponin

The saponin content of peas ranges from 1.1 for yellow peas to 2.5 for green peas (Fenwick and Oakenfull, 1983; Price et al., 1986) which is lower than the levels found in lentils (3.7 to 4.6 g/kg). Saponins are secondary plant metabolites containing a carbohydrate portion (either mono-or-oligosaccharide) attached to an aglycone, which may be steroidal or triterpenoid in structure. Saponins are found in a relatively small number

of food plants, primarily legumes such as soybeans, chick peas, peanuts and spinach (Oakenfull, 1981; Khokhar and Chauhan, 1986; Jood et al., 1986).

Though saponins are practically non-toxic to man when taken orally (Merck Index, 1976), they are known to have a number of physiological affects on animals of which the most interesting is that they can lower plasma cholesterol concentrations (Newman et al., 1957; Griminger and Fisher, 1958; Malinow et al., 1977; Topping et al., 1980; Oakenfull , 1981). It has also been suggested that this effect may also occur in human beings and foods rich in saponins may reduce the risk of heart disease (Cheeke, 1976; Oakenfull et al., 1979; Potter et al., 1979). Saponins seems to induce adsorption of bile acids on the dietary fibre in the intestine (Burkitt and Trowell, 1975) presumably because of their strongly surface active properties. Adsorption of bile acids on the dietary fibre will cause increased faecal loss; this loss would be offset by increased conversion of cholesterol into bile acids in the liver thus lowering the blood levels. Saponins impart a bitter taste to the plant foods and cause physiological disturbances and toxicity to the human system (George, 1965). The lethal dose of saponins vary from 25 to 3000 mg/kg body weight. Chick peas, soybeans, lucerne sprouts and P. vulgaris have been reported to be the rich sources of saponins. (Fenwick and Oakenfull, 1983). There was no difference between the saponin content (on dry weight basis) of raw navy beans and canned baked beans (Oakenfull, 1981) or raw broad beans and canned broad beans (Birk, 1969). According to Fenwick and Oakenfull (1983) chick pea, soybean and kidney bean contained saponins in

abundance. Moth bean was found to be a significant source of saponin, containing 2833.5 to 3349.3 mg per cent in the four newly evolved high yielding varieties of moth bean (Khokhar, 1984). A variation of 5.6 to 2.0 per cent was observed by Khokhar and Chauhan (1986) in various legumes. Saponin content (mg/100 g) among the rice bean varieties varied from 2175 to 2450 alongwith some significant varietal differences (Kaur and Kapoor, 1990).

Khokhar and Chauhan(1986) stated that soaking in mineral salt solution was more effective in removing saponin from the seed than soaking in ordinary water. Kaur and Kapoor (1990) reported that on soaking for 12 h, rice bean seeds lost 3.6 to 6.1 per cent saponin. In soaked and dehulled beans, there was 25 to 29 per cent reduction in saponin content in faba bean varieties (Sharma, 1989). Drum et al. (1990) observed significant ($P < 0.05$) decreases in the total saponin content following the soaking and canning of dry beans. A possible mechanism for the observed decrease in the saponin content of the soaked and canned beans with processing is the hydrolysis of the glycosidic bond between the sapogenin and glycosidic residue during thermal processing.

The loss of saponin from the seeds during soaking may, perhaps, be attributed to the leaching out of saponin in the soaking medium through simple diffusion (Khokhar and Chauhan, 1986).

According to Weiss (1952) heat processing improved the typical taste due to saponins in raw legumes and generally improved their flavour. Khokhar and Chauhan (1986) found that cooking could reduce saponin level of moth bean significantly. Kataria et al. (1989) reported that saponin

reduction varied from 8 to 18 per cent when the legume seeds of amphidiploids (green gram x black gram) and the parents were cooked after 12 h soaking and from 4 to 15 per cent when unsoaked seeds were cooked. Similar findings have also been reported for rice bean, mung bean and faba bean too (Kaur and Kapoor, 1990; Kataria et al., 1989; Sharma, 1989).

Loss during cooking may perhaps indicate thermolabile nature of saponins. Whether cooking results in formation of poorly extractable complex between saponins and sugar or amino acid is not known (Khokhar and Chauhan, 1986; Jood et al., 1986).

Pressure cooking (1.05 kg/ cm^2 , 121°C for 15 minute) of soaked seeds of moth bean in plain water lowered the amount of saponin by 35 to 44 per cent (Khokhar and Chauhan, 1986). According to Sharma (1989) soaking followed by dehulling and autoclaving for 15 minute reduced the saponin content upto 50 per cent. The maximum reduction in saponin content was observed (81 to 84 per cent) when after soaking, seeds were dehulled and autoclaved for 25 minute. Significant reduction up to 35 to 39 per cent on autoclaving was observed in black gram by Jood et al. (1986).

Germination of legumes has been reported to decrease saponins by earlier workers (Jood et al., 1986; Kataria et al., 1989; Sharma, 1989; Kaur and Kapoor, 1990). longer the period of germination, more was the loss of saponin content. The reduction in saponin level during germination was due to enzymatic degradation as reported by Khokhar and Chauhan (1986) and Kataria et al (1989).

2.3.1.4 Trypsin inhibitor activity

Trypsin is a proteolytic enzyme secreted by the pancreas.

Trypsin inhibitors are the characteristic constituents of legume grains and are known to affect the digestibility and hence, the protein quality of legumes. Trypsin inhibitors are present in varying amounts in various legumes including peanuts, navy beans, lime bean, soybean etc. The trypsin inhibitor activity in raw and processed seeds of fields beans, broad beans, peas, lentils, chick pea and soybean was investigated by Gallardo et al. (1974). Highest inhibitor activity was found in soybean.

The trypsin inhibitor content of peas is one-tenth the level found in soybeans (Glycine max) and is similar to that of the field bean (Vicia faba) (Hove and King, 1979; Valdebouze et al., 1980). The trypsin inhibitor content depends on the type of pea. Wrinkled seeded varieties had less trypsin inhibitor activity than smooth seeded types and spring types (2700-5500 u/g); on average had less than winter types (5700-11700 u/g) (Valdebouze et al., 1980).

The presence of antinutritional factor such as trypsin inhibitor, which affects the utilization of pulse protein, has been known since long. Trypsin inhibitors have the ability to inhibit the trypsin activity of stomach. In plants trypsin inhibitors protect the cytoplasm from the trypsin containing bodies. They act as defence mechanism against the invading microbes and insects (Ryan and Santarius, 1976). Trypsin inhibitors function by combining with the active enzyme to form tightly bound enzyme substrate like complex. These complexes are very stable. According to Green and Neurath (1953), affinity of trypsin for inhibitors is much greater than that for natural substrates.

Trypsin inhibitors is present in beans (Sathe and Salunkhe, 1981) and is the most heat resistant antinutritional known (Antunes and Sgarbieri, 1980). Trypsin inhibitor contents of legume seeds were reported as soybeans 26.2; P. vulgaris 3.4 to 11.6; P. lunatus 20.2; Vicia faba 2.7 and Pisum sativum 0.7 to 3.5 units. The level of trypsin inhibitor was higher in species of American origin than in those of Asian origin (Benken and Budanova, 1976).

The inhibitor contents in the four varieties of moth bean ranged significantly from 1676 to 2718.7 units/ 100 g. The trypsin inhibitors activity (calculated as TI units per g of extracted protein) has been reported as 47.10 in Mucuna utilis. Janardanan and Lakshmanan (1985) observed that the raw hybrid variety of cluster bean had lower trypsin inhibitory activity of 29.8 per cent whereas the local variety had 52 per cent. The study carried out by Singh et al. (1985) indicated that trypsin inhibitor activity was detected in all the strains of rice bean and ranged from 15.30 to 28.04 TIU/ml.

Johns (1986) showed that the trypsin inhibitor content of field pea varieties ranged from 88 to 716 U/g. The trypsin inhibitors activity (TIA/g) ranged between 36.9 to 55.7 in rice bean (Kaur and Kapoor, 1990). The inhibitor activity (TIU/g) varied significantly from 832 to 1487 in green gram and the black gram parents (Kataria et al., 1989).

Various processing methods have been known to reduce the level of trypsin inhibitors activity in legumes. Deshpande and Cheryan (1983) studied the changes in levels of trypsin inhibitor activity of 4 dry beans (P. vulgaris) on soaking the seeds in distilled water, (NaHCO_3) sodium-bi-carbonate and a mixed salt solution. They reported that a greater reduction

in the trypsin inhibitor activity (TIA) of beans was observed on soaking in sodium-bi-carbonate or mixed solution than in distilled water. Alkali treatment (boiling the seeds with sodium carbonate at 100°C for 20 minute) was found to be the most effective method for inactivation of trypsin inhibitor activity (Manorma and Sarojini, 1982).

A loss of 2 to 10 per cent in trypsin inhibitor activity of moth bean during soaking in plain water and 28 to 35 per cent during soaking in mineral salt solution was observed (Khokhar and Chauhan, 1986). Kadam et al. (1986) reported that soaking of moth bean for 8 h decreased trypsin inhibitor activity by 20 per cent.

Sharma (1989) noticed that soaking of seeds in ordinary water reduced this activity by 4 to 5 per cent in Faba bean. Further, when the soaked seeds were dehulled, 10 per cent loss over the control values was noticed in both the varieties; mainly because trypsin inhibitors are present in testa of faba beans (Bond, 1976).

Loss of solids including trypsin inhibitors during soaking may be influenced by the concentration gradient governing the rate of diffusion and by the physical barriers in cotyledons, cell wall and seed coat, which limit the diffusion of water of the soaking medium. Since the trypsin inhibitors are generally low molecular weight proteins, these are likely to pass out from the seed to the soaking medium easily. The sodium salts when present in the soaking medium are likely to alter the porosity of pulse seed coat. This is perhaps one of the factors responsible for the greater loss of solids like trypsin inhibitors from the seed. Further, these chemicals may create ionic environment which may account for greater losses

of inhibitors. Under these conditions, changes in the seed coat permeability may be much greater and rapid thus allowing higher solid losses (Deshpande and Cheryan, 1983).

The extent to which the trypsin inhibitors in legumes is destroyed by heat is a function of the temperature, duration of heating, particle size and moisture conditions (Albrecht et al., 1967). The inhibitory activity of Lathyrus sativus could be destroyed almost completely by heating up to 120 minute (Roy and Rao, 1971). Trypsin inhibitors found in faba bean are heat labile in nature (Nitsan, 1971; Bhatti, 1974 and Rahma et al., 1987). Warsey et al. (1974) and Marquardt et al. (1975) observed that heating of faba beans for 1 h at 70°C and at pH 12.0 completely destroyed trypsin inhibitor activity.

Al Baker et al. (1982) noticed that heating the soaked legume seeds at 121°C for 30 minute brought about complete inactivation of inhibitor activity. Chick pea trypsin inhibitor retained only 17 per cent of its activity after being heated at 80°C for 30 minute, black eyed pea inhibitor retained 74 and 58 per cent of its activity after heating for 30 minute at 80 and 100°C, respectively. Heat treatments for up to 30 minute at 121°C though sufficient to inactivate trypsin and chymotrypsin inhibitors, did not appear to affect the amino acid composition of the soy flours (Friedman et al., 1991).

In general, if the beans first are soaked overnight, steaming at atmospheric pressure serves to inactivate the trypsin inhibitor of soybeans almost completely. While studying the effect of different heat treatments on trypsin inhibitor activity of four varieties of soybean. Manorma and Sarojini

(1982) found that soaking of seeds in water for 24 h and then steaming under 15 lb pressure in a pressure cooker was the best method for inactivation of trypsin inhibitor activity.

While studying the varietal differences and effect of processing, Reddy and Reddy (1985) reported that boiling and pressure cooking decreased the activity of the trypsin inhibitor to a significant extent. Complete destruction of trypsin inhibitor activity of cowpea on boiling for 20 minute was observed by Bansal et al. (1988).

Tan and Wong (1982) suggested that prolonged ordinary cooking for 45 to 60 minute of whole bean was required to reduce the trypsin inhibitor activity substantially. Ordinary cooking or pressure cooking after soaking in plain water, soaking in mineral salt solution and sprouting almost eliminated the trypsin inhibitor activity from the seeds of moth bean (Khokhar and Chauhan, 1986).

Deo (1987) showed that cooking completely destroyed the trypsin inhibition of all peas evaluated. He further stated that the increase in true digestibility on cooking may well be due to the elimination of trypsin inhibitors which interfere with digestion. Marickar and Pattabiraman (1988) observed that antitryptic activity was reduced by 77 per cent in red gram and 99 per cent in green gram on cooking at 100°C for 30 minute. Ordinary cooking of soaked as well as soaked and dehulled seeds reduced the TIA by 51 to 56 per cent and 75 to 76 per cent in faba beans (Sharma, 1989).

In general, autoclaving in an atmosphere of steam at 15 lb/sq inch for 10 to 15 minute serve to inactivate the trypsin inhibitor of soybean almost completely. Tannous and Ullah (1969) reported complete elimination

of antitrypsin activity in peas as a result of autoclaving the seeds at 121°C for 5 minute. Pandhye and Salunkhe (1980) showed that autoclaving for 10 minute at 116°C resulted in only 62 per cent loss of the trypsin inhibitor activity.

Griffiths (1984) showed that at or below 80°C trypsin and chymotrypsin enzymes inhibitors were stable and its inhibitory properties unaffected at 100°C, a small significant reduction in activity was observed. Saini (1989) showed that autoclaving for 5 minute completely destroyed trypsin inhibitor activity in legumes and dehulled seeds for 15 minute led to a reduction of 85 to 88 and 92 to 94 per cent in faba beans. Further when the time of autoclaving was increased to 25 minute the reduction was 95 and 97 to 98 per cent (Sharma, 1989). This was due to the heat labile nature of the inhibitor. Trypsin inhibitor destroying effect of cooking is one of the major contributory factors towards increasing the protein quality especially protein digestibility of legume seeds (Sharma, 1989).

Germination resulted in 37 per cent loss of TIA in moth bean (Subbulakshmi et al., 1976). Collins and Saunders (1976) observed that the beans when soaked, germinated (3 days) and rinsed twice daily lost TIA upto 13.2 per cent. The trypsin inhibitor activity was significantly reduced to 42 to 60 per cent when seeds after soaking in water were allowed to germinate for 60 h.

Kadam et al. (1986) reported that soaking of moth bean for 8 h decreased trypsin inhibitor activity by 20 per cent. Further the germination of seed for 24 h resulted in 70 per cent reduction in inhibitor activity and after 48 h germination this activity was completely destroyed. More recently,

Kamalakannan et al. (1981) and Chitra and Sadasivam (1986) have shown that between 85 and 88 per cent of the trypsin inhibitor activity was lost from the seeds after 48 h of germination.

Decrease in trypsin inhibitor activity of faba bean on germination was reported by Rahma et al. (1987). Verma and Mehta (1988) reported 30 per cent loss in trypsin inhibitor activity on germination of rice beans whereas a complete destruction of this activity was observed in chick pea on germination for 8 days (Bansal et al., 1988).

The reductions in trypsin inhibitor activity during germination may probably be attributed to the mobilization and breakdown of chemical constituents including trypsin inhibitors (Sharma, 1989).

2.3.2 In vitro digestibility

2.3.2.1 Starch digestibility (in vitro)

Legumes contain a large amount of carbohydrates varying from 55 to 60 per cent (EI-Faki et al., 1984). Composition of carbohydrates differ in various legumes but starch is the major constituent of available carbohydrates (Nigam and Giri, 1961) in food legumes, known to possess low digestibility (Kumar and Venkataraman, 1976; Geervani and Theophilus, 1980; EI - Faki et al., 1984). This may be ascribed to chain length and amount of amylose (Rao, 1976; Srinivasa, 1976) and the presence of amylose inhibitors (Singh et al., 1982), phytate and polyphenols (Thompson and Yoon, 1984) in the foods.

Starch digestibility varies among legumes. EI-Faki et al. (1984) observed the in vitro starch digestibility in chick pea, horse gram and cowpea to be 80.63, 78.60 and 79.00 per cent respectively. Mature bean seeds are

less digestible than immature seeds. This could result from changes in the composition of starch and non-starchy components during maturation (Greenwood and Thompson, 1962; Elbert and Witt, 1968). It is feasible that normally digestible carbohydrates (such as starch) may not be completely digested if the organism lacks sufficient digestive capacity relative to the amount or type of carbohydrate ingested. This may be due to consumption of carbohydrates which are less accessible or resistant to hydrolysis (Hellendoorn, 1978).

Various domestic processing and cooking methods including soaking, dehulling, cooking, germination etc. have been reported to improve the starch digestibility of different legumes. Boralkar and Reddy (1985) observed that 12 h soaking and germination (24, 36 and 48 h) of soybean brought about a marked improvement in the in vitro digestibility of starch.

Factors like amylose inhibitors, phytic acid and polyphenols are reported to inhibit alpha-amylase (Deshpande and Cheryan, 1984; Thompson and Yoon, 1984). Soaking may improve starch digestibility possibly by decreasing the level of these antinutritional factors in the seed. According to previous workers (Rao and Deosthale, 1982; Khokhar and Chauhan, 1986) soaking and other treatments including cooking, autoclaving and sprouting of pulses are known to reduce the level of phytate, tannin and amylase inhibitors which may to some extent, be responsible for the increase in starch digestibility of processed and cooked legume grains.

Cooking increased the carbohydrate digestibility considerably in moth bean and horse gram in both ungerminated and germinated legumes (Subbulakshmi et al., 1976). The rate of amyolysis in the cooked samples

was about 3 times than that observed with the uncooked samples. In vitro starch digestibility increased on cooking of chick pea, green gram, cowpea, black gram and red gram (Rao, 1969; Kumar and Venkataraman, 1976). EL - Faki et al. (1984) observed an increased starch digestibility during boiling, pressure cooking and germination. Kataria et al. (1990) reported 3 to 6 fold increase in soaked ordinarily cooked seeds of amphidiploids (black gram x green gram). Kaur and Kapoor (1990) stated 4 to 7 fold increase in starch digestibility of unsoaked cooked seeds of rice bean cultivars. On cooking of soaked seeds, per cent increase was 34 to 66 per cent in different varieties of faba bean (Sharma, 1989).

Differences in starch digestibility during different heat treatment may be due to differences in extent of starch gelatinisation. Significant difference in amylolysis rates in the processed legume seeds, as compared to the raw, have been reported (Subbulakshmi et al., 1976; Geervani and Theophilus, 1980; El-Faki et al., 1984). They also observed a significant increase in in vitro carbohydrate digestibility following the boiling of whole legume seeds. Enhanced digestibility of cooked legume starches by alpha-amylase could be attributed to the swelling and rupturing of starch granules which facilitates more randomized configuration for alpha-amylase to affect hydrolysis, the disintegration of various bean components during cooking and inactivation of α amylase inhibitors.

Increased starch digestibility after germination has been reported in various legumes including soybean, moth bean, rice bean, faba bean. (Boralkar and Reddy, 1985; Khokhar, 1984; Kaur, 1986; Sharma, 1989). Bednarski et al. (1985) attributed the significant increase in starch digestibility

of faba beans on germination to increase in alpha amylolytic activity.

During germination the activity of certain enzymes like amylase present in seeds increases (Varner, 1965). As a result of this enhanced enzymatic activity, the seeds undergo pronounced metabolic changes and the structural profile of the various organic components is altered (Koller et al., 1962). The carbohydrates are converted into simple sugars in which they are translocated to the germinating axis (HSu et al., 1973). These changes promote digestibility of sprouted legumes in the uncooked state (Aykroyd and Doughty, 1964).

The increase in digestibility of the germinated and processed beans was thought to be due to leaching of protease inhibitors during soaking and rinsing preparation (Kakade and Evans, 1966).

2.3.2.2 Protein digestibility (in vitro)

Legumes contain about 2 to 3 times more protein as compared to cereals but the digestibility is poor (Liener, 1962). The digestion of protein meals by proteolytic enzymes such as pepsin, trypsin and papain under in vitro condition has been used to evaluate the quality of proteins and considerable work has been done on legume seed protein to find out the release of amino acids. Although the pulses contain a fairly high content of proteins, its digestibility is low, the reasons being either the rapid discharge of protein from the intestine or resistance to protein hydrolysis by gastrointestinal enzymes. In any case, significant losses of nitrogen occur in faeces even when cooked legumes are consumed.

Due to the presence of antinutritional factors, legumes are poorly digested in stomach resulting in stomach upsets. The digestibility is affected

by a number of factors like cooking and processing, the amount of protein consumed and the state of gastrointestinal tract. In raw state, a number of factors like saponins, glycosides, inhibitors or proteolytic enzymes, tannins, oxalates and phytates lower the protein digestibility (Anon, 1973). Griffiths and Moseley (1980) suggested the presence of polyphenols to be responsible for low digestibility of field beans, polyphenols in dry beans decreased the protein digestibility probably by making protein partially unavailable or by inhibiting digestive enzymes (Bressani and Elias, 1979). Various workers (Tan et al. 1984; Singh, 1984; Knuckles et al., 1985) have reported that antinutritional factors like trypsin inhibitors, phytate and polyphenols adversely affected protein digestibility. Ray (1969) attributed the poor protein digestibility of raw seeds of horse gram to trypsin inhibitors.

The relatively low protein digestibility of legumes may be attributed to the resistance of globulins, the major protein in pulse seed to the proteolytic enzymes (Walker and Kochhar, 1983). Variation in protein digestibility of legume strains have been observed not only among species but also among varieties of species.

Rossi et al. (1984) compared chick pea cultivars and revealed that in vitro protein digestibility was 78 per cent in black and yellow seeds. Gross (1983) reported in vitro protein digestibility to be 68.9 per cent for raw winged bean. According to Tas et al. (1984) protein digestibility (in vitro) for raw winged beans was 68.8 per cent. The value for peas has been reported to be 92 per cent (Jaffe, 1950) Saharan (1991) studied protein digestibility of different varieties of field and vegetable peas. The per cent digestibility of protein varied from 62.6 to 64.7 in raw pea samples.

Various studies have revealed that soaking improved the in viro protein digestibility of different legumes (Khan and Ghafoor, 1978; Rockland et al., 1979; Khokhar, 1984; Kataria, 1986; Kaur and Kapoor, 1990; Sharma, 1989).

Rockland et al. (1979) and Khokhar (1984) observed the higher protein digestibility during soaking of legumes in mixed salt solutions. The reason being that mixed salt solutions removed certain antinutritional factors of dry bean more affectively and to a greater degree than when water was used as soaking medium. Kataria (1986) reported an increase of 21 to 50 per cent when the amphidiploids (green gram x black gram) were soaked . for 18 h. An increase to the extent of 14 to 17 per cent in protein digestibility over control values was noticed when faba beans were soaked in water (Sharma, 1989). The reason of increase digestibility due to soaking is that may result in leaching out of phytate, trypsin inhibitors, polyphenols, tannins and other factors from seed affecting the protein in the seed (Deshpande and Cheryan, 1983; Reddy et al., 1985). Soaking may also initiate activation of certain enzymes resulting in mobilization of proteins, carbohydrates and fats (Sharma, 1989).

Cooking and heat processing has been known to increase the digestibility of legume proteins (Subba Rao and Subramanyan, 1950; Jaffe, 1950; Ray, 1969; Kamalakannan et al., 1981; Coffey et al., 1985; Kaur, 1986; Saharan, 1991). Kakade and Evans (1963) and Kakade (1969) found that heating increased the in vitro digestibility of pulses due to inactivation of trypsin inhibitors and selective denaturation of protein.

According to Laurena et al. (1987) simple wet heat treatment like

boiling at atmospheric pressure and pressurised boiling above 100°C temperature could increase protein digestibility by 6 to 26 per cent in cowpea while pressurised steaming increased in vitro protein digestibility only by 1.1 to 4.2 per cent by reducing the polyphenol content of mature red seeds of cowpea.

Ray (1969) studied the in vitro digestibility of raw and autoclaved seeds of horse gram (Dolichos lablab). The poor digestibility of raw seeds by trypsin, may, however, be attributed to the presence of trypsin inhibitors in it. Satwadhar et al. (1981) and EL-Faki et al. (1984) showed that cooking improved the protein digestibility of chick pea, horse gram and cowpea by destroying trypsin inhibitors. Autoclaving also improved the protein digestibility in black gram and winged beans (Kamalakannan et al., 1981; Ekfenyong and Brochers, 1979). Tas et al. (1984) observed that in vitro protein digestibility of raw winged bean ranged from 68.8 to 72.9 per cent and heat treatments increased in vitro digestibility to 76 to 90 per cent Kataria (1986) reported an increase in the protein digestibility to the tune of 23 to 28 and 8 to 27 per cent after cooking of the soaked and unsoaked seeds, respectively in amphidiploids (green gram x black gram). Saharan (1991) reported an increase to the extent of 99 to 10.87 per cent in different pea varieties after autoclaving at 15 psi for 15 minute. As a result of cooking of legumes, drastic reduction occurs in the content of antinutrients like phytic acid (Kataria et al., 1988), polyphenols (Jood et al., 1987) and saponins (Jood et al., 1986) which may partly be responsible for the enhancement the in vitro protein digestibility of cooked peas.

The increase in protein digestibility of legumes on autoclaving may

be due to destruction of trypsin inhibitors (Kakade and Evans 1963; Kakade, 1969; Ray, 1969; Bender, 1972; Satwadhar et al., 1981; El-Faki et al., 1984; Kataria, et al., 1989). A probable reason is that globulins making up the large portion of legume seed protein are resistant to denaturation and in the native state are not readily broken down by digestive enzymes (Walker and Kochhar, 1983). Pulses contain a wide range of antinutritional factors some of them including tannins, phytate, lectins and saponins etc. which may be involved in lowering protein digestibility in raw seeds. Reduction in the contents of these antinutritional factors brought by processing and cooking may be responsible for increasing protein digestibility (Jood et al., 1987; Kataria et al., 1988; Sharma, 1989) and because of opening of protein structure through denaturation too (Kataria, 1986).

Germination has been reported to increase in vitro protein digestibility of moth bean (Subbulakshmi et al., 1976; Satwadhar et al., 1981; Khokhar and Chauhan, 1986) chick pea, cowpea and horse gram (El -Faki et al., 1984), soybean (Boralkar and Reddy, 1985), rice bean (Kaur, 1986) and faba beans (Youssef et al., 1987; Rahma et al., 1987; Sharma, 1989).

Hamza (1983) stated that action of hydrolytic enzymes during germination is responsible for increase in protein digestibility. Decrease in antinutritional factors like trypsin inhibitors, tannins, phytates during germination may also be responsible for increase in protein digestibility (Khokhar, 1984; Sharma, 1989). Improvement in protein digestibility may be attributed to the modification and degradation of storage proteins (Kataria et al., 1989). Sprouting cause mobilization of proteins with the help of

proteases leading to the formation of polypeptides, oligo-peptides and free amino acids (Kataria, 1986; Youssef, 1987).

2.3.3 Minerals

2.3.3.1 Total minerals

Besides high protein content, pulses contain a good amount of minerals also. The data obtained from earlier studies has shown that different minerals in raw whole seed of pea are, calcium 0.3 to 1.4 g/kg; phosphorus. 2.2 to 5.1 g/kg; iron 22.0 to 490.0mg/kg; zinc 20.4 to 63.5 mg/kg; copper 4.9 to 10.1 mg/kg and manganese 8.7 to 139.0 mg/kg, respectively. The cooked whole pea seeds contained calcium 0.13 to 1.0 g/kg; phosphorus 0.8 to 3.8 g/kg; iron 11.1 to 518 mg/kg; zinc 8.7 to 46.5 mg/kg; copper 1.9 to 9.8 mg/kg and manganese 4.0 to 10.27 mg/kg, respectively (Hove et al., 1978; Magar and Sizer, 1978; Etchevers, 1980; Reichert and Mackenzie, 1982; Kumar and Kapoor, 1983; Rameo et al., 1983; Wills, et al., 1984; Lopez et al., 1986).

Phosphorus, calcium and magnesium are the major minerals present in common pulses whereas zinc, copper, iron and manganese are the minor ones (Singh et al., 1976).

As reported by Kumar and Kapoor (1984) the calcium content and density of legumes varied from 109.6 to 281.9 mg/100 g and 31.82 to 78.31 mg/100 calories, gram being the highest and lentil being the lowest in calcium content and density. The iron content of different varieties of legumes varied from 6.83 to 12.90 mg/100 g and iron density ranged from 1.97 to 3.76 mg/100 calories.

Gopalan et al. (1984) have reported the calcium and phosphorus of rice bean as 302 and 297 mg/100 g and that of green gram as 124 and 326 mg/100g, respectively. Different varieties of rice bean were found to contain calcium, phosphorus, iron, zinc, copper and manganese ranging from 286.7 to 326.8; 233.7 to 248.8; 5.3 to 7.7; 2.8 to 3.2; 1.2 to 1.8 and 2.5 to 3.5, respectively (Kaur, 1986).

Lynch et al. (1984) observed low level of iron for soybeans, lentils and split peas. The phosphorus, calcium and iron content of Mucuna utilis were 300, 900 and 15 mg/100 g (Janardanan and Lakshmanan, 1985) whereas Reddy and Reddy (1985) have reported the calcium and iron content of local variety of cluster bean as 2065.22 and 73.37 mg/100 g, respectively and that of hybrid variety as 1856.383 and 68.085 mg/100 g, respectively.

Minerals in cooked legumes were about one-third to one-half of the values in raw beans, with Mg, P and K leaching into the cooking water (Meiners, et al., 1976). Cooked pea seeds seemed to contain generally lower levels of iron (Savage and Deo, 1989). On the other hand mineral retention during cooking in dry beans was found to be 80 to 90 per cent with exception of sodium and total calcium retentions (Augustin et al., 1981 and Koehler and Burke, 1981). Meiners et al. (1976) confirmed that considerable losses of all minerals occurred on cooking of dry legumes.

Kumar et al. (1978) noted a reduction in Ca^{++} content in all the three legumes i.e. black gram chick pea and green gram as a result of cooking. The loss of Ca^{++} content was low in green gram (11.6%)

while in chick pea, it was considerably high (42.2%). The losses occurring during cooking may be because cooking involves a complex reaction system. Thereby the Ca^{++} which is concentrated in the parenchymal cells migrates into the interior of cell and complexes with phytate ions. Further the permeability of cell wall is altered by the presence of Ca^{++} and Mg^{++} ions. More soluble calcium salts might be formed during these changes which get leached out.

Ologhobo and Fetuga, (1984) reported that cooking and autoclaving only slightly decreased the total phosphorus content in some Nigerian varieties of legumes. Among the different processes, germination caused the most pronounced loss of total phosphorus in all varieties of cowpea, followed by soaking while cooking and autoclaving only slightly decreased (Ologhobo and Fetuga, 1984). The reason for loss of total phosphorus during germination being that during the early stages of germination, the liberated inorganic phosphorus is transported to the embryo for further Synthesis of Organic phosphorus (Sartirana and Bianchetti, 1967).

In the later stages of germination, a significant loss of Ca^{++} was found in all the legumes and this loss may be due to leaching of inorganic compounds during germination (Kumar et al., 1978). But no significant changes were noticed in magnesium, iron, manganese, and zinc content of both the legumes due to cooking (Borade et al., 1984).

Total magnesium, zinc and potassium did not change after autoclaving but the per cent extractable magnesium, zinc and potassium in the autoclaved samples were significantly higher than in the non-autoclaved soybean meal indicating a change in solubility during the heat treatment (Changpradee et al., 1984)

treatment (Chompreeda and Fields, 1984).

2.3.3.2 HCl extractable minerals

Extractable minerals in a food are those which are soluble in 0.03 N HCl, the concentration of HCl found in human stomach (Chompreeda and Fields, 1984). The amount of HCl extractable minerals in food indicated an index of their bioavailability from the foods. Thus, the solubility or extractability of minerals in food subject to in vitro gastric and intestinal digestions is a useful indicator of minerals bioavailability. Kaur (1986) studied the effect of different processing and cooking method on the HCl extractability of minerals in rice bean varieties. She noted that after 12 h soaking there was a significant reduction in the extractable calcium content of all the rice bean varieties whereas increase in germination time from 40 to 60 h caused an increase in calcium extractability. The responsibility for the Ca^{++} loss during soaking can be attributed to leaching out of calcium into the soaking water (Kumar et al., 1978).

According to Kaur (1986) some significant varietal differences in extractable phosphorus content were noticed when the unsoaked and soaked seeds of rice bean were ordinary cooked. She also observed an increase in extractable phosphorus content during autoclaving of soaked and unsoaked seeds over cooking of unsoaked and soaked seeds. The extractability of phosphorus from soybean decreased during autoclaving by 27.1 per cent. This may be because of heating, a complex of phosphorus is formed, which limits the extraction (Chompreeda and Fields, 1984).

Kaur (1986) noted that varietal x period interaction in extractable zinc content was significant during sprouting, ordinary cooking and autoclaving but non-significant during soaking whereas varietal x period interaction in extractable copper content of pulses was significant during sprouting, ordinary cooking and autoclaving but non-significant during soaking.

MATERIALS AND METHODS

Materials and methods have been divided in to the following sub-heads:

- 3.1 Materials
- 3.2 Physico-chemical properties
- 3.3 Processing and cooking methods
- 3.4 Nutritive value
 - 3.4.1 Proximate analysis
 - 3.4.2 Carbohydrates
- 3.5 Antinutritional factors
 - 3.5.1 Phytic acid
 - 3.5.2 Polyphenols
 - 3.5.3 Saponin
 - 3.5.4 Trypsin inhibitor activity
- 3.6 In vitro digestibility
 - 3.6.1 Starch digestibility
 - 3.6.2 Protein digestibility
- 3.7 Mineral composition
- 3.8 Statistical analysis

3.1 Materials

The seeds of four varieties of peas (Pisum sativum) namely, Bonneville, Arkel, HFP4 (Aparna) and Rachna were procured from the Departments of Vegetables and Plant Breeding, College of Agriculture, Haryana Agricultural University, Hisar. Bonneville and Arkel are vegetable pea varieties whereas HFP4 (Aparna) and Rachna are field pea varieties.

The selection of these varieties was done on the basis of high yield. The yield potential of Rachna and HFP4 was 28 and 37 q/ha, respectively, whereas the yield of green pods of Bonneville and Arkel was 75 to 80 and 50 q/ha, respectively.

The seeds were cleaned of dust and other foreign particles prior to domestic processing and cooking treatments. Raw seeds were powdered in an electric grinder (Cyclotec, M/S Tecator, Höganäs, Sweden, using 0.5 mm sieve size), packed in air tight containers and used as a control. The processing and cooking treatments were done in triplicates.

3.2 Physico-chemical properties

Unprocessed seeds of the varieties were analysed for physico-chemical properties.

3.2.1 Density

Seeds (100 g) were weighed accurately and transferred to a measuring cylinder. Then 100 ml distilled water was added to it. Seed volume was recorded as total volume (ml) -100 ml. Density was recorded as g/ml.

3.2.2 Hydration capacity

Seeds weighing (100g) were counted and transferred to a measuring cylinder, and 100 ml water was added. The cylinders were covered with aluminium foils and left overnight at room temperature. Next day seeds were drained, superfluous water removed with filter paper and swollen seeds reweighed Hydration capacity per seeds was determined by using the following formula:

$$\text{Hydration capacity per seed} = \frac{\text{Weight of soaked seeds} - \text{Weight of seeds before soaking}}{\text{No. of seeds}}$$

3.2.3 Hydration index

Hydration index was calculated as below :

$$\text{Hydration index} = \frac{\text{Hydration capacity per seed}}{\text{Weight of one seed (g)}}$$

3.2.4 Swelling capacity

Seeds weighing (100 g) were counted, their volume noted and soaked overnight. The volume of the soaked seeds was noted in graduated cylinder. Swelling capacity per seed was determined by using the following formula:

$$\text{Swelling capacity} = \frac{\text{Volume after soaking} - \text{Volume before soaking}}{\text{No. of seeds}}$$

3.2.5 Swelling index

Swelling index was calculated as below :

$$\text{Swelling index} = \frac{\text{Swelling capacity per seed}}{\text{Volume of one seed (ml)}}$$

3.2.6 Cooking time

Seeds (100 g) were taken in beakers fitted with condensers to avoid evaporation during boiling. Water was added in a ratio of 1:4 (w/v). Samples were stirred at 2 minute interval. After 45 minute one seed was withdrawn without interrupting the boiling. Degree of

cooking was tested by pressing seeds between fingers. If seeds were felt uncooked, one seed was again tested after 5 minute. This procedure continued until five seeds tested were found cooked. At this time total cooking time was recorded.

3.3 Processing and cooking methods

3.3.1 Soaking

Seeds were soaked in double distilled water for 6, 12 and 18 h at 30°C in an incubator and seed to water ratio used was 1.5 (w/v) . The soaked seeds were washed and rinsed with double distilled water.

3.3.2 Dehulling

After soaking the seeds overnight (12 h), hulls were removed manually.

3.3.3 Ordinary cooking

The seeds soaked for 12 h and unsoaked seeds were cooked in crude fibre beakers. Water was added three times to the weight of soaked seeds. Unsoaked seeds were also cooked in the same manner, using a seed to water ratio of 1:4 (w/v). Samples were cooked until soft as felt between fingers.

3.3.4 Autoclaving

Both soaked (12 h) and unsoaked seeds were autoclaved at 15 lbs/inch² pressure for 10 minute . Seeds and water ratio was 1 : 2 (w/v) in case of soaked seeds while this ratio was 1:3 (w/v) in unsoaked seeds.

3.3.5 Sprouting

The soaked seeds (12 h) were taken in sterile petriplates lined with wet filter papers and kept in an incubator at 30°C for 12, 24

and 48 h for sprouting.

Preparation of processed samples

All the processed samples were dried in the hot air oven kept at 60°C to a constant weight, ground in an electric grinder (Cyclotec, M/S Tecator, Höganäs, Sweden) using 0.5 mm sieve size and packed in air tight containers for further chemical analysis.

3.4 Nutritive value

3.4.1 Moisture, crude protein, fat, ash, crude fibre and carbohydrate

3.4.1.1 Moisture

Moisture in the sample was calculated by employing the standard method of analysis (AOAC, 1980).

3.4.1.2 Crude protein (AOAC, 1980)

Reagents

- i- N/100 H_2SO_4
- ii- Boric acid (4%)
- iii- Mixed indicator solution: Took 0.5 g bromocresol green and 0.1 g methyl red, dissolved in 100 ml 95 per cent ethanol and adjusted the solution with few drops of dilute NaOH or HCl to bluish purple colour.
- iv- NaOH (45%)
- v- Digestion mixture : 10 g K_2SO_4 , 0.5 g $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ and 2 g FeSO_4 .

Procedure

Digested one g sample with 25 ml concentrated H_2SO_4 and a pinch of digestion mixture. The nitrogen in ammonical salt was distilled

with 45 per cent NaOH in MicroKjeldahl apparatus. The ammonia liberated was absorbed in 10 ml boric acid solution containing a few drops of mixed indicator and titrated against H_2SO_4 (N/100). The end point was indicated by the change of colour. A factor 6.25 was applied to convert the amount of nitrogen to crude protein.

3.4.1.3 Crude fat

Crude fat was estimated by employing the standard method of analysis (AOAC, 1980) using the Soxhlet extraction apparatus.

Procedure

Weighed 5 g of dry sample and transferred it to an extraction thimble dried overnight at 105°C. Placed the thimble in Soxhlet extractor fitted with a condensor and flask containing sufficient petroleum ether. The extraction was carried out for 6 h. After the extraction, thimble flask were removed and dried in the hot air oven at 60°C to a constant weight, cooled in a desiccator to room temperature and weighed. The loss in the weight of the thimble or gain in the weight of the flask was the estimate of the ether extract in the sample.

3.4.1.4 Ash (AOAC, 1980)

Procedure

Placed the requisite number of silica crucibles in muffle furnace to heat at 550°C for 15 minute. Removed the crucibles, cooled in a desiccator for one hour. Weighed accurately 5 g of material in to each crucible. Heated each sample on a hot plate till smoking ceased and the sample become thoroughly charred. Placed the crucibles inside the muffle furnace and ashed at 550°C for 5 to 6 h. When the ash become clean and white in appearance, the crucibles were removed from

the furnace, cooled in a desiccator and weighed. The loss in weight represented the organic and residue the ash content.

3.4.1.5 Crude fibre (AOAC, 1980)

Reagents

- i- Hydrochloric acid (1% v/v).
- ii- Sulphuric acid stock solution (10% w/v): Took 55 ml conc. H_2SO_4 and diluted it to one litre.
- iii- Sulphuric acid working solution: Diluted 125 ml of the stock solution to one litre.
- iv- Sodium hydroxide stock solution (10% w/v): Dissolved 100 g NaOH in water and diluted to one litre.
- v- Sodium hydroxide working solution (1.25%): Diluted 125 ml of the stock solution to one litre.
- vi- Antifoam : 2% Silicon antifoam in CCl_4 .

Procedure

Weighed one g of fat free dried sample in a one litre tall beaker. Added 200 ml 1.25% H_2SO_4 and few drops of antifoam. Kept the solution boiling for 30 minute under bulb condensers. **Beaker** was rotated occasionally to mix the contents and removed the particles from the side. Filtered the contents of the beaker through funnel. Washed the sample back into the tall beaker with 200 ml 1.25 per cent sodium hydroxide. Brought to boiling point. Boiled exactly for 30 minute. Transferred all insoluble matter to the sintered crucible by means of boiling water till acid free. Washed twice with alcohol. Washed three times with

acetone. Dried at 100°C to constant weight. Ashed in a muffle furnace at 550°C for 1 h. Cooled the crucible in a desicator, reweighed and the percentage of crude fibre in the samples was calculated.

3.4.1.6 Carbohydrate

Amount of carbohydrate was calculated from the sum of moisture, crude protein, fat, ash and crude fibre and lastly subtracting it from 100.

3.4.2 Carbohydrates

Total soluble sugars other than starch were extracted according to the procedure of Cerning and Guilhot (1973).

Extraction

Twenty five ml ethonol (80 %) was added to 500 mg sample in a round bottom flask. The flask was connected to a condensor and kept on a heating mantel for 30 minute with occasional stirring. The extract was cooled and centrifuged at 8000 rpm for 15 minute. The supernatant was collected in a beaker. The above procedure was repeated twice, each time taking 25 ml 80 per cent ethanol. The residue, thus, obtained was preserved and used for starch estimation. The combined extract in the beaker was evaporated to dryness on a boiling water bath. The residue was dissolved in distilled water to make 100 ml.

3.4.2.1 Total soluble sugars

Total soluble sugars were estimated by the method of Yemm and Willis (1954).

Reagents

- i- Standard sugar solution : Glucose (40 mg) was dissolved in water and made up to 100 ml. This contained 400 ug glucose/ ml.

- ii- Anthrone reagent (0.2% anthrone in 70% H_2SO_4).

This reagent was prepared fresh daily and allowed to stand for 30 to 40 minute before use.

Estimation

Freshly prepared 10 ml anthrone reagent was pipetted in a thick walled corning test tube (150 x 25 mm) and chilled in ice cold water. One ml of the sugar extract was taken and diluted to 10 ml with water. Out of the diluted sugar extract, one ml was taken and was layered on the anthrone reagent. It was cooled for 3 to 5 minute and thoroughly mixed while still immersed in ice cold water. The tube were heated in a boiling water bath for 10 minute and immediately cooled in cold water. The absorbance was then read at 625 nm against a suitable blank.

The amount of sugars was determined by referring to a standard curve prepared by using different concentrations (40 to 200 ug glucose). From standard curve, 0.219 OD corresponded to 40 ug glucose.

3.4.2.2 Reducing sugars

Reducing sugars were estimated by Somogyi's modified method (Somogyi, 1945).

Reagents

- i- Copper reagent A: It was prepared by dissolving 25 g potassium tartarate, 20 g sodium bicarbonate and 200 g anhydrous sodium sulphate in about 800 ml distilled water and then diluted to one litre.

- ii- Copper reagent B: It was prepared by dissolving 15 g copper sulphate in 100 ml distilled water containing two drops of HCl.
- iii- Arsenomolybdate reagent : Ammonium molybdate (25 g) was dissolved in 450 ml water followed by addition of 25 ml conc. H_2SO_4 while stirring sodium hydrogen arsenate (3 g) was dissolved in 25 ml water and then added to above solution with stirring. The solution was kept in an incubator at 37°C for 24 h before use. The reagent was stored in a glass stoppered brown bottle.
- iv- Copper reagent A and B were mixed in the ratio of 25:1 (v/v) before use.
- v- Standard sugar solution : Glucose (25 mg) was dissolved in distilled water and made to 100 ml. This contained 250 ug glucose/ml.

Estimation

Four ml test extract obtained in 3.4.2 was taken in a Folin-Wu tube graduated at 25 ml. One ml mixed copper reagent was added and then heated for 20 minute in a boiling water bath. To this one ml arsenomolybdate reagent was added, mixed thoroughly and the contents diluted to 25 ml. A stable blue colour quickly appeared which was read at 520 nm against blank.

A standard curve with concentrations ranging from 50 ug to 300 ug was prepared. Optical density of 0.109 corresponded to 50 ug glucose. The amount of reducing sugar in a sample was determined by referring to the standard curve.

3.4.2.3 Non reducing sugars

Amount of non-reducing sugars was calculated from the difference between the total soluble sugars and reducing sugars.

3.4.2.4 Starch

Starch from the sugar free pellet obtained after centrifugation was estimated by the method of Clegg (1956).

Extraction

Starch was extracted at room temperature. Five ml water was added to the aforesaid residue of the test material and while stirring 6.5 ml of 52 per cent perchloric acid was added. The contents were stirred continuously for five minute and then occasionally for next 15 minute. Twenty ml water was then added and centriufged. The supernatant was collected in a 100 ml volumetric flask. Five ml water was added to residue and repeated the extraction with 52 per cent perchloric acid, stirring occasionally for next 30 minute. The contents of the tube were washed in to the flask containing the test extract the diluted to 100 ml with water. It was then filtered discarding first 5 ml of filtrate. One ml extract was used for glucose estimation using anthrone reagent by the method of Yemm and Willis (1954) as described earlier. Starch was calculated using the following formula:

$$\text{Starch} = \text{Glucose} \times 0.9$$

3.4.2.5 Total available carbohydrates

The total available carbohydrates were calculated by sum of total soluble sugars and starch.

3.5 Antinutritional factors

3.5.1 Phytic acid

Phytic acid content was determined by the method of Davies and Reid (1979).

Reagents

- i- 0.5 M HNO_3 . Nitric acid (15.96 ml having 69.5% eassay) was diluted to 500 ml with water.
- ii- Ferric ammonium sulphate : Ferric ammonium sulphate (216 mg) was dissolved in water and volume was made to 500 ml with water.
- iii- Ammonium thiocynate : Ammonium thiocynate (10 g) was dissolved in water and made to 100 ml.
- iv- Iso-amyl alcohol
- v- Sodium phytate : Sodium phytate (5.5%) H_2O , 97 per cent purity and containing 12 Na/mole 30.54 mg was dissolved in 100 ml of 0.5 M nitric acid which gave a solution containing 20 mg phytic acid in 100 ml or 200 ug phytic acid/ml.

For plotting a standard curve, different concentrations i.e. 0.4 to 1.0 ml of standard sodium phytate solution containing 40 to 240 ug phytic acid were taken and made to 1.4 with water. 0.6000 OD corresponded to 160 ug phytic acid.

Extraction

The sample (500 mg) was extracted with 20 ml of 0.5 M HNO_3 for 3 h with continuous shaking on a shaker followed by centrifugation at 8,000 rpm for 15 minute.

Procedure

One ml supernatant was taken in a test tube and made to a final volume of 1.4 ml with water. Then one ml ferric ammonium sulphate solution was added. The tubes were mixed thoroughly and placed in a boiling water bath for 20 minute. After cooling down to room temperature under running tap water. 5 ml isoamyl alcohol was added. Immediately after mixing the tubes by inversion, 0.1 ml ammonium thiocyanate solution was added. The tubes were well shaken well and then the contents, were centrifuged at 3000 rpm for 10 minute. Colour intensity was read at 465 nm against iso amyl alcohol blank exactly after 15 minute of addition of ammonium thiocyanate.

3.5.2 Polyphenols

Extraction

The polyphenolic compounds were extracted from the defatted sample (500 mg) by refluxing with 50 ml methanol containing 1% HCl for 4 h (Singh and Jambunathan, 1981). The extract was concentrated by evaporating methanol on a boiling water bath and brought its volume to 25 ml with methanol containing HCl. The amount of phenolic compounds were estimated as tannic acid equivalent according to Folin-Denis procedure (Swain and Hills, 1959).

Reagents

- i- Folin-Denis Reagent : Added 100 g sodium tungstate, 20 g phosphomolybdic acid, 50 ml phosphoric acid to 750 ml water and refluxed for 2 h, cooled and diluted it to one litre.
- ii- Tannic acid solution : Dissolved 100 mg tannic acid in water and made upto litre. Twenty ml of this stock solution was further diluted to 100 ml with water to give working standard

solution which contained two ug tannic acid per ml

- iii- Saturated sodium carbonate solution : Dissolved 350 g sodium carbonate in one litre of water at 70°C to 80°C cooled, seeded and filtered through glass wool.

Extimination

Test solution (0.2 ml) was diluted to 8.5 ml with water in a test tube. After thorough mixing, added 0.5 ml Folin-Denis reagent and the tube was well shaken exactly after three minute, one ml saturated sodium carbonate solution was added and the tube was thoroughly shaken again. After one h the absorbance was read at 725 nm using a suitable blank. If the solution was cloudy or precipitates appeared, it was centrifuged before readings were taken.

A standard curve was plotted by taking 0.5 ml to 4.0 ml working tannic acid standard solution (containing 10 ug to 80 ug tannic acid). 0.4000 OD corresponded to 40 ug tannic acid.

3.5.3 Saponin

Saponin was extracted and determined by the modified method of Gestetner et al. (1966).

Reagents

- i- Standard saponin solution : Dissolved 100 mg saponin in acetic acid to make 100 ml.
- ii- 1 N H_2SO_4 in dioxane : Water (1:3 v/v).
- iii- Acetic acid (10%).
- iv- Na_2SO_4
- v- Conc. H_2SO_4

Procedure

Five hundred mg pulse flour was taken in an extraction flask, dispersed in 50 ml IN H_2SO_4 in dioxane: Water (1:3) and hydrolysed under reflux for 8 h. The contents were cooled, diluted with addition of 5 ml water. Saponins were extracted with 25 ml diethyl ether. The combined ether extracts were washed with water, made moisture free by adding Na_2SO_4 and then dried. After drying, the residue was taken up in the minimal amount of benzene and purified on a column of alumina. For preparing column, 5 g freshly activated alumina (aluminium oxide active acidic) was suspended in 100 ml benzene and 0.2 ml 10 per cent aqueous acetic acid, stirred vigorously for 30 minute, poured into a column of 15 mm diameter and washed with 250 ml of benzene. Saponin extract (1-2 ml) was loaded on the column. Various impurities were removed by washing the column with 100 ml benzene and the saponins were then eluted with 100 ml 3 per cent solution of methanol in benzene. The saponin solution was concentrated nearly to dryness and the residues taken up in 10 ml acetic acid. To 2.0 ml acetic acid solution of saponins, 1 ml glacial acetic acid followed by 2 ml conc. H_2SO_4 was added. The tubes were cooled to room temperature and the absorbance was read at 530 nm against a blank containing three ml glacial acetic acid and two ml conc. H_2SO_4 .

A standard curve was prepared by taking 0.4 ml to 2 ml standard saponin solution (0.4 mg to 2 mg saponin) and 0.080 OD corresponded to 0.4 mg saponin.

3.5.4 Trypsin inhibitor activity

Trypsin inhibitor activity was determined by the modified method of Roy and Rao (1971).

Reagents

- i- 0.1 M phosphate buffer (pH 7.6): Sixteen ml NaH_2PO_4 (0.2 M) and 84 ml Na_2HPO_4 (0.2 M) were diluted to 200 ml with water and pH adjusted to 7.6.
- ii- 0.05 M phosphate buffer (pH 7.0): Fifty ml 0.1 M phosphate buffer was diluted to 100 ml with water and pH adjusted to 7.0.
- iii- Casein solution (2%) : A suspension of 2 g casein was prepared with phosphate buffer (0.1 M pH 7.6) and dissolved by warming on a steam bath for 10 minute. The cooled solution was made to 100 ml with phosphate buffer and stored in a refrigerator.
- iv- Trypsin solution (5 mg/ml): Trypsin (125 mg, 20,000 units/g) was dissolved in 25 ml phosphate buffer (0.1 M, pH 7.6).
- v- 0.001 N HCl : Conc. HCl (8.88 ml) was added to one litre of water. Ten ml of it was taken and volume was made to litre with water to give 0.001 N HCl.
- vi- Trichloroacetic acid (5%) : Trichloroacetic acid (5g) was dissolved in water and volume made to 100 ml.

Extraction

One g seed flour was taken in a 100 ml conical flask and 0.05 M phosphate buffer (pH 7.0) was added to it. The contents were shaken for 3 h and centrifuged at 10,000 rpm for 20 minute. The following sets of

incubation mixtures were prepared :

	<u>Test</u>	<u>Control</u>	<u>Blank</u>
Phosphate buffer (0.1 M, 7.6 pH)	1.0 ml	1.1 ml	1.0 ml
Trypsin (5 mg/ml)	0.5 ml	0.5 ml	0.5 ml
HCl (0.001 N)	0.4 ml	0.4 ml	0.4 ml
TCA (5%)	-	-	6.0 ml
Casein (2%)	2.0 ml	2.0 ml	2.0 ml
Extract	0.1 ml	-	0.1 ml

Incubation at 37°C for 20 minute.

TCA (5%)	6.0 ml	6.0 ml	-
-----------	--------	--------	---

After incubation and addition of TCA, the contents were centrifuged at 10,000 rpm for 10 minute. The TCA soluble proteins in the supernatant were determined by the method of Lowry et al. (1951).

Reagents

- i- 2% Na_2CO_3 in 0.1 N NaOH
- ii- 0.5% CuSO_4 in 1% sodium citrate

Fifty parts of (i) solution and one part of (ii) solution were mixed just before use.

- iii- Alkaline CuSO_4 .
- iv- 1 N Folin-Ciocalteu phenol reagent.

Determination

To 0.5 ml supernatant 5 ml alkaline CuSO_4 solution was added was mixed thoroughly and allowed to stand for 10 minute at room temperature.

Then 0.5 ml Folin-Ciocalteu phenol reagent (IN) was added and again immediately mixed. A blank by taking water was run against side by side. The colour intensity was read after 30 minute at 520 nm against blank.

For preparing a standard curve 0.1 ml to 0.5 ml standard casein solution containing 400 ug/ml was taken 0.070 OD corresponded to 40 mg of casein.

Trypsin inhibitor Units : One unit of trypsin was defined as the amount of enzyme which converted one mg casein to TCA soluble components at 37°C for 20 minute at pH 7.6. One unit of inhibitor activity is that which reduces the activity of trypsin by one unit under the assay conditions.

3.6 In vitro digestibility

3.6.1 Starch digestibility (in vitro)

In vitro starch digestibility was assessed by employing pancreatic amylase (Singh et al., 1982).

Reagents

- i- 0.2 M Phosphate buffer (pH 6.9): Fifty ml 0.2 M (27.28 g/lit) potassium dihydrogen phosphate was added to 46.8 ml 0.2 M (35.598 g/lit) disodium hydrogen phosphate and made upto 200 ml with water.
- ii- Pancreatic amylase : Twenty mg pancreatic amylase (Sigma Chemical Company, USA) was dissolved in 50 ml 0.2 M phosphate buffer (pH 6.9).
- iii- Dinitrosalicylic reagent : Dissolved 10 g 3,5, dinitrosalicylic acid, 300 g sodium - potassium tartarate and 16 g NaOH in carbon

dioxide free water & made to 1000 ml. The reagent was stored in brown bottle and protected from carbon-dioxide.

- iv- Standard maltose solution: Dissolved 100 mg maltose monohydrate in water and made upto 100 ml.

Extimination

Twenty five mg of defatted sample was dispersed in one ml 0.2 M phosphate buffer, pH 6.9. Added 0.5 ml pancreatic amylase to sample suspension and incubated in water bath at 37°C for two h. After the incubation period was over, 3 ml dinitrosalicylic acid reagent was quickly added and the mixture was heated for 5 minute in a boiling water bath. After cooling, the solution was made to 25 ml with distilled water and filtered prior to measurement of absorbance at 550 nm. A blank was run simultaneously incubating the sample, the dinitrosalicylic acid reagent was added before addition of the enzyme solution. Maltose was used as standard and values were expressed as mg maltose released per g defatted sample. Standard curve was prepared by taking 0.8 to 8 mg maltose from a standard maltose solution. 0.058 OD corresponded to 0.8 mg maltose.

3.6.2 Protein digestibility (in vitro)

In vitro digestibility of protein was carried out by the method of Akeson and Stahlmann (1964) as modified by Singh and Jambunathan (1981).

Reagents

- i- Pepsin : Dissolved 40 mg pepsin (3000 units) in HCl (pH 2.0 prepared by diluting the acid with water and made upto 100 ml.

- ii- 10 per cent Trichloroacetic acid (TCA).
- iii- 5 per cent TCA
- iv- 0.1 M Borate buffer (pH 6.8).
 - a) 0.2 Boric acid : Dissolved 12.4 g boric acid in water and made the volume to one litre.
 - b) 0.05 M Borax solution : Dissolved 19.05 g borax in water and made the volume to one litre. For preparing the borate buffer, added 140 ml 0.2 M boric acid, 50 ml distilled water and few drops of 0.05 M borax solution to adjust the pH at 6.8.
- v- 0.1 M Borate buffer (pH 6.8) containing 0.025 M calcium chloride was prepared by dissolving 2.75 g calcium chloride in one litre of the buffer.
- vi- 0.2 N NaOH: Dissolved 8 g NaOH in water and made the volume to one litre.
- vii- Pancreatin : Dissolved 50 mg pancreatin (Sigma Chemical Company, USA) in 100 ml 0.1 M borate buffer (pH 6.8) containing calcium chloride.

Procedure

Two hundred mg ground sample was taken in a fifty ml conical flask, added 5 ml pepsin solution to it and incubated the contents at 37°C for 16 h in a water bath shaker. A few drops of toluene were added to each flask to check the growth of microbes. After incubating for 16 h the pH was adjusted to 7.0 with 0.2 N sodium hydroxide solution. Then 2 ml pancreatin solution was added to each flask and incubated at 37°C in a

water bath shaker for 24 h. Then 7 ml 10 per cent TCA was added. The contents were centrifuged at 12,000 rpm for 20 minute and the residue washed twice with 5 ml of 5 per cent TCA. The supernatants were pooled and the volume was made upto 25 ml with 5 per cent TCA. Five ml aliquot was taken and dried at 80-90°C in a hot air oven and the nitrogen contents were determined by MicroKjeldahl method (AOAC, 1980). The protein of the sample was determined by multiplying N content by a factor 6.25. The digested protein of the sample was determined by subtracting the residual protein from the total protein of sample. Protein digestibility was calculated by the following formula:

$$\text{Protein digestibility (\%)} = \frac{\text{Digested protein}}{\text{Total protein}} \times 100$$

3.7 Mineral composition

3.7.1 Digestion

One g ground sample was taken in a 150 ml conical flask. To this 25-30 ml diacid mixture (HNO_3 : HClO_4 : 5:1 v/v) was added and kept overnight. Next day it was digested by heating till clear white precipitates settled down at the bottom. The crystals were dissolved by diluting in double distilled water. The contents were filtered through Whatman # 42 filter paper. The filtrate was made to 50 ml with double distilled water and was used for determination of total Ca, P, Fe, Zn and Cu.

3.7.2 Calcium

Calcium in the digested sample was determined by titration method of Vogel (1962).

Reagents

- i- Standard CaCO_3 (N/100): Dissolved 0.5 g CaCO_3 in 6N HCl and made the volume to one litre with water.
- ii- EDTA (N/100): Dissolved 1.86 g EDTA (Disodium salt) in water and made the solution to 1000 ml.
- iii- NaOH solution (10%).
- iv- Hydroxylamine hydrochloride solution (5%).
- v- Triethanolamine.
- vi- Calcon indicator: Dissolved 0.4 g calcon in 100 ml methanol.
- vii- Polyvinyl alcohol : One per cent solution in water.

Procedure

Pipetted a suitable volume of aliquot (10 ml) in a conical flask and added about 10 ml water. Added 10 per cent NaOH drop by drop to adjust the pH to neutrality. Added ten drops of 5 per cent hydroxylamine hydrochloride solution with continuous stirring. Added ten drops of triethanolamine followed by 2.5 ml of 1 per cent polyvinyl alcohol. Added 2 ml 10 per cent NaOH. Finally added a few drops of calcon indicator. A violet colour appeared which was then titrated against N/100 EDTA solution to give bluish green end point.

Calculation

$$\text{Ca meq. /lit} = \frac{\text{EDTA used NEDTA} \times 1000}{\text{Aliquot taken}}$$

$$\text{mg Ca/100 g} = \frac{\text{Ca(meq/ lt)} \times 20 \times 50 \times 100}{100}$$

Where 50 was the volume of digested material made from one g sample.

3.7.3 Phosphorus

Phosphorus was determined colorimetrically by the method of Chen et al. (1956).

Reagents

- i- Ascorbic acid (10%).
- ii- Ammonium molybdate (2.5%).
- iii- Reagent C: Mixed 6 N H_2SO_4 , water, 2.5 per cent ammonium molybdate and 10 per cent ascorbic acid in the ratio of 1:2:1:1 (v/v), respectively. This reagent was prepared fresh every day.
- iv- Standard phosphorus solution: Dissolved 0.351 g pure anhydrous monopotassium dihydrogen orthophosphate in a few ml of water and 10 ml 10N H_2SO_4 . The volume was made to one litre with water. This stock solution contained 80 ug p/ml.
Diluted 25 ml stock solution to one litre which served as working standard solution. It contained 2 ug p/ml. Two to three drops of chloroform was added for preserving the solution.

Procedure

Pipetted a suitable aliquot (1 ml) of the mineral extract in a test tube and made the volume to 4 ml with water. Added 4 ml Reagent C and mixed well. Incubated the contents at 37°C in a water bath for 90 minute. Removed and allowed to cool to room temperature and read absorbance at 820 nm against a suitable blank. Standard curve was plotted

using one to eight ug P. 0.390 OD corresponded to 4 ug P.

3.7.4 Trace minerals

Trace minerals including iron, zinc and copper in acid digested samples were determined by the Atomic Absorption Spectrophotometer 2380, PERKIN-ELMER (U.S.A.) in the Department of Foods and Nutrition, Haryana Agricultural University, Hisar according to the method of Lindsey and Norwell (1969).

3.7.5 HCl extractable minerals

Minerals including calcium, phosphorus, iron, zinc and copper were extracted in 0.03 N HCl (Peterson et al., 1943) and estimated to assess the bioavailability of these minerals in the pea samples.

To one g sample, 50 ml 0.03 N HCl was added. The mixture was incubated at 37°C in a shaker-cum-water bath for three h to stimulate conditions that occur in human stomach. The mixture was then filtered through an ashless filter paper (Whatman # 42). The filtrate was oven dried, digested in the diacid mixture and proceeded for the determination of individual minerals as detailed above Ca 3.7.2 P 3.7.3 trace minerals 3.7.4.

3.8 Statistical analysis

The data were subjected to statistical analysis for analysis of variance and correlation coefficients in a complete randomised design according to standard methods (Panse and Sukhatme, 1961).

RESULTS AND DISCUSSION

The experimental results have suitably been presented and discussed under following heads and sub-heads:

- 4.1 Physico-chemical properties
- 4.2 Nutritive value
 - 4.2.1 Proximate composition
 - 4.2.2 Carbohydrates
- 4.3 Effect of domestic processing and cooking
 - 4.3.1 Antinutritional factors
 - 4.3.1.1 Phytic acid
 - 4.3.1.2 Polyphenols
 - 4.3.1.3 Saponin
 - 4.3.1.4 Trypsin inhibitor activity
 - 4.3.2 In vitro digestibility
 - 4.3.2.1 Starch
 - 4.3.2.2 Protein
 - 4.3.3 Minerals
 - 4.3.3.1 Total
 - 4.3.3.2 HCl extractable

4.1 Physico-chemical properties

Physico-chemical properties such as density, hydration capacity, hydration index, swelling capacity, swelling index and cooking time of four varieties of peas have been presented in Table-1.

Density among the four varieties of peas varied from 1.18 to 1.30 g/ml; the highest being in Rachna and the lowest being in Arkel. Rachna had significantly ($P < 0.05$) higher density followed by HFP4 ,

Table 1 : Physico-chemical properties of peas

Varieties	Density (g/ml)	Hydration capacity (g/seed)	Hydration index	Swelling capacity (ml/seed)	Swelling index	Cooking time (min.)
Vegetable peas						
Bonneville	1.26±0.01	0.21±0.01	1.09±0.04	0.49±0.04	0.75±0.02	83±0.04
Arkel	1.18±0.04	0.24±0.03	1.59±0.03	0.55±0.02	2.36±0.03	102±0.03
Field peas						
HFP4 (Aparna)	1.27±0.01	0.22±0.03	0.98±0.01	0.50±0.02	1.59±0.02	106±0.01
Rachna	1.30±0.07	0.18±0.03	0.93±0.09	0.43±0.05	1.59±0.09	106±0.07
SE (m)	±0.07	±0.03	±0.02	±0.06	±0.20	±0.06
CD (P < 0.05)	0.21	0.09	0.06	0.20	0.60	0.20

Values are mean ± S.D. of three independent determinations

Bonneville and Arkel. Bonneville and HFP4 had almost similar density values.

Hydration capacity (g/seed) ranged from 0.18 to 0.24 among the different vegetable and field pea varieties Table-1. Rachna (field pea) had the minimum hydration capacity whereas the Arkel (Vegetable pea) had the maximum hydration capacity. The hydration capacity of Bonneville and Arkel, Bonneville and Rachna, and Arkel and Rachna differed significantly ($P < 0.05$) whereas Bonneville and HFP4 had almost similar hydration capacity. Similarly, hydration index of Arkel was the highest followed by Bonneville, HFP4 and Rachna. Rachna, having the lowest hydration capacity had the minimum hydration index too.

Swelling capacity and swelling index of Arkel were significantly ($P < 0.05$) higher than those of Bonneville, HFP4 and Rachna. Among all the varieties, Arkel had the highest hydration capacity, hydration index, swelling capacity and swelling index. As Arkel, the vegetable pea variety has the maximum hydration capacity, swelling capacity thereby it may require less cooking time too which will be useful for saving fuel energy.

Generally, legumes require a long period for cooking hence, consideration for cooking time is of paramount importance. The minimum (83 minutes) and maximum time (106 minutes) for cooking was observed in case of Bonneville, the vegetable pea variety and HFP4 and Rachna, the field pea varieties, respectively Table-1. Both the field pea varieties i.e. Rachna and HFP4 had the similar cooking time. Vegetable pea varieties i.e. Bonneville and Arkel had more hydration and swelling capacity and required less cooking time too than those of the field pea varieties i.e. HFP4 and

Rachna. A negative but non-significant correlation was obtained between the hydration as well as swelling capacity and cooking time of peas.

Physico-chemical parameters as mentioned above are important parameters which ultimately play an important role in cooking of legumes. The results of the present study are consistent with those mentioned by previous workers (Ahmad and Shehata, 1982; Sharma, 1989) for other legumes. They reported that the legumes having the higher hydration and swelling coefficients require less cooking time and hence, are preferred by the consumers and processors too. As cooking of vegetable peas would require less fuel, energy and thereby, should be preferred over the field peas.

4.2 Nutritive value

4.2.1 Proximate composition

Table 2 gives the proximate composition of newly evolved high yielding vegetable and field cultivars of peas. Moisture content ranged from 4.89 to 6.62 in different pea varieties Table-2. Peas had 19.5 to 20.5 per cent crude protein the highest being in Arkel and the lowest in HFP4. There were no significant differences in the crude protein content of three varieties of peas namely, Bonneville, Rachna and Arkel Table-2.

Vegetable pea varieties i.e. Bonneville and Arkel had significantly ($P < 0.05$) higher levels of fat, ash and crude fibre than those of the field pea varieties i.e. Rachna and HFP4. Bonneville had

Table 2 : Proximate composition of peas (g/100 g, on dry matter basis)

Varieties	Moisture	Protein	Fat	Ash	Crude fibre	Carbohydrates
Vegetable peas						
Bonneville	6.41±0.16	20.26±0.57	2.79±0.12	4.08±0.07	9.33±0.08	57.13±0.05
Arkel	5.41±0.04	20.56±0.20	2.28±0.12	4.71±0.09	10.30±0.06	56.74±0.05
Field peas						
HFP4 (Aparna)	4.89±0.05	19.50±0.47	1.55±0.02	3.06±0.05	6.02±0.02	64.98±0.01
Rachna	6.62±0.08	20.47±0.34	1.47±0.11	2.83±0.10	3.97±0.03	64.64±0.09
SE (m)	±0.17	±0.18	±0.13	±0.11	±0.11	±0.34
CD(P < 0.05)	0.51	0.54	0.39	0.35	0.35	1.12

Values are means ± S.D. of three independent determinations

significantly ($P < 0.05$) more fat and less ash and crude fibre contents than those of Arkel. HFP4 and Rachna had similar fat and ash values, whereas crude fibre content was significantly ($P < 0.05$) more in HFP4. Carbohydrate content was found to be maximum i.e. 64.98 per cent in HPF4 followed by Rachna (64.64%), Bonneville (57.13%) and Arkel (56.74%) Table-2.

The values for crude protein, fat, ash and crude fibre are within the range reported earlier for peas (Evans and Boulter, 1980; Reichert and Mackenzie, 1982; Welch and Griffiths 1984; Lopez et al., 1986; Gueguen and Barbot, 1988; Savage and Deo, 1989).

4.2.2 Carbohydrates

Different pea varieties were analysed for total soluble sugars, reducing sugars, non-reducing sugars, starch and total available carbohydrate contents Table-3 and significant ($P < 0.05$) varietal differences were noticed. Total soluble sugar content of pea varieties varied from 5.81 to 6.98 g/100 g. When compared to field peas, the vegetable pea varieties had significantly ($P < 0.05$) higher levels of total soluble sugars. Bonneville had the maximum total soluble sugar content followed by Arkel, HFP4 and Rachna.

The reducing sugar content of all the four pea varieties differed significantly ($P < 0.05$) among themselves with Arkel and HFP4 (Aparna) having the maximum (577.0 mg/100 g) and the minimum(410.6 mg/100 g) Table-3. Both the field pea varieties (Rachna and HFP4) had significantly ($P < 0.05$) less content of reducing sugars than that of vegetable pea varieties i.e. Bonneville and Arkel. Similarly, the non-reducing sugar content of

Table 3 : Total soluble sugars (g/100 g), reducing sugars (mg/100 g), non-reducing sugars (g/100 g), starch (g/100 g) and total available carbohydrates content (g/100 g) of peas (on dry matter basis)

Varieties	Total soluble sugars	Reducing sugars	Non-reducing sugars	Starch	Total available carbohydrates
Vegetable peas					
Bonneville	6.98±0.03	531.0±0.04	6.44±0.03	53.42±0.03	60.40±0.03
Arkel	6.81±0.03	577.0±0.04	6.23±0.03	61.42±0.02	68.23±0.02
Field peas					
HFP4 (Aparna)	5.97±0.05	410.6±0.06	5.56±0.04	62.75±0.01	68.72±0.02
Rachna	5.81±0.05	432.6±0.08	5.38±0.06	63.75±0.01	69.56±0.01
SE (m)	±0.07	±0.86	±0.02	±0.12	±0.11
CD (P < 0.05)	0.21	2.82	0.06	0.36	0.35

Values are means ± S.D. of three independent determinations

different pea varieties varied significantly ($P < 0.05$) among themselves; the maximum (6.44 g/100 g) and minimum (5.38 g/100 g) being in Bonneville and Rachna, respectively.

There were significant varietal differences in starch content of peas. Rachna, had the maximum starch content followed by HFP4, Arkel and Bonneville Table-3. Total available carbohydrate content among the field and vegetable pea cultivar varied significantly ($P < 0.05$); Rachna and Bonneville having the highest (69.5 g/100 g) and the lowest (60.4 g/100g) levels Table-3. The findings of the present study are consistent with those reported earlier (Singh et al., 1977; Fleming 1981; Fleming and Reichert, 1983; Wills et al., 1984; Savage and Deo, 1989).

4.3 Effect of domestic processing and cooking

4.3.1 Antinutritional factors

4.3.1.1 Phytic acid

Phytic acid is known to be major storage form of phosphorus in legumes and is considered to be an antinutritive factor in peas. The phytic acid content ranged from 630.33 to 780.33 mg/100 g among field and vegetable pea varieties Table-4 . All the pea varieties differed significantly ($P < 0.05$) in their phytic acid content. The vegetable pea cultivars had significantly ($P < 0.05$) lower level of phytic acid than that of field pea varieties. Among the vegetable and field pea varieties, Arkel and Rachna had higher content of phytic acid i.e. 651.66 and 780.33 mg/100g , respectively. Different workers have reported a wide variation for phytic acid content among different varieties of peas i.e. 4.7 to 8.20 g/kg (Elkowiec and Sosulski, 1982; Kumar and Kapoor, 1983; Manan et al., 1987).

Table 4 : Effect of soaking and dehulling on phytic acid content of peas (mg/100 g, on dry matter basis)

Varieties	Control	Period of soaking			Soaked and dehulled
		6 h	12 h	18 h	
Vegetable peas					
Bonneville	630.33±0.4	598.69±0.3 (-5)	581.81±0.3 (-8)	554.64±0.8 (-12)	574.66±0.1 (-9)
Arkel	651.66±0.6	621.33±0.3 (-5)	603.32±0.3 (-7)	575.82±0.2 (-12)	596.67±0.1 (-8)
Field peas					
HFP4 (Aparna)	761.33±0.4	730.73±0.3 (-4)	712.64±0.1 (-6)	685.41±0.2 (-10)	705.49±0.7 (-7)
Rachna	780.33±0.4	749.86±0.2 (-4)	731.68±0.3 (-6)	705.12±0.1 (-10)	724.54±0.1 (-7)
SE (m)	±0.97	±0.30	±0.16	±0.05	±0.45
CD (P < 0.05)	3.16	1.0	0.48	0.15	1.35

Values are means ± S.D. of three independent determinations

Figures in parentheses indicate per cent decrease (-) over control values

Boulter (1982) emphasized the role of phytate in bean hardening. He reported that hard to cook peas contained more than 50 per cent phytate than normal. This adverse attribute increases the cooking time and is of paramount importance to people in under developed countries where energy sources are scarce and expensive.

Soaking as well as dehulling of the soaked seeds contributed significantly ($P < 0.05$) towards lowering down the phytic acid content in field and vegetable pea cultivars Table-4. On 6 h soaking the percent loss ranged from 4 to 5 in vegetable and field peas. With an increase in the period of soaking i.e. 6 to 12 and 12 to 18 h further reductions in phytate content of peas were noticed. After 18 h of soaking, the maximum and minimum losses occurred in Vegetable and field peas, respectively; longer the period of soaking, more were the losses in phytate content. Soaked and dehulled peas had significantly ($P < 0.05$) lower levels of phytic acid than control. The reduction in phytic acid content of soaked and dehulled pea varieties varied from 7 to 9 per cent Table- 4.

The loss phytic acid in the soaked pea seeds may be because of leaching of phytate ions into soaking water under the influence of concentration gradient (difference in chemical potential) which governs the rate of diffusion. Similar results for reduction in phytic acid in the soaked legumes have been reported earlier (Deshpande and Cheryan, 1983; Ologhobo and Fetuga, 1984).

Ordinary cooking of unsoaked, soaked and soaked-dehulled pea seeds brought about a significant decrease in the phytic acid content than

Table 5: Effect of ordinary cooking on phytic acid content of peas (mg/100 g, on dry matter basis)

Varieties	Control	Unsoaked and cooked	Soaked and cooked	Soaked, dehulled and cooked
Vegetable peas				
Bonneville	630.33±0.4	586.89±0.5 (- 7)	572.64±0.1 (- 9)	446.54±0.6 (- 29)
Arkel	651.66±0.6	608.15±0.2 (- 7)	593.73±0.9 (-9)	466.59±0.7 (-28)
Field peas				
HFP4 (Aparna)	761.33±0.4	717.58±0.1 (-6)	704.16±0.8 (- 8)	576.77±0.7 (-24)
Rachna	780.33±0.4	736.55±0.1 (-6)	723.21±0.2 (-7)	596.66±0.8 (-24)
SE(m)	±0.97	±0.44	±0.13	±0.13
CD(P < 0.05)	3.16	1.32	0.39	0.39

Values are means ± S.D. of three independent determinations

Figures in parentheses indicate per cent decrease (-) over control values

the control i.e. unsoaked and unsoaked pea seeds Table-5. Cooking of unsoaked seeds also lowered down the phytic acid content of peas but the loss appeared to be less when soaked and soaked dehulled were ordinarily cooked. The percent loss of phytic acid ranged 24 to 29 when the seeds of different pea cultivars were soaked, dehulled and cooked; the maximum and minimum loss being in Bonneville and field peas, respectively.

On autoclaving of unsoaked seeds there was a significant reduction in phytic acid content i.e. to the extent of 6 to 8 per cent in different pea cultivars Table-6. Autoclaving of soaked as well as soaked-dehulled seeds caused a greater loss in phytic acid content than autoclaving of unsoaked seeds of vegetable and field peas. The unprocessed seeds of Bonneville contained 630.3 mg/100 g phytic acid which was reduced by 8, 13 and 51 per cent after autoclaving of unsoaked, soaked and soaked-dehulled pea seeds. Similar trends for reduction in phytic acid content were observed for other pea cultivars also. Autoclaving of soaked-dehulled seeds appeared to be more beneficial for lowering down the phytic acid content; per cent loss ranged from 41 to 51 in pea varieties.

As obvious decrease noticed in phytic acid content of field & vegetable pea varieties due to ordinary cooking and autoclaving may be attributed to the formation of insoluble complexes between phytate and other components (Kumar et al., 1978). Results of the present study are similar to those reported by Manan et al. (1987). They reported that cooking of peas resulted in considerable reduction (82%) in the phytic acid content of Pakistani varieties without any loss of total phosphorus. Similar reduction in phytate content during the combine process of soaking and cooking has been reported in various legumes including moth bean, rice bean and faba beans

Table 6: Effect of autoclaving on phytic acid content of peas (mg/100 g, on dry matter basis)

Varieties	Control	Unsoaked and autoclaved	Soaked and autoclaved	Soaked, dehulled and autoclaved
Vegetable peas				
Bonneville	630.3±0.4	582.6±0.9 (- 8)	546.3±0.8 (-13)	306.5±0.1 (- 51)
Arkel	651.7±0.6	604.4±0.1 (- 7)	566.6±0.1 (- 13)	333.6±0.1 (-49)
Field peas				
HFP4 (Aparna)	761.3±0.4	713.8±0.2 (- 6)	676.6±0.1 (- 11)	446.8±0.1 (- 41)
Rachna	780.3±0.4	732.8±0.2 (- 6)	696.4±0.3 (- 11)	460.7±0.1 (-41)
SE(m)	±0.97	±0.14	±0.17	±0.11
CD(P < 0.05)	3.16	0.47	0.51	0.35

Values are means ± S.D. of three independent determinations

Figures in parentheses indicate per cent decrease (-) over control values

(Khokhar, 1984; Kaur and Kapoor, 1990 ; Sharma, 1989).

Germination also resulted in a significant ($P < 0.05$) loss of phytic acid in field and vegetable pea seeds. As the period of germination was prolonged i.e. 0 to 12, 12 to 24 and 24 to 48 h, significant ($P < 0.05$) and successive reduction in phytic acid content was observed Table-7. A loss of 6 to 8 per cent occurred during 12 h germination which enhanced further with rise in the period of germination. After 48 h of sprouting, pea seeds contained phytic acid which 67 to 83 per cent less than that in the unprocessed seeds. Rachna and Bonneville had the maximum and minimum phytic content after 48 h of germination, respectively. Germination for 24 and 48 h seemed to be having the most pronounced effect on decreasing the phytic acid content of the pea seeds when compared to other processing methods.

Loss of phytic acid during germination may be due to hydrolytic activity of phytase reported to be present in various plant foods (Chang, 1967; Shrivastava, 1964; Mandal et al., 1972; Mandal and Biswas, 1970; Lolas and Markakis, 1977). Germination has been reported earlier by different workers to have a diminishing effect on the phytic acid content of various legumes including cowpea, soybean and lima bean (Ologhobo and Fetuga, 1984), moth bean (Khokhar, 1984), rice bean (Kaur, 1986) and faba bean (Sharma, 1989).

4.3.1.2 Polyphenols

The polyphenolic compounds in the pea have been expressed as tannic acid equivalents. Raw unprocessed vegetable and field peas were found to contain varying amounts of polyphenols i.e. 1.80 to 2.10 mg/100 g Table-8 . There were non-significant differences between the

Table 7 : Effect of germination on phytic acid content of peas (mg/100 g, on dry matter basis)

Varieties	Control	Period of germination		
		12h	24 h	48 h
Vegetable peas				
Bonneville	630.3±0.4	580.8±0.3 (- 8)	481.8±0.3 (-24)	106.5±0.2 (-83)
Arkel	651.7±0.6	602.3±0.3 (- 8)	503.3±0.3 (-23)	133.6±0.1 (-80)
Field peas				
HFP4 (Aparna)	761.3±0.4	711.6±0.1 (-7)	612.6±0.1 (-20)	246.8±0.1 (-68)
Rachna	780.3±0.4	730.7±0.3 (-6)	621.7±0.3 (-20)	260.7±0.1 (-67)
SE(m)	±0.97	±0.05	±0.11	±0.12
CD($P < 0.05$)	3.16	0.15	0.35	0.36

Values are means ± S.D. of three independent determinations

Figures in parentheses indicate per cent decrease (-) over control values

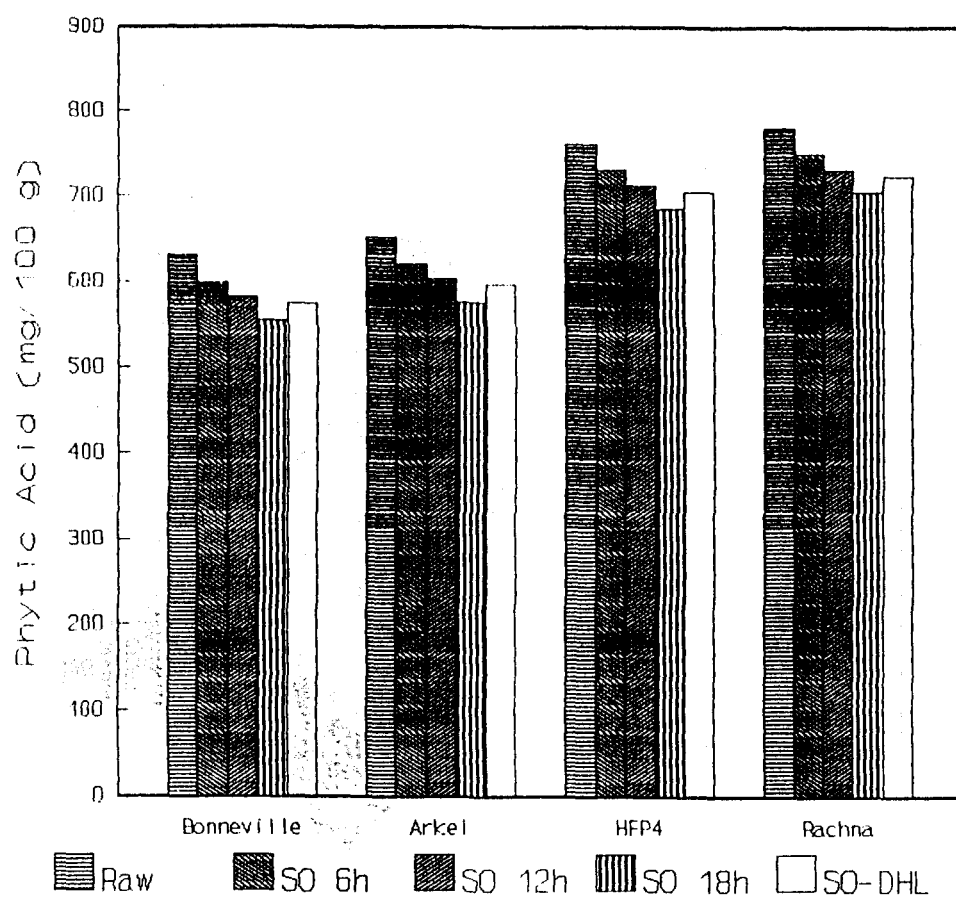


Fig. 1: Effect of Soaking (SO) and Dehulling (DHL) of Peas on Phytic Acid Content.

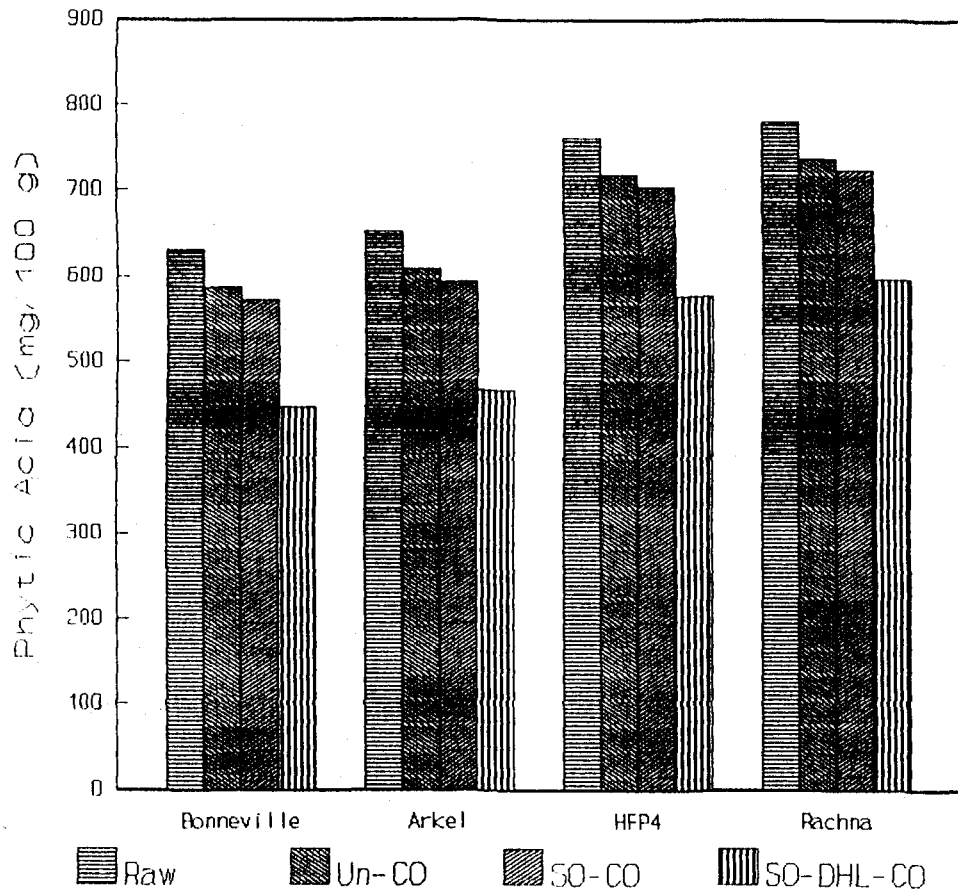


Fig.2 : Effect of Cooking (CO) of Unsoaked, Soaked and Soaked+dehulled Peas on Phytic Acid Content.

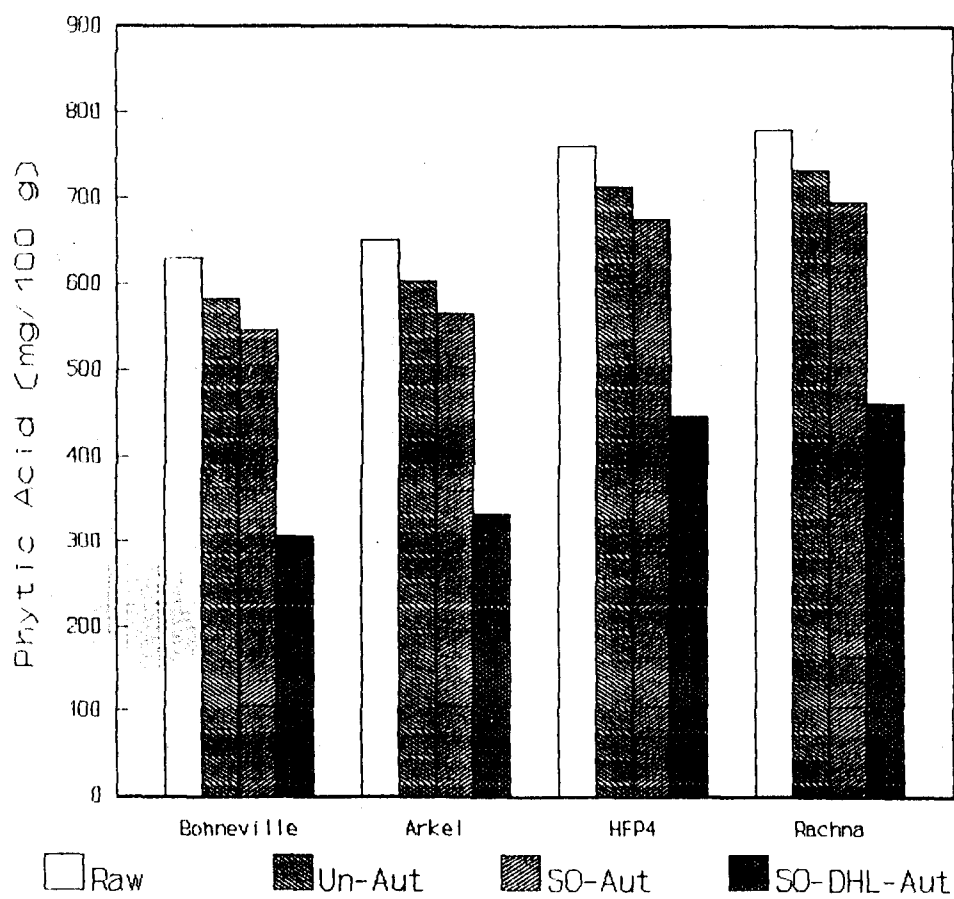


Fig.3 : Effect of Autoclaving (Aut) of Unsoaked, Soaked and Soaked+Dehulled Peas on Phytic Acid Content.

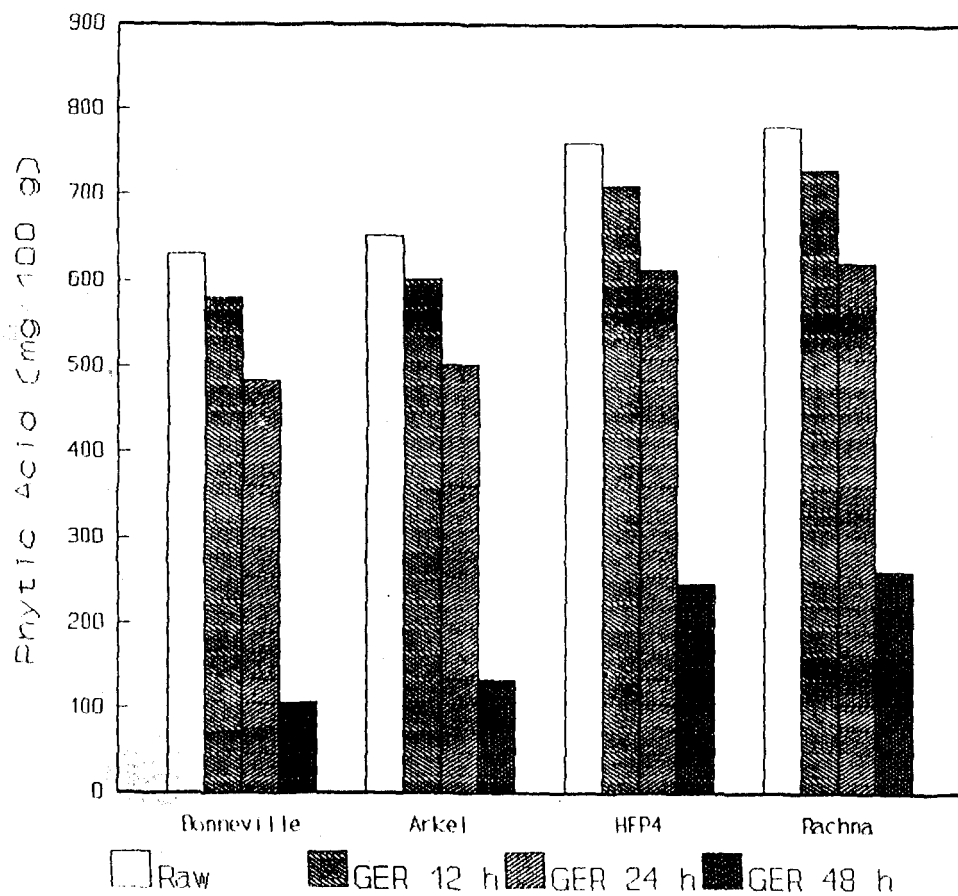


Fig. 4 : Effect of Germination (GER) of Peas on Phytic Acid Content.

Table 8 : Effect of soaking and dehulling on polyphenolic content of peas (mg/100 g, on dry matter basis)

Varieties	Control	Period of soaking			Soaked and dehulled
		6h	12 h	18 n	
Vegetable peas					
Bonneville	1.8±0.06	1.05±0.03 (-42)	0.85±0.02 (-53)	0.76±0.03 (-58)	0.57±0.03 (-68)
Arkel	1.9±0.05	1.16±0.02 (-39)	0.98±0.01 (-48)	0.84±0.04 (-56)	0.64±0.02 (-66)
Field peas					
HFP4 (Aparna)	2.1±0.05	1.36±0.02 (-35)	1.18±0.01 (-44)	1.06±0.01 (-50)	0.87±0.01 (-59)
Rachna	2.0±0.03	1.24±0.02 (-38)	1.05±0.02 (-48)	0.97±0.02 (-52)	0.76±0.02 (-62)
SE (m)	±0.05	±0.02	±0.01	±0.02	±0.03
CD (P < 0.05)	0.15	0.06	0.04	0.06	0.09

Values are means ± S.D. of three independent determinations

Figures in parentheses indicate per cent decrease (-) over control values

polyphenol contents of HFP4 (Aparna) and Rachna, Rachna and Arkel and Bonneville and Arkel. Both the field pea varieties had significantly ($P < 0.05$) higher amount of polyphenols than those of vegetable pea cultivars. The concentration of tannins in the seed of field peas seem to be the function of the colour of seed coat.

According to Savage and Deo, (1989) the tannin content of pea seeds ranged from 0.2 to 0.4 g/kg while phenolic acid content in peas was reported as 26 mg/kg. The phenolic group of tannins binds to enzymes and other proteins by hydrogen bonding to amide groups to form insoluble complexes. Polyphenols and tannins react with the alpha amino group of lysine and polymerize into tannin-protein complexes, which will make large blocks of amino acids resistant to the digestive enzymes of monogastric animals (Sosulski, 1979). Lindgren (1975) using laying hens clearly showed that peas containing higher level of tannins had a significantly lower metabolizable energy content and lower crude protein digestibility than low tannin containing peas.

The regression coefficient linking tannin content and the digestible crude protein in hens would suggest that a reduction in tannin content of 1 per cent in peas would result in an increase of crude protein digestibility of 5 per cent .

Soaking of peas for varying periods had marked reducing effect on the polyphenols and it increased with increase in the time period of soaking. After 6 h soaking the polyphenolic contents were lowered down to the extent of 35 to 42 Table-8. When this period of soaking was increased to 12 and 18 h, the percentage losses in polyphenolic compounds varied from 44 to 53 and 50 to 58, respectively. Soaking for 12 h and

followed by dehulling had the most pronounced effect on the reduction of polyphenols. After dehulling of soaked seeds, 59 to 68 per cent polyphenolic contents were lost. After soaking and dehulling, Bonneville and HFP4 had the maximum and minimum polyphenol contents, respectively. As polyphenols are present on the periphery of the seed, hence, there is a possibility of their passing out into the soaking medium through seed coat. Loss of polyphenols during soaking may be attributed to this effect. As seed coat contains maximum amount of tannins, a cumulative effect of soaking and dehulling was more pronounced. Previous workers (Deshpande and Cheryan, 1983; Kaur, 1986; Kataria et al., 1989; Sharma, 1989) also reported similar results for various legumes including rice bean, amphidiploids (green gram x black gram), faba beans.

Cooking of unsoaked seeds had marginal reducing effect on polyphenolic content of different pea cultivars. A loss of 8 to 9 per cent was observed in peas which were cooked without prior soaking Table-9. Cooking after soaking and dehulling brought about a significant ($P < 0.05$) decrease in the polyphenolic content of all the pea varieties. The processes including soaking as well as cooking could lower down the polyphenolic compounds to the extent of 49 to 56 per cent Table-9. This loss became greater when cooking was done after soaking and dehulling. The raw seeds of Arkel contained 1.90 mg/100 g polyphenols and these were reduced to 0.307 mg/100 g after cooking of the soaked-dehulled seeds. The minimum loss i.e. 68 per cent was noticed in seeds of HFP4 cultivar.

On autoclaving of unsoaked seeds of different pea cultivars, a significant ($P < 0.05$) reduction in polyphenol levels was observed when

Table 9 : Effect of ordinary cooking on polyphenolic content of peas (mg/100 g, on dry matter basis ,

Varieties	Control	Unsoaked and cooked	Soaked and cooked	Soaked, dehulled and cooked
Vegetable peas				
Bonneville	1.8±0.06	1.64±0.02 (-9)	0.79±0.05 (-56)	0.38±0.04 (-79)
Arkel	1.9±0.05	1.72±0.01 (-9)	0.89±0.09 (-53)	0.30±0.02 (-84)
Field peas				
HFP4 (Aparna)	2.1±0.05	1.94±0.02 (-8)	1.08±0.02 (-49)	0.68±0.01 (-68)
Rachna	2.0±0.03	1.84±0.01 (-8)	0.99±0.08 (-51)	0.58±0.01 (-71)
SE(m)	±0.05	±0.04	±0.07	±0.03
CD (P < 0.05)	0.15	0.13	0.21	0.09

Values are means ± S.D. of three independent determinations

Figures in parentheses indicate per cent decrease (-) over control values

Table 10: Effect of autoclaving on polyphenolic content of peas (mg/100 g, on dry matter basis)

Varieties	Control	Unsoaked and autoclaved	Soaked and autoclaved	Soaked, dehulled and autoclaved
Vegetable peas				
Bonneville	1.8±0.06	1.59±0.4 (-12)	0.68±0.7 (-62)	0.27±0.05 (-85)
Arkel	1.9±0.05	1.68±0.06 (-12)	0.75±0.09 (-61)	0.21±0.02 (-89)
Field peas				
HFP4 (Aparna)	2.1±0.05	1.88±0.6 (-11)	0.99±0.8 (-53)	0.58±0.01 (-72)
Rachna	2.0±0.03	1.77±0.01 (-12)	0.85±0.03 (-58)	0.48±0.01 (-76)
SE(m)	±0.05	±0.02	±0.04	±0.02
CD(P<0.05)	0.15	0.06	0.13	0.06

Values are means ± S.D. of three independent determinations

Figures in parentheses indicate per cent decrease (-) over control values

compared to those of the control i.e. raw seeds. But this loss was more when the soaked seeds were autoclaved. A reduction to the extent of 11 to 12 per cent in unsoaked-autoclaved seeds was further raised (53 to 62 per cent) after autoclaving of the soaked seeds of different pea cultivar. The effect of autoclaving was noticed to be more vigorous when soaked and dehulled pea seeds were processed. Autoclaving of soaked-dehulled seeds could decrease the polyphenolic levels to the extent of 89 per cent in Arkel. Effect of ordinary cooking as well as autoclaving on dehulled seed was more as compared to the whole seeds which is attributed to the removal of tannins during dehulling Table-10.

Binding of polyphenols with other organic substances and protein or to alterations in the chemical structure of polyphenols which cannot be extracted by available methods, may explain a decrease in tannins of the legume grains during cooking. Moist heating involving ordinary cooking and autoclaving, may be responsible for destruction of polyphenols. The results of the present study are similar to those reported by earlier workers (Savage and Deo, 1989; Reddy et al., 1985; Ekfenyong, 1985; Sharma, 1989).

Among all the different processing methods, germination seemed to have a marked lowering effect on polyphenolic compounds present in peas Table-11. With an increase in the period of germination i.e. 12 to 24 and 24 to 48 h, losses went on increasing. Germination for 12 h led to reduction in the polyphenol level by 44 to 53 per cent in field and vegetable pea cultivars. After 48 h germination pea seeds had the minimum

Table 11 : Effect to germination on polyphenolic content of peas (mg/100 g, on dry matter basis)

Varieties	Control	Period of germination		
		12h	24 h	48 h
Vegetable peas				
Bonneville	1.8±0.06	0.84±0.02 (-53)	0.57±0.03 (- 68)	0.15±0.07 (- 92)
Arkel	1.9±0.05	0.97±0.01 (- 49)	0.50±0.00 (-74)	0.08±0.03 (- 96)
Field peas				
HFP4 (Aparna)	2.1±0.05	1.17±0.01 (-44)	1.08±0.7 (- 49)	0.34±0.02 (- 84)
Rachna	2.0±0.03	1.03±0.02 (- 48)	0.98±0.01 (- 51)	0.24±0.01 (-88)
SE(m)	±0.05	±0.01	±0.01	±0.01
CD (P < 0.05)	0.15	0.04	0.04	0.04

Values are means ± S.D. of three independent determinations

Figures in parentheses indicate per cent decrease (-) over control values

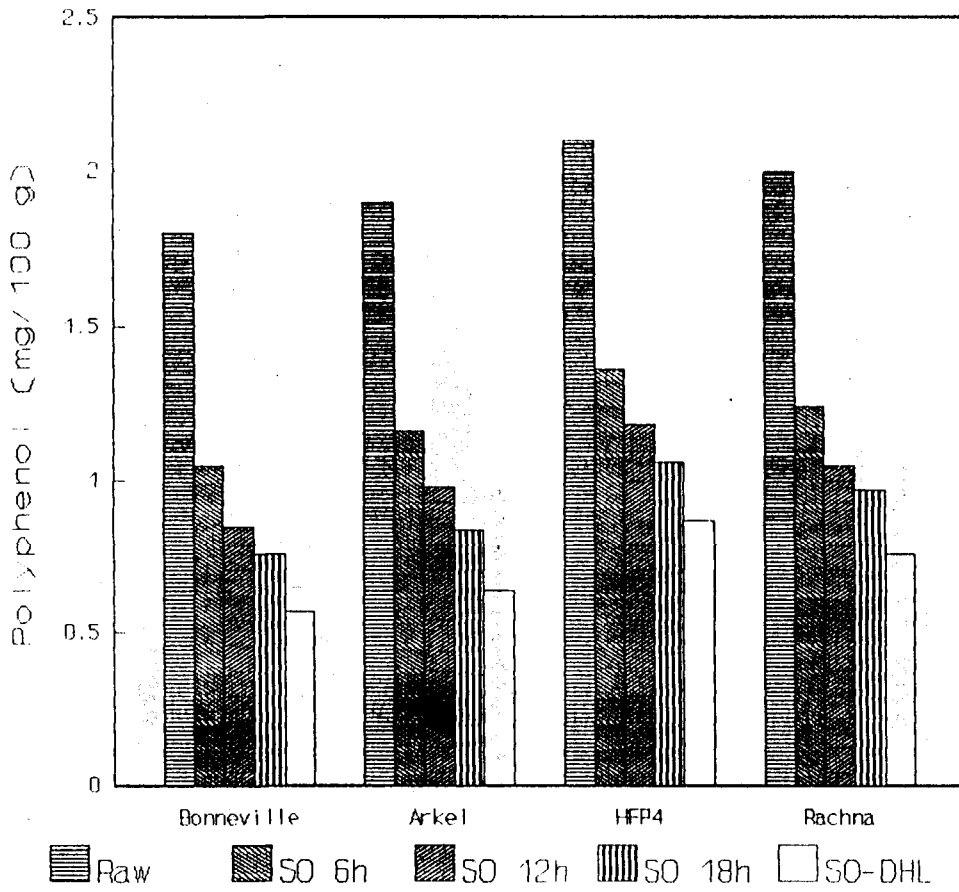


Fig. 5 : Effect of Soaking (SO) and Dehulling (DHL) of Peas on Polyphenolic Content.

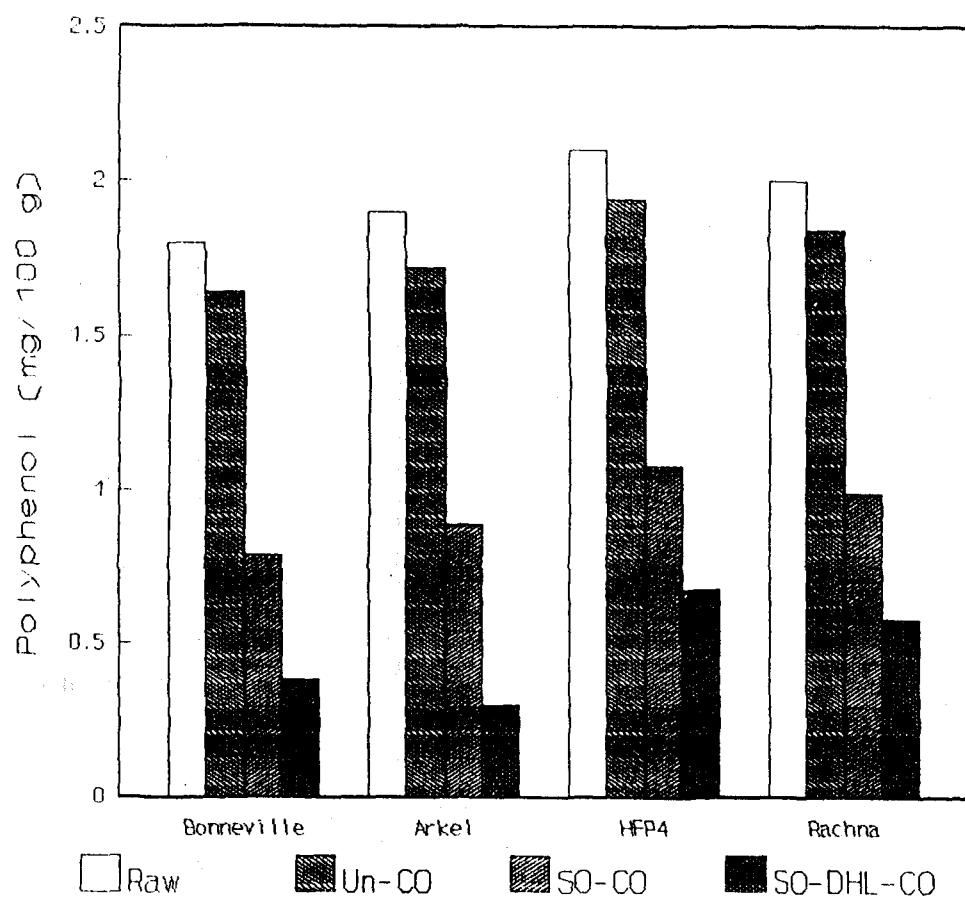


Fig. 6 : Effect of Cooking (CO) of Unsoaked, Soaked and Soaked+Dehulled Peas on Polyphenolic Content

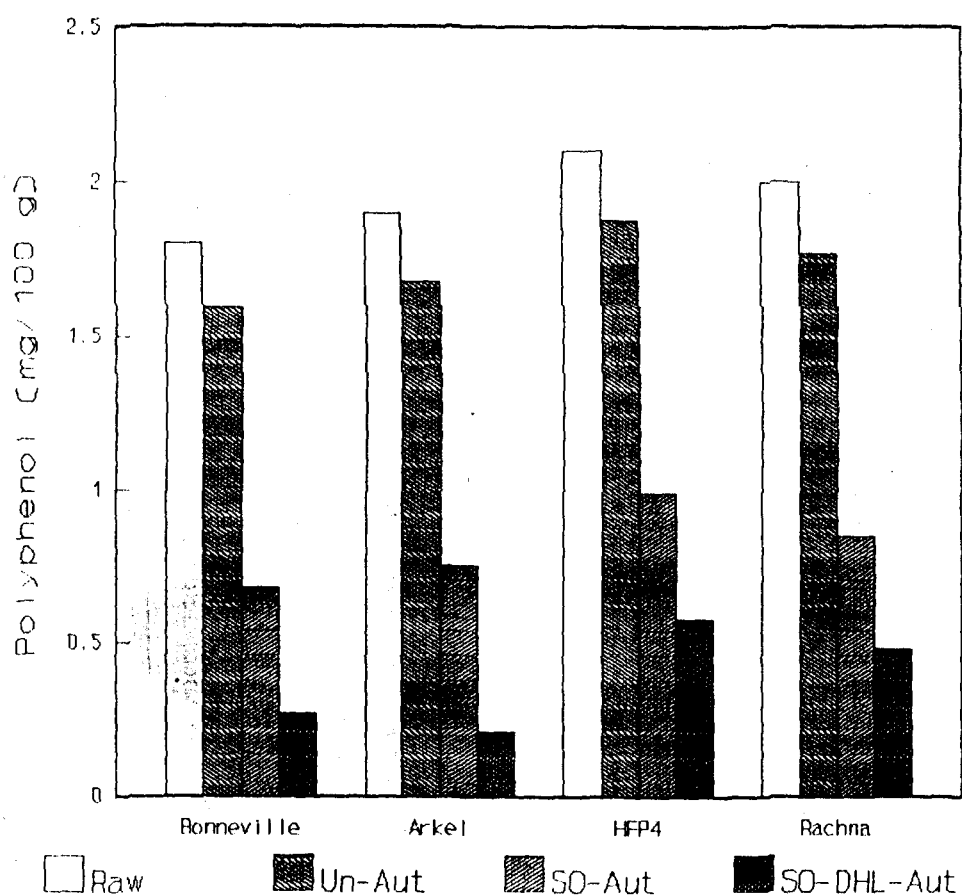


Fig.7 : : Effect of Autoclaving (Aut) of Unsoaked, Soaked and Soaked+Dehulled Peas on Polyphenolic Content.

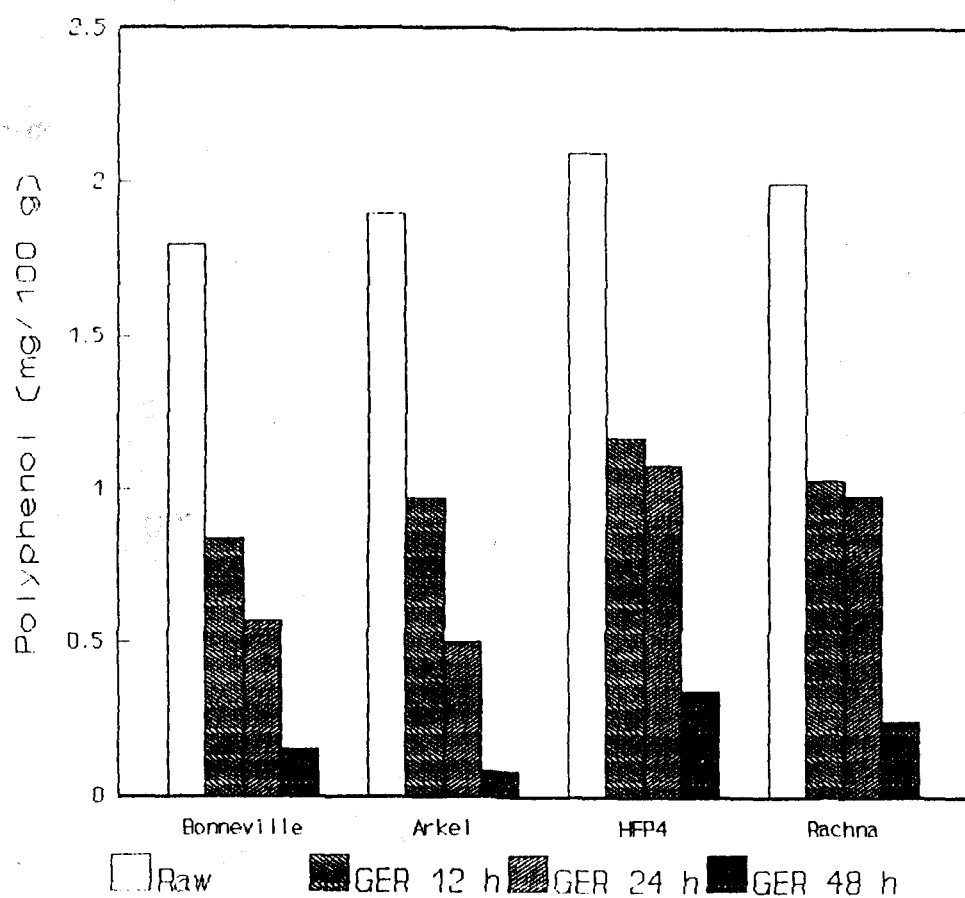


Fig.8: Effect of Germination (GER) of Peas on Polyphenolic Content.

content of polyphenols and it was 84 to 96 per cent less as compared to polyphenolic content of raw seeds. Among all the varieties, maximum reduction (96%) was found in seeds of Arkel variety after 48 h germination. Before germination, soaking is also done and some loss of polyphenol during soaking is also expected because of its leaching into the soaking water. Further decrease in polyphenol contents during germination may be attributed to the presence of polyphenol-oxidase and enzymatic hydrolysis (Rao and Deosthale, 1982; Jood et al., 1987). Germination has been reported to decrease the tannin content of moth bean, faba bean, chick pea etc. in previous studies. (Khokhar, 1984; Sharma, 1989).

4.3.1.3 Saponin

Saponin content varied from 240 to 251 and 109 to 119 mg per 100 g in vegetable and field pea varieties, respectively Table-12.

After soaking of vegetable and fields peas for varying periods i.e. 6, 12 and 18 h, saponin content reduced significantly ($P < 0.05$). After 18 h soaking, vegetable peas contained saponins which were less by 3 to 26 per cent when compared to unsoaked peas. As a result of soaking, reduction in saponin was significant ($P < 0.05$) and more in field peas as compared to vegetable peas. HFP4 and Rachna showed a reduction to the extent of 9 to 44 and 9 to 36 per cent, respectively when these seeds were soaked for different periods.

Dehulling of the soaked peas further brought about significant ($P < 0.05$) losses of saponin; the percent loss was higher in field peas i.e. HFP4 and Rachna when compared to vegetable pea varieties (Bonneville and Arkel). The values for reduction in saponin content due to soaking and dehulling of soaked pea differed significantly ($P < 0.05$) among the different

Table 12 : Effect of soaking and dehulling on saponin content of peas (mg/100 g, on dry matter basis)

Varieties	Control	Period of soaking			Soaked and dehulled
		6 h	12 h	18 h	
Vegetable peas					
Bonneville	251±0.05	241.2±0.05 (-4)	230.9±0.08 (-8)	186.5±0.02 (-26)	220.5±0.02 (-12)
Arkel	240±0.05	232.6±0.11 (-3)	222.5±0.01 (-7)	182.4±0.02 (-24)	212.7±0.07 (-11)
Field peas					
HFP4 (Aparna)	109±0.07	99.0±0.03 (-9)	90.5±0.01 (-17)	60.5±0.03 (-44)	80.6±0.01 (-26)
Rachna	119±0.07	108.6±0.02 (-9)	98.2±0.02 (-17)	76.5±0.04 (-36)	84.4±0.02 (-29)
SE (m)	±0.57	±2.15	±0.11	±0.25	±0.41
CD (P < 0.05)	1.86	7.01	0.35	0.81	1.33

Values are means ± S.D. of three independent determinations

Figures in parentheses indicate per cent decrease (-) over control values

pea varieties. The loss of saponin from the peas during soaking may be possibly due to leaching out of saponins into the water through simple diffusion. Similar results have also been reported by previous workers (Kataria et al., 1989; Khokhar and Chauhan, 1986; Kaur, 1986; Sharma, 1989) who observed that soaking for different periods reduced the saponin content of moth bean, rice bean, amphidiploids of green gram and black gram for faba beans.

When the unsoaked, soaked as well as soaked-dehulled pea seeds were cooked, reduction in saponins varied from 5 to 28 and 13 to 49 per cent in vegetable and field pea varieties, respectively Table-13. Per cent loss in saponin content varied from 6 to 13 when the unsoaked field and vegetable pea seeds were cooked. Cooking of the soaked seeds had more reducing effect on the saponin content; the reduction to the extent of 8 to 19 per cent was noticed in soaked and cooked peas. The maximum lowering effect on saponin content was observed when soaking for 12 h was followed by dehulling and cooking of field as well as vegetable pea cultivars. The saponin content of pea varieties varied significantly ($P < 0.05$) among themselves when cooking of unsoaked, soaked as well as soaked-dehulled peas was done.

Autoclaving at 1.05 kg/cm^2 at 15 minute caused a significant ($P < 0.05$) reduction in saponin content of unsoaked vegetable as well as field pea varieties; the maximum loss being in Rachna followed by HFP4 (Aparna), Bonneville and Arkel in descending order Table-14. Soaking alone and soaking followed by dehulling of peas further reduced the saponin content up to 50 and 68 per cent, respectively. The maximum loss in saponin content occurred when the pea seeds were dehulled after soaking and autoclaved.

Table 13 : Effect of ordinary cooking on saponin content of peas (mg/100 g, on dry matter basis)

Varieties	Control	Unsoaked and cooked	Soaked and cooked	Soaked, dehulled and cooked
Vegetable peas				
Bonneville	251±0.05	236.9±0.05 (-6)	229.3±0.02 (-9)	181.5±0.01 (-28)
Arkel	240±0.05	227.0±0.01 (-5)	220.5±0.01 (-8)	177.6±0.01 (-26)
Field peas				
HFP4 (Aparna)	109±0.07	95.3±0.01 (-13)	88.5±0.01 (-19)	55.3±0.02 (-49)
Rachna	119±0.07	103.5±0.02 (-13)	96.2±0.02 (-19)	75.2±0.02 (-37)
SE (m)	±0.57	±0.28	±0.17	±0.16
C.D.(P < 0.05)	1.86	0.91	0.51	0.48

Values are means ± S.D. of three independent determinations

Figures in parentheses indicate per cent decrease (-) over control values

Table 14 : Effect of autoclaving on saponin content of peas (mg/100 g, on dry matter basis)

Varieties	Control	Unsoaked and autoclaved	Soaked and autoclaved	Soaked, dehulled and autoclaved
Vegetable peas				
Bonneville	251±0.05	232.3±0.02 (-7)	180.5±0.02 (-28)	160.5±0.02 (-36)
Arkel	240±0.05	223.4±0.02 (-7)	176.7±0.02 (-26)	156.4±0.03 (-35)
Field peas				
HFP4 (Aparna)	109±0.07	91.4±0.04 (-16)	54.9±0.01 (-50)	34.5±0.07 (-68)
Rachna	119±0.07	99.1±0.08 (-17)	70.7±0.01 (-41)	55.2±0.02 (-54)
SE (m)	±0.57	±0.59	±0.15	±0.22
C.D. (P < 0.05)	1.86	1.92	0.45	0.71

Values are means ± S.D. of three independent determinations

Figures in parentheses indicate per cent decrease (-) over control values

Hence autoclaving of the soaked and dehulled peas appear to be more beneficial over autoclaving of soaked or unsoaked seeds for bringing about a reduction in saponins.

Loss during ordinary cooking and autoclaving may, perhaps, indicate, thermolabile nature of saponins. Not much is known about the formation of a poorly extractable complex between saponins and sugars or amino acids upon cooking (Khokhar and Chauhan, 1986). Our results contradict the earlier report that saponin are not destroyed during cooking and processing but are consistant with those reported by Kaur, 1986.

Sprouting of vegetable and field pea seeds for different time periods i.e. 12, 24 and 48 h at 30°C had a lowering effect on the saponin content Table-15. As the period of germination prolonged, a more pronounced reduction in saponin content of peas was noticed. The maximum loss occurred in HFP4 (Aparna) followed by Rachna. Arked and Bonneville when these were germinated for 12 h; the percent loss ranged from 8 to 21. With an increase in the period of germination i.e. 12 to 24 and 24 to 48 h, further significant ($P < 0.05$) losses in saponin content to the extent of 20 to 34 and 67 to 84 per cent, respectively were observed. Germination for 48 h had the maximum saponin lowering effect in the seeds of field pea cultivars i.e. HFP4 (Aparna) and Rachna. The saponin loss during germination may be due to enzymatic degradation but this explanation is still not well established. Various workers reported a reduction in saponin content of moth bean (Khokhar, 1984), rice bean (Kaur, 1986), Amphidiploids of green gram and black gram (Kataria, 1986) and faba beans (Sharma, 1989).

Table 15 : Effect of germination on saponin content of peas (mg/100 g, on dry matter basis)

Varieties	Control	Period of germination		
		12 h	24 h	48 h
Vegetable peas				
Bonneville	251±0.05	229.2±0.01 (-9)	200.4±0.01 (-20)	80.1±0.01 (-68)
Arkel	240±0.05	220.5±0.01 (-8)	192.6±0.01 (-20)	78.8±0.05 (-67)
Field peas				
HFP4 (Aparna)	109±0.07	86.5±0.02 (-21)	72.6±0.01 (-33)	17.2±0.04 (-84)
Rachna	119±0.07	95.3±0.04 (-20)	78.5±0.03 (-34)	28.5±0.04 (-76)
SE(m)	±0.57	±0.16	±0.14	±0.10
C.D.(P < 0.05)	1.86	0.48	0.47	0.30

Values are means ±S.D. of three independent determinations

Figures in parentheses indicate per cent decrease (-) over control values

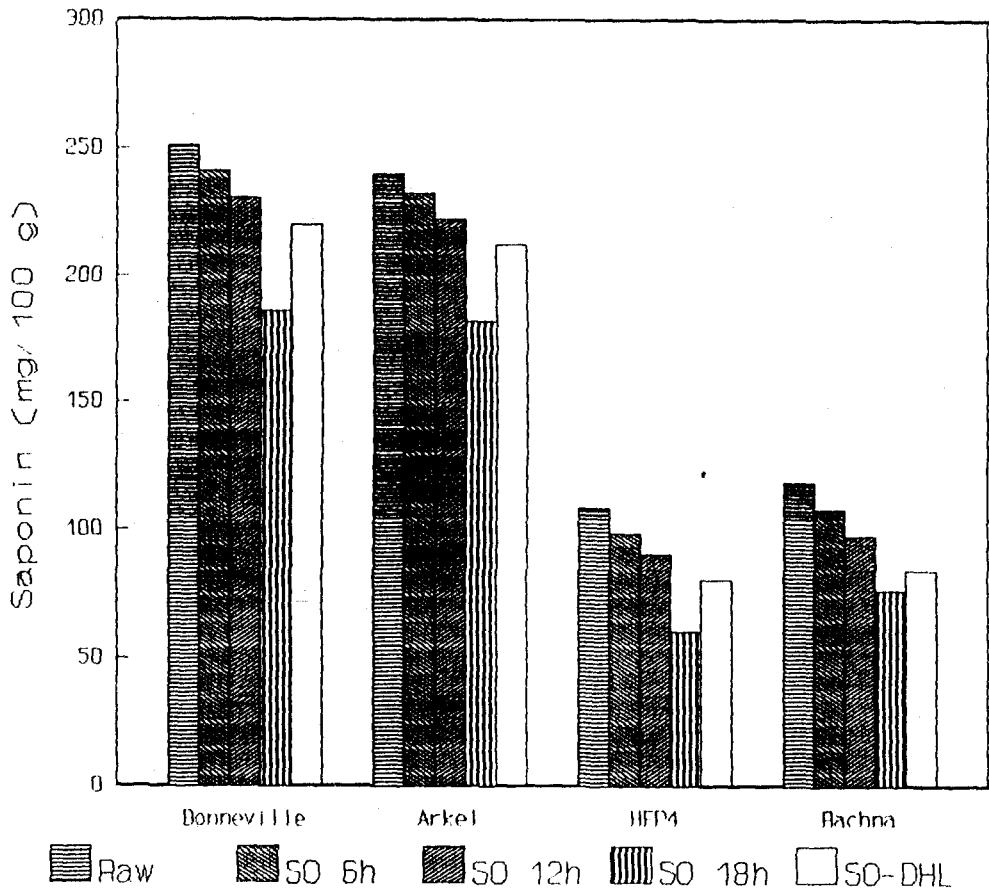


Fig. 9 : Effect of Soaking (SO) and Dehulling (DHL) of Peas on Saponin Content.

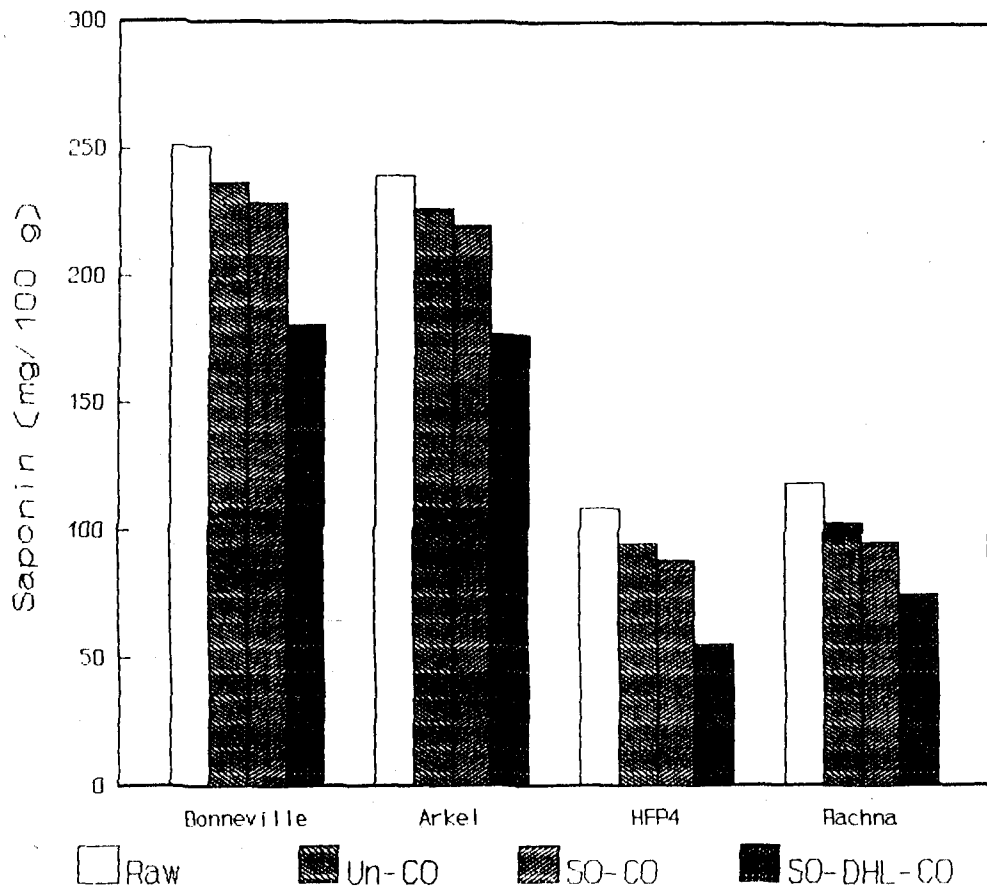


Fig.10 : Effect of Cooking (CO) of Unsoaked, Soaked and Soaked+Dehulled Peas on Saponin Content.

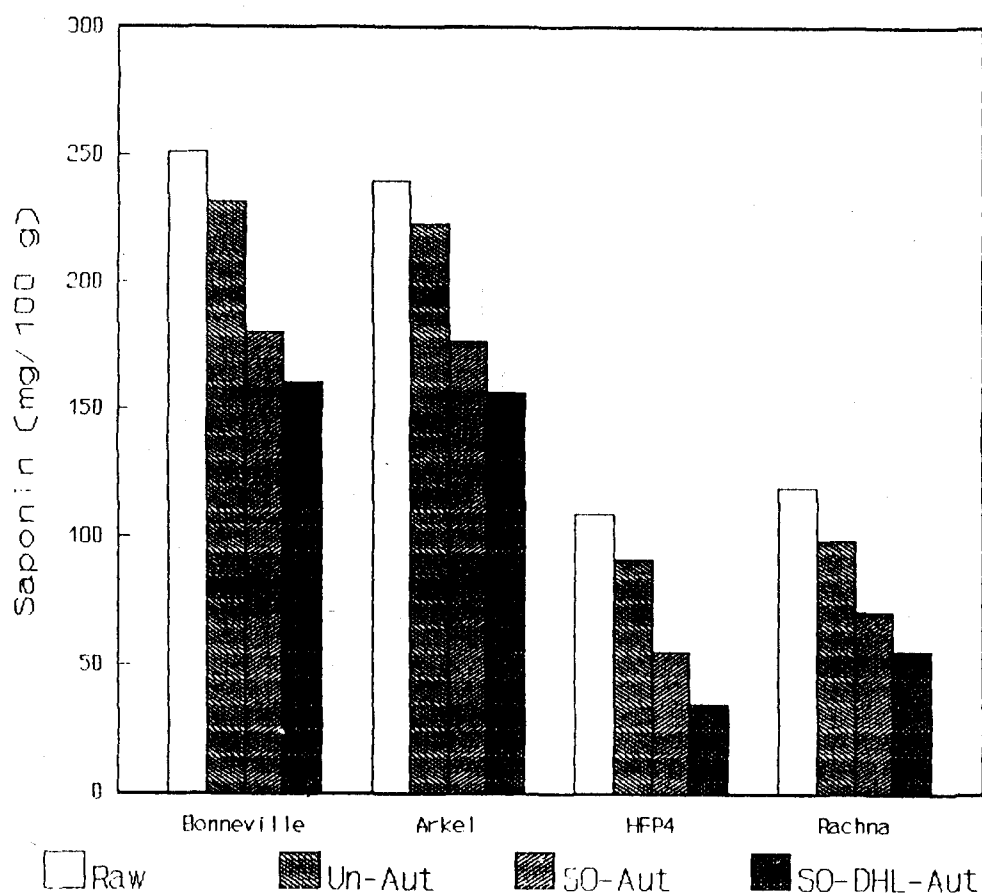


Fig.11 : Effect of Autoclaving (Aut) of Unsoaked, Soaked and Soaked+Dehulled Peas on Saponin Content.

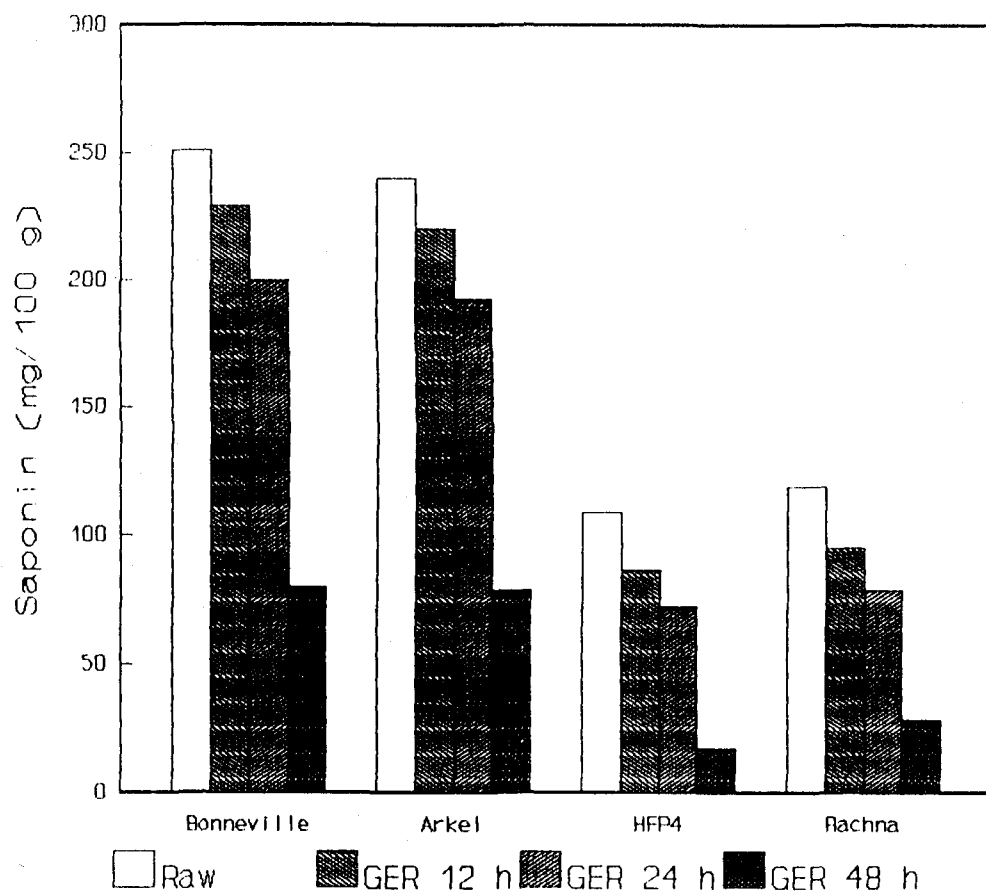


Fig.12 : Effect of Germination (GER) of Peas on Saponin Content.

4.3.1.4 Trypsin inhibitor activity

Trypsin inhibitors present in considerable amount in legumes are known to affect the digestibility of proteins. Raw unprocessed seeds of vegetable and field pea varieties contained varying amounts of trypsin inhibitor activity i.e. 922.4 to 989.5 TIU/g Table-16. There were significant differences between trypsin inhibitor activity of vegetable and field pea cultivar. Rachna and Bonneville had the maximum and minimum trypsin inhibitor activity, respectively. According to Savage and Deo (1989) the trypsin inhibitor content depends upon the type of peas. He reported that Wrinkled seeded peas had less trypsin-inhibitory activity than smooth-seeded types and spring types (2700 to 5500 u/g) on average had less than winter types (5700-11700 u/g). Valdebouze et al. (1980) stated that 90 per cent of the trypsin inhibitor activity was found in the kernel and 10 per cent in the testa, in direct proportion to the weight distribution of these factors in the whole pea seeds. These figures contradict with the range of values reported by Savage and Deo (1989) i.e. 150 to 10800, 250 to 870 and 3000 to 12000 u/g in whole seeds, testa and kernel of peas, respectively. Deo (1987) showed that trypsin inhibitor content ranged from 0 u/g for variety Rovar to 71 u/g for cultivar Whero of peas. John (1986) showed that the trypsin inhibitor content of field pea varieties ranged from 58 to 716 u/g.

Soaking of seeds in water for 6 h could marginally reduce the trypsin inhibitor activity; the per cent loss ranged from 0.80 to 1.0 only Table-16. As the period of soaking was increased to 12 and 18 h, further losses in trypsin inhibitor activity occurred.

Table 16 : Effect of soaking and dehulling on trypsin inhibitor activity in peas (TIU/g, on dry matter basis)

Varieties	Control	Period of soaking			Soaked and dehulled
		6 h	12 h	18 h	
Vegetable peas					
Bonneville	922.4±0.4	913.3±0.5 (-0.99)	888.0±0.3 (-4)	525.1±0.4 (-43)	829.2±0.1 (-10)
Arkel	927.6±0.8	920.2±0.5 (-0.80)	893.1±0.2 (-4)	540.2±0.7 (-42)	839.2±0.3 (-10)
Field peas					
HFP4 (Aparna)	980.3±0.5	970.2±0.2 (-1.03)	946.2±0.8 (-4)	588.3±0.6 (-40)	892.1±0.4 (-9)
Rachna	989.5±0.9	981.3±0.2 (-0.83)	955.2±0.6 (-3)	608.2±0.6 (-39)	902.0±0.1 (-9)
SE (m)	±0.15	±0.10	±0.05	±0.10	±0.06
CD (P<0.05)	0.45	0.30	0.15	0.30	0.20

Values are means ± S.D. of three independent determinations

Trypsin inhibitor units : One unit of trypsin was defined as the amount of enzymes which converted one mg casein in TCA soluble components at 37°C for 20 minute at pH 7.6

Figures in parentheses indicate per cent decrease (-) over control values

A loss of 3 (H FP4 and Rachna) to 4 per cent (Bonneville) in trypsin inhibitor activity was noticed after 12 h soaking. Trypsin inhibitor activity was reduced to almost half in all the four pea varieties after soaking for 18 h. Soaking (12 h) followed by dehulling also brought about a decrease in trypsin inhibitor activity to the extent of 9 to 10 per cent, compared to 12 h soaking alone. Loss of trypsin inhibitors during soaking may possibly be due to leaching out of solids against concentration gradient governing the rate of diffusion. Generally, trypsin inhibitors are low molecular weight proteins and hence, they are likely to pass out from the seed to the soaking medium easily. Earlier workers (Deshpande and Cheryan, 1983; Sharma, 1989) also reported that soaking of dry legumes in water reduced the trypsin inhibitor activity.

Cooking of unsoaked, soaked and soaked-dehulled pea seeds was found to be effective in lowering down the level of trypsin inhibitors. Cooking of unsoaked seeds could not bring about a drastic reduction in trypsin inhibitor activity; only 2.0 per cent loss occurred over the control. The trypsin inhibitor activity in Bonneville, Arkel, HFP4 and Rachna was significantly ($P < 0.05$) reduced to 73, 68, 65 and 67 per cent, respectively when seeds after soaking in water for 12 h were cooked to softness. It was further decreased as a result of cooking of the soaked and dehulled pea seeds. Maximum reduction in trypsin inhibitor activity was observed in Bonneville followed by Arkel, Rachna and HFP4 when their seeds were soaked-dehulled and cooked Table-17.

Autoclaving for 15 psi for 15 minute lowered down the trypsin inhibitor activity in different pea cultivars. There was not much reduction in the level of trypsin inhibitors when unsoaked seeds were autoclaved. When soaked and dehulled pea seeds were autoclaved, 90 to 95 per cent trypsin inhibitor was lost over the control values. After soaking, dehulling and autoclaving,

Tables 17 : Effect of ordinary cooking on trypsin inhibitor activity in peas (TIU/g, on dry matter basis)

Varieties	Control	Unsoaked and cooked	Soaked and cooked	Soaked, dehulled and cooked
Vegetable peas				
Bonneville	922.4±0.4	905.1±0.05 (-2)	249.2±0.2 (-73)	201.1±0.5 (-78)
Arkel	927.6±0.8	910.2±0.1 (- 2)	299.2±0.7 (-68)	228.1±0.5 (-75)
Field peas				
HFP4 (Aparna)	980.3±0.5	963.2±0.2 (- 2)	342.1±0.4 (-65)	309.2±0.4 (-68)
Rachna	989.5±0.9	972.2±0.4 (- 2)	331.2±0.8 (-67)	300.1±0.4 (-70)
SE(m)	±0.15	±0.15	±0.07	±0.05
CD (P < 0.05)	0.45	0.45	0.21	0.15

Values are means ± S.D. of three independent determinations

Trypsin inhibitor units: One unit of trypsin was defined as the amount of enzymes which converted one mg casein to TCA soluble components at 37°C for 20 minute at pH 7.6

Figures in parentheses indicate per cent decrease (-) over control values

Table 18: Effect of autoclaving on trypsin inhibitor activity in peas (TIU/g, on dry matter basis)

Varieties	Control	Unsoaked and autoclaved	Soaked and autoclaved	Soaked, dehulled and autoclaved
Vegetable peas				
Bonneville	922.4±0.4	898.0±0.1 (-3)	101.2±0.8 (-89)	50.2±0.1 (-95)
Arkel	927.6±0.8	902.3±0.1 (-3)	128.2±0.70 (-86)	62.2±0.1 (-93)
Field peas				
HFP4 (Aparna)	980.3±0.5	954.2±0.8 (-3)	209.1±0.8 (-79)	100.1±0.8 (-90)
Rachna	989.5±0.9	962.2±0.4 (-3)	200.0±0.3 (-80)	99.1±0.4 (-90)
SE (m)	±0.15	±0.10	±0.05	±0.05
CD (P< 0.05)	0.45	0.30	0.15	0.15

Values are means ± S.D. of three independent determinations

Trypsin inhibitor units: One unit of trypsin was defined as the amount of enzymes which converted one mg casein to TCA soluble components at 37°C for 20 minute at pH 7.6

Figures in parentheses indicate per cent decrease (-) over control values

Bonneville cultivar had only 50.2 TIU/g. The trypsin inhibitor activities varied significantly ($P < 0.05$) among unprocessed, raw autoclaved pea seeds Table-18.

Trypsin inhibitors are heat labile and this may explain the destroying effect of cooking on trypsin inhibitor activity. Results of this study are well supported by the previous studies done in various legumes by different workers (Manorma and Sarojini, 1982; Marickar and Pattabiraman, 1986; Ologhobo and Fetuga, 1983; Sharma, 1989). Manorma and Sarojini (1982) reported that soaking of soybean seeds in water (20 h) followed by steaming in a pressure cooker (15 Psi) was the best method for inactivation of trypsin inhibitor activity.

Sprouting for 12, 24 and 48 h reduced the level of trypsin inhibitors to a varying extent Table -19 . Longer the period of germination, more were the losses in trypsin inhibitor activities of peas. Germination for 12 h decreased this autinutrient by 6 to 7 per cent. Varietal differences were found to have a significant ($P < 0.05$) effect on the destruction of trypsin inhibitor activity in sprouted peas. After 24 and 48 h germination, the per cent loss in trypsin inhibitor activity varied from 49 to 62. A decrease in trypsin inhibitor activity during germination may perhaps be due to the mobilization and breakdown of chemical constituent including trypsin inhibitor. Similar findings have been reported in various legumes in different studies (Bansal, 1988; Verma and Mehta, 1988; Sharma, 1989). Bansal (1988) reported the complete destruction of trypsin inhibitor activity in sprouted Chick pea (8 days).

4.3.2 In vitro digestibility

4.3.2.1 Starch digestibility

Starch digestibility (in vitro) expressed as mg maltose released/g

Table 19 : Effect of germination on trypsin inhibitor activity in peas (TIU/g, on dry matter basis)

Varieties	Control	Period of germination		
		12 h	24 h	48 h
Vegetable peas				
Bonneville	922.4±0.4	858.1±0.2 (- 7)	475.0±0.2 (-49)	350.2±0.9 (-62)
Arkel	927.6±0.8	863.2±0.6 (-7)	490.2±0.5 (-47)	370.2±0.1 (-60)
Field peas				
HFP4 (Aparna)	980.3±0.5	920.2±0.6 (-6)	538.1±0.3 (-45)	432.3±0.3 (-56)
Rachna	989.5±0.9	930.2±0.5 (-6)	550.3±0.6 (-44)	420.3±0.6 (-58)
SE (m)	±0.15	±0.10	±0.08	±0.11
CD ($r<0.05$)	0.45	0.30	0.27	0.35

Values are means ± S.D. of three independent determinations

Trypsin inhibitor units : One unit of trypsin was defined as the amount of enzymes which converted one mg casein to TCA soluble components at 37°C for 20 minute at pH 7.6

Figures in parentheses indicate per cent decrease (-) over control values

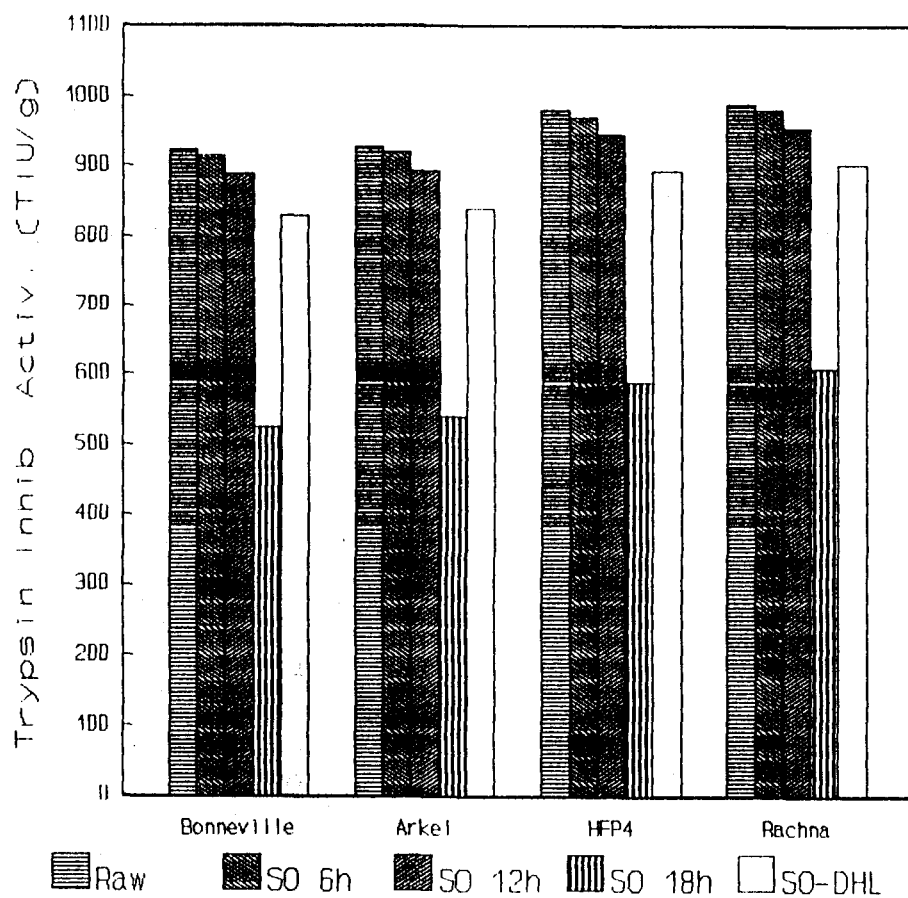


Fig.13 : Effect of Soaking (SO) and Dehulling (DHL) of Peas on Trypsin Inhibitor Activity.

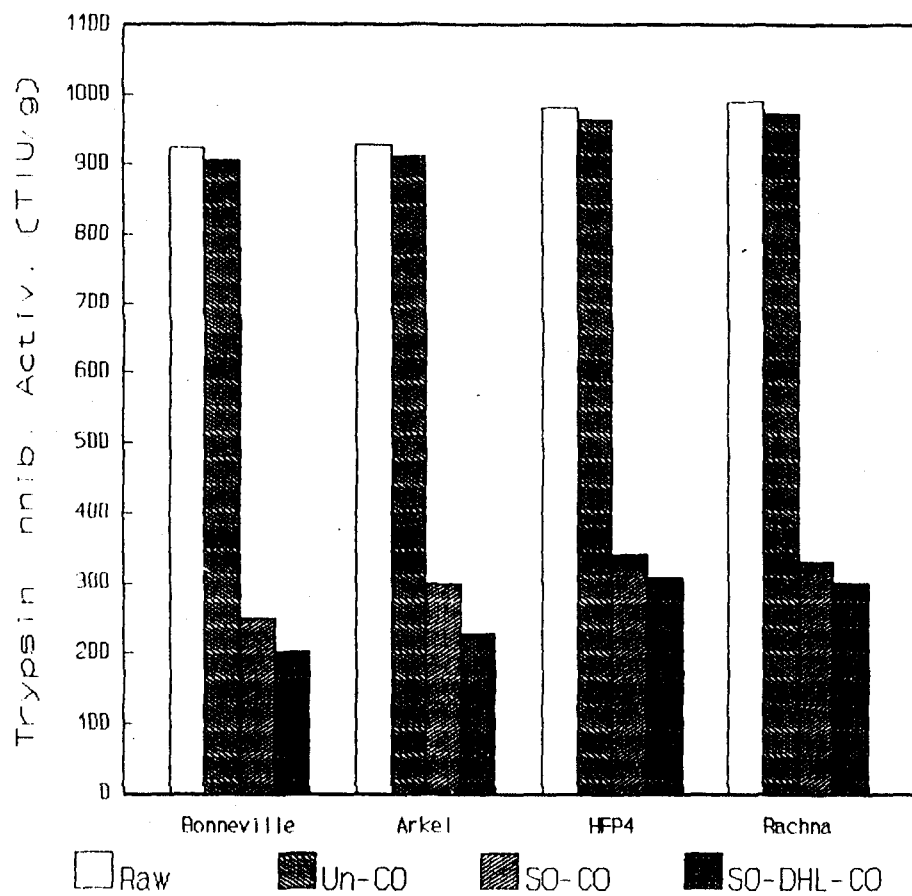


Fig. 14 : Effect of Cooking (CO) of Unsoaked, Soaked and Soaked+Dehulled Peas on Trypsin Inhibitor Activity.

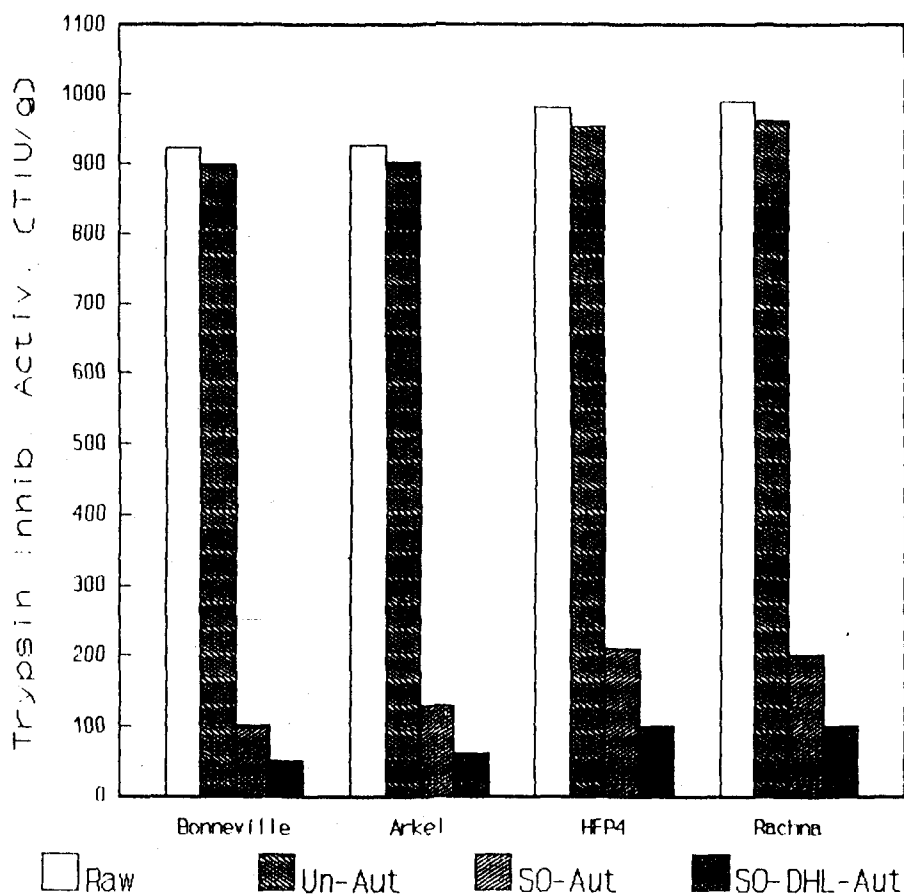


Fig. 15 : Effect of Autoclaving (aut) of Unsoaked, Soaked and Soaked+Dehulled Peas on Trypsin Inhibitor Activity.

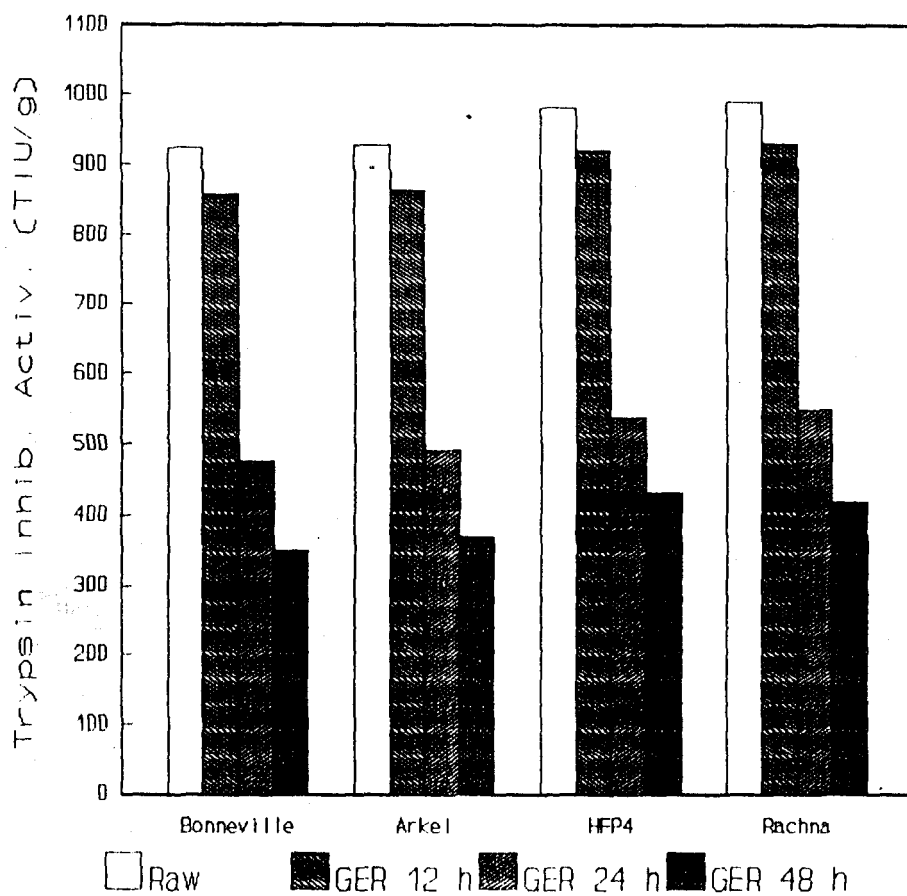


Fig. 16 : Effect of Germination (GER) of Peas on Trypsin Inhibitor Activity.

flour was 30.53 to 36.53 in raw unprocessed seeds of different pea cultivars. Field pea cultivars viz. HFP4 and Rachna had significantly ($P = 0.05$) lower in vitro starch digestibility when compared to that of vegetable pea varieties Table-20.

A significant ($P = 0.05$) improvement in starch digestibility occurred when pea seeds were soaked in water for different time periods; it improved with an increase in the period of soaking Table-20. There was an increase of 8 to 13 per cent over control values in seeds soaked for 6 h. Soaking for 12 h enhanced the starch digestibility which was 17 to 23 per cent higher than the corresponding values in raw unprocessed pea seeds. Among all the time periods, maximum improvement in starch digestibility was noticed when the seeds were soaked for 18 h. The highest and the lowest improvement was found in Rachna (48%) and Bonneville (36%), respectively. The corresponding values for enhancement in starch digestibility in soaked and dehulled pea seeds seemed to be higher than the seeds which were soaked for 12 h.

Enhancement of starch digestibility as a result of soaking, may be attributed to loss of antinutritional factors like phytic acid, polyphenols etc. which inhibit the activity of alpha amylase and thus, lower the starch digestibility (Deshpande and Cheryan, 1984). Reduction in the levels of phytic acid and polyphenols after soaking the legumes as reported in the present study Table -4 and 8 and other workers (Boralkar and Reddy, 1985; Kataria, 1986; Sharma, 1989) may support our findings.

On cooking the unsoaked pea seeds, in vitro starch digestibility improved to a great extent in all the pea cultivars. The maximum improvement was witnessed in Rachna (55%) followed by HFP4 (45%), Arkel (43%) and

Table 20 : Effect of soaking and dehulling on in vitro starch digestibility of peas (mg maltose released/g meal, on dry matter basis)

Varieties	Control	Period of soaking			Soaked and dehulled
		6 h	12 h	18 h	
Vegetable peas					
Bonneville	36.53±0.03	39.33±0.05 (+8)	42.62±0.01 (+17)	49.70±0.01 (+36)	47.30±0.02 (+29)
Arkel	35.30±0.01	38.23±0.02 (+8)	41.64±0.05 (+18)	48.30±0.03 (+37)	46.60±0.14 (+32)
Field peas					
HFP4 (Aparna)	30.53±0.04	33.60±0.03 (+10)	36.20±0.01 (+19)	43.13±0.01 (+41)	41.36±0.03 (+35)
Rachna	31.23±0.02	35.16±0.02 (+13)	38.43±0.07 (+23)	46.33±0.06 (+48)	44.46±0.05 (+42)
SE (m)	±0.12	±0.45	±0.04	±0.09	±0.04
CD (P < 0.05)	0.40	1.35	0.13	0.30	0.13

Value are means ± S.D. of three independent determinations

Figures in parentheses indicate per cent increase (+) over control values

Table 21 : Effect of ordinary cooking on in vitro starch digestibility of peas (mg maltose released/g meal, on dry matter basis)

Varieties	Control	Unsoaked and cooked	Soaked and cooked	Soaked, dehulled and cooked
Vegetable peas				
Bonneville	36.53±0.03	51.80±0.01 (+42)	54.50±0.05 (+49)	78.43±0.02 (+115)
Arkel	35.30±0.01	50.60±0.03 (+43)	53.30±0.02 (+51)	77.16±0.01 (+119)
Field peas				
HPF4 (Aparna)	30.53±0.04	44.23±0.01 (+45)	48.10±0.02 (+58)	72.33±0.03 (+137)
Rachna	31.23±0.02	48.46±0.02 (+55)	52.30±0.01 (+67)	77.40±0.03 (+148)
SE (m)	±0.12	±0.11	±0.05	±0.18
CD (P<0.05)	0.40	0.35	0.15	0.54

Values are means ± S.D. of three independent determinations

Figures in parentheses indicate per cent increase (+) over control values

Bonneville (42%) Table-21 . However, cooking of soaked seeds brought about further significant ($P < 0.05$) increase in starch digestibility; more than $1\frac{1}{2}$ to 2 fold increase in starch digestibility was noticed. Rachna had significantly ($P < 0.05$) higher starch digestibility than the other three varieties. There were significant ($P < 0.05$) differences among the values for starch digestibility of different field and vegetable pea cultivars when the seeds were soaked-dehulled and cooked. An improvement in starch digestibility appeared to be significantly higher when compared to that of unsoaked and soaked cooked seeds. An enhancement to the extent of 148 per cent was noticed in Rachna which was the highest among different field and vegetable pea varieties. As a result of cooking of the soaked and dehulled seeds of different cultivars the improvement in starch digestibility varied significantly ($P < 0.05$) among themselves.

Autoclaving has a more pronounced effect on starch digestibility than ordinary cooking. Autoclaving of unsoaked seeds enhance the starch digestibility but the loss was relatively less as compared to soaked seeds. The starch digestibility improved tremendously when the unsoaked, soaked and soaked dehulled pea seeds were autoclaved Table-22. On autoclaving of the unsoaked seeds, starch digestibility enhanced to an extent of 46 to 65 per cent. Autoclaving of soaked seeds was noticed to further increase starch digestibility. More than 2 fold increase occurred in the soaked-autoclaved pea seeds. Autoclaving of soaked and dehulled seeds was noticed to give an all time high starch digestibility. The improvement in starch digestibility almost doubled in the soaked-dehulled autoclaved pea seeds.

During cooking, swelling and rupturing of starch granules of the legumes take place and it may be contributing towards the improvement

Table 22 : Effect of autoclaving on in vitro starch digestibility of peas (mg maltose released/g meal, on dry matter basis)

Varieties	Control	Unsoaked and autoclaved	Soaked and autoclaved	Soaked, dehulled and autoclaved
Vegetable peas				
Bonneville	36.53±0.03	53.23±0.02 (+46)	71.46±0.03 (+96)	82.33±0.03 (+125)
Arkel	35.30±0.01	52.43±0.02 (+49)	70.33±0.03 (+99)	81.23±0.01 (+130)
Field peas				
HFP4	30.53±0.04	47.36±0.02 (+55)	65.13±0.01 (+113)	76.60±0.02 (+151)
Rachna	31.23±0.02	51.40±0.03 (+65)	69.33±0.04 (+112)	81.16±0.01 (+169)
SE (m)	+0.12	±0.13	±0.21	±0.16
CD (P < 0.05)	0.40	0.39	0.65	0.48

Values are means ± S.D. of three independent determinations

Figures in parentheses indicate per cent increase (+) over control values

in starch digestibility in cooked legumes. This facilitates more randomised configuration for alpha amylase to affect hydrolysis. Cooking has also been reported to inactivate amylase inhibitors, phytates and tannins which may be responsible for the increase in starch digestibility. The initial soaking treatment ensures uniform expansion of seed coat and cotyledon matrix and cellulose hydration to aid in heat transfer and subsequent tenderization. This may be the reason behind higher starch digestibility in soaked-cooked seeds over the unsoaked-cooked ones.

Previous workers have also reported improved starch digestibility in various legumes including chick pea, cowpea, black gram, red gram and faba beans (EL-Faki et al., 1984; Rao, 1969; Jood et al., 1988; Sharma, 1989).

There was an appreciable improvement in starch digestibility of sprouted pea seeds; it increased with an increase in the period of germination Table-23. After 12 h germination, Rachna and Arkel had the highest and the lowest increase in starch digestibility, respectively. There were significant ($P < 0.05$) differences in the starch digestibility of different pea cultivars sprouted for 12, 24 and 48 h. When the sprouting was done for 24 h, 55 to 75 per cent increase was noticed in starch digestibility over the control values. Further increase in the germination period from 24 to 48 h had pronounced effect on the digestibility of starch. About 2 fold increase was noticed in different pea cultivars sprouted for 48 h.

An increase in digestibility upon germination is expected because of the pre-digestion of starch molecules by amylolytic enzymes. Amylases and phosphorylases may become active during germination and hence, catalyse

Table 23 : Effect of germination on in vitro starch digestibility of peas (mg maltose released/g meal, on dry matter basis)

Varieties	Control	Period of germination		
		12 h	24 h	48 h
Vegetable peas				
Bonneville	36.53±0.03	45.53±0.02 (+25)	56.46±0.04 (+55)	64.26±0.01 (+76)
Arkel	35.30±0.01	43.53±0.05 (+23)	55.50±0.29 (+57)	63.53±0.03 (+80)
Field peas				
HFP4 (Aparna)	30.53±0.04	38.36±0.04 (+26)	50.33±0.01 (+65)	58.66±0.01 (+92)
Rachna	31.23±0.02	41.60±0.02 (+33)	54.53±0.07 (+75)	63.26±0.01 (+103)
SE (m)	±0.12	±1.73	±0.17	±0.14
CD (P < 0.05)	0.40	5.64	0.51	0.47

Values are means ± S.D. of three independent determinations

Figures in parentheses indicate per cent increase (+) over control values

Table 24 : Correlation co-efficients of antinutritional factors with in vitro digestibility of starch

Treatments	Antinutritional factors			Trypsin inhibitor activity
	Phytic acid	Polyphenols	Saponins	
Raw	-0.7232**	0.9681**	-0.8220**	0.8328**
6 h soaking	-0.2878	-0.5004	0.7190**	-0.1031
12 h soaking	-0.7554**	-0.5069	-0.8532**	0.8567**
18 h soaking	0.8981**	-0.4868	-0.0526	-0.7372**
Soaked (12 h) dehulled	-0.8433**	-0.7134**	0.7507**	0.8634**
Unsoaked and cooked	-0.7682**	0.5080	0.7998**	-0.1090
Soaked (12 h) and cooked	0.8576**	-0.7081**	-0.3305	0.8550**
Soaked (12 h), dehulled and cooked	0.9768**	0.9663**	0.7298**	-0.3903
Unsoaked and autoclaved	-0.7867**	-0.5021	0.7352**	0.8537**
Soaked (12 h) and autoclaved	0.3252	0.9624**	0.2887	-0.4056
Soaked (12 h), dehulled and autoclaved	-0.7807**	0.9561**	0.7228**	-0.3974
12 h sprouting	-0.8507**	-0.5022	-0.8554**	0.8582**
24 h sprouting	-0.2937	-0.6056*	0.2827	-0.6520*
48 h sprouting	0.8704**	0.9561**	0.5747	-0.8167**

* Significant at 5% level

** Significant at 1% level

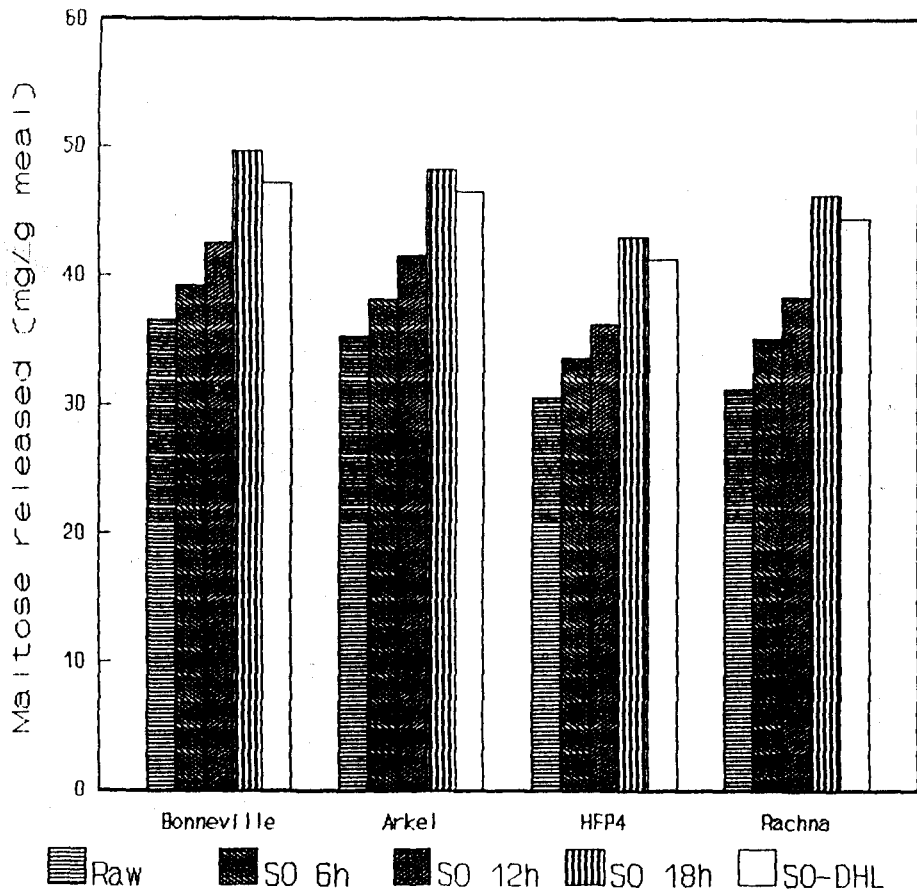


Fig.17 : Effect of Soaking (SO) and Dehulling (DHL) of Peas on In Vitro Starch Digestibility.

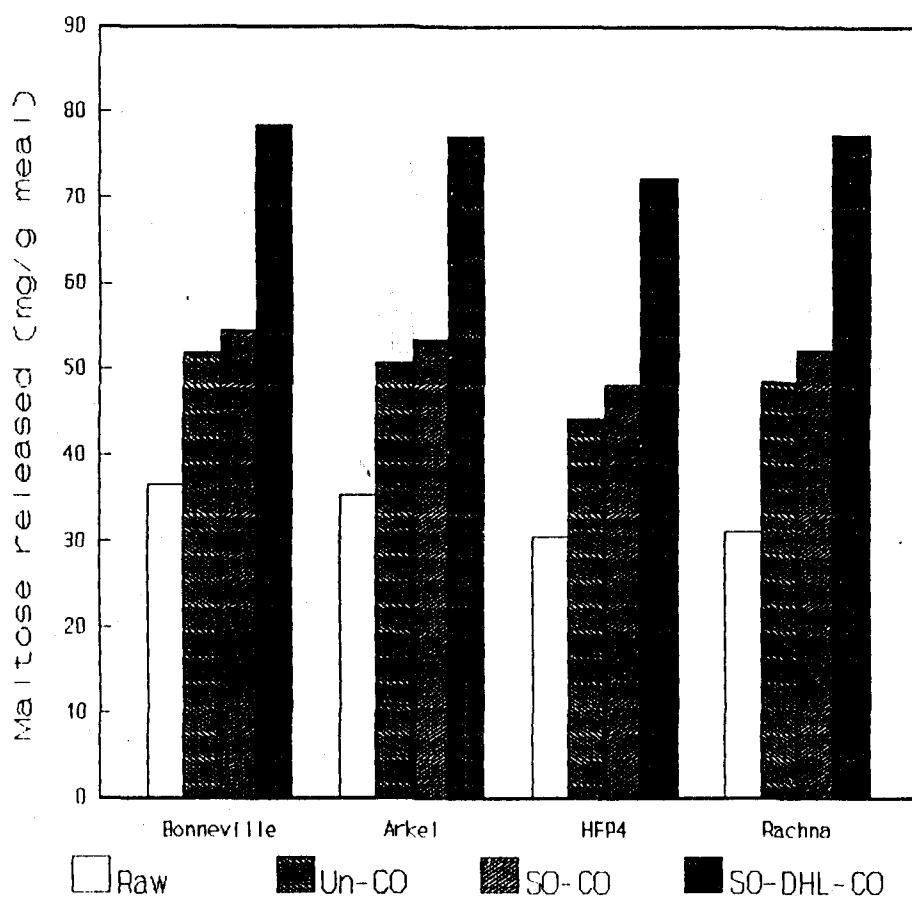


Fig.18 : Effect of Cooking (CO) of Unsoaked, Soaked and Soaked+Dehulled Peas on In Vitro Starch Digestibility.

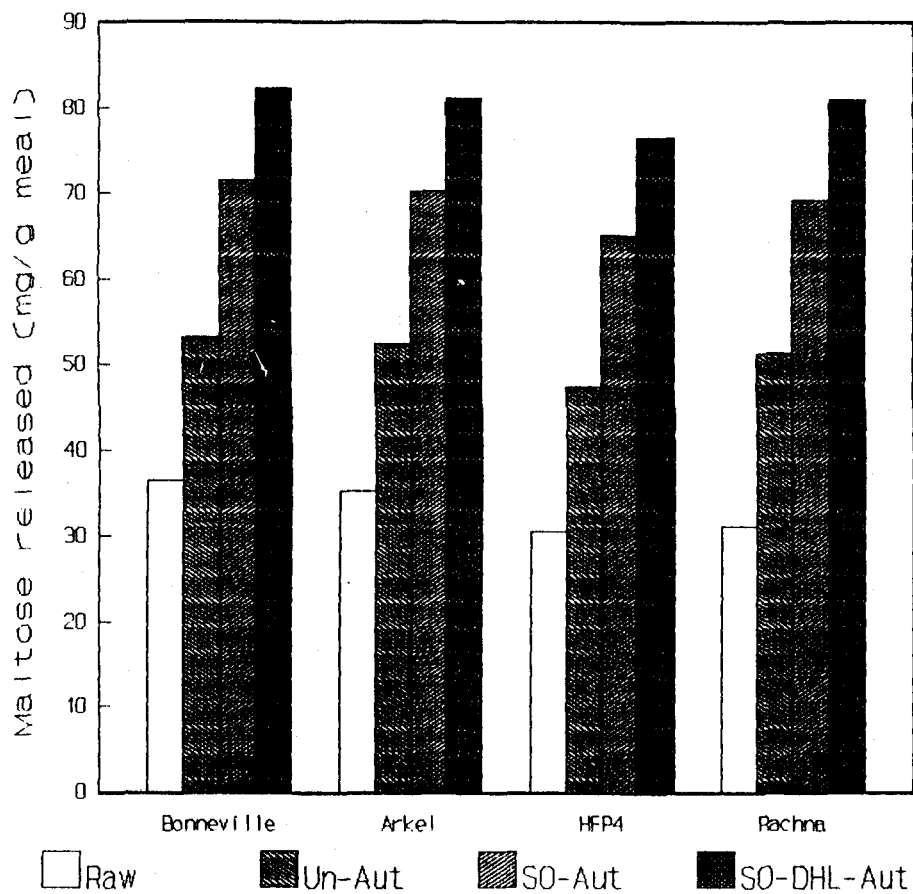


Fig. 19 : Effect of Autoclaving (Aut) of Unsoaked, Soaked and Soaked+Dehulled Peas on In Vitro Starch Digestibility.

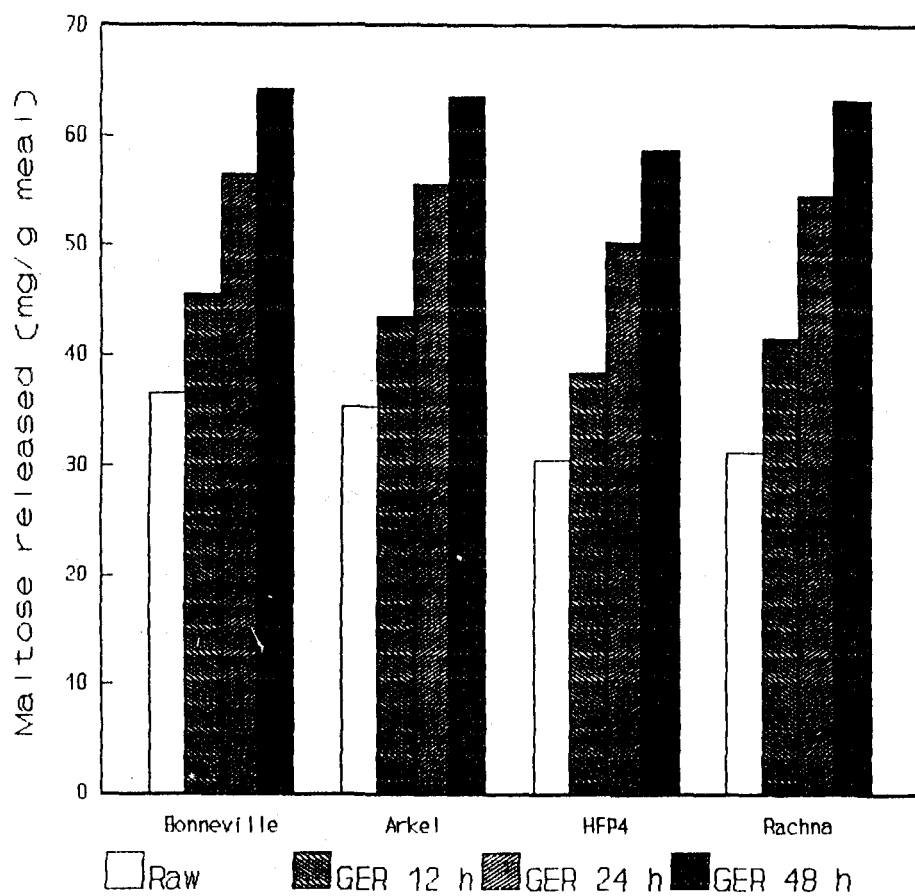


Fig. 20 : Effect of Germination (GER) of Peas on In Vitro Starch Digestibility.

during germination. The resulting enhanced concentration of oligosaccharides in the sprouts may, attribute to better starch digestibility (Jaya and Venkataraman, 1980; Nnanna and Philips, 1988).

The beneficial effect of sprouting for varying periods on starch digestibility has been reported earlier by some workers (Kataria et al., 1989; Nnanna and Philips, 1988). On the contrary, Ganesh Kumar and Venkataraman (1976) found that germination for increasing time lowered in vitro starch digestibility in legumes and that subsequent cooking did not reverse the trend.

4.3.2.2 In vitro Protein digestibility

Protein digestibility was found to be 60.40 to 66.46 per cent in raw unprocessed seeds of different pea varieties Table-25. Field pea cultivars viz. HFP4 and Rachna had significantly ($P < 0.05$) lower in vitro protein digestibility when compared to that of vegetable pea varieties Table-25 .

An improvement in protein digestibility occurred when pea seeds were soaked in water for different time periods; it improved with an increase in the period of soaking Table-25. There was an increase of 7.0 to 8.0 per cent over control values in seeds soaked for 6 h. Soaking for 12 h enhanced the protein digestibility which was 16.0 to 19.0 per cent higher than the corresponding values in raw unprocessed pea seeds. Among all the time periods maximum increase in protein digestibility was noticed when the seeds were soaked for 18 h, the highest and the lowest improvement was found in HFP4 (31.00 %) and Arkel (29.00 %), respectively. The corresponding values for enhancement in protein digestibility in soaked (12 h)

Table 25 : Effect of soaking and dehulling on in vitro protein digestibility (%) of peas (on dry matter basis)

Varieties	Control	Period of soaking			Soaked and dehulled
		6 h	12 h	18 h	
Vegetable peas					
Bonneville	64.41±0.11	69.36±0.22 (+8)	76.33±0.04 (+19)	83.33±0.13 (+29)	78.16±0.11 (+21)
Arkel	66.46±0.11	71.36±0.13 (+7)	77.13±0.09 (+16)	85.43±0.23 (+29)	79.40±0.11 (+19)
Field peas					
HFP4(Aparna)	60.40±0.23	65.40±0.33 (+8)	71.63±0.12 (+19)	79.36±0.14 (+31)	73.46±0.09 (+22)
Rachna	60.59±0.12	65.46±0.14 (+8)	72.30±0.19 (+19)	78.66±0.12 (+30)	72.66±0.08 (+30)
SE (m)	±0.14	±0.20	±0.16	±0.23	±0.11
CD (P < 0.05)	0.47	0.60	0.48	0.69	0.35

Values are means ± S.D. of three independent determinations

Figures in parentheses indicate per cent increase (+) over control values

and dehulled pea seeds seemed to be higher than the seeds which were soaked for 12 h. Improvement in protein digestibility as a result of soaking, may be attributed to leaching out of phytate, trypsin inhibitors, polyphenols, saponins and other factors from this study Table 4, 16, 8, 12 and previous workers (Kataria et al., 1989; Kaur and Kapoor, 1990). Soaking of legumes may also initiate activation of certain enzymes resulting in mobilization of proteins, carbohydrates and fats (Khokhar, 1984).

On cooking the unsoaked pea seeds, protein digestibility (in vitro) improved to a great extent in all the pea cultivars. The maximum improvement was witnessed in Rachna (16.36%) followed by HFP4 (16.06%), Bonneville (15.71%) and Arkel (14.85%) (Table-26). However, cooking of soaked seeds brought about further increase in protein digestibility. Arkel had significantly ($P < 0.05$) higher protein digestibility than Bonneville, HFP4 and Rachna but HFP4 and Rachna differed non-significantly. There were significant ($P < 0.05$) differences among the values for protein digestibility of different field and vegetable pea cultivars when the seeds were soaked, dehulled and cooked. A rise in protein digestibility of pea seeds which were soaked and dehulled prior to cooking, appeared to be significantly ($P < 0.05$) higher when compared to that of cooked pea seeds which were soaked or unsoaked. An enhancement to the extent of 30.0 per cent was noticed in HFP4 which was the highest among different field and vegetable pea varieties. As a result of cooking of the soaked and dehulled seeds of different pea cultivars the improvement in protein digestibility varied significantly ($P < 0.05$) among themselves.

Autoclaving had a more pronounced effect on protein digestibility than ordinary cooking. Autoclaving of unsoaked seeds improved the protein digestibility but the increase was relatively less as compared to that of soaked

Table 26 : Effect of ordinary cooking in in vitro protein digestibility (%) of peas (on dry matter basis)

Varieties	Control	Unsoaked and cooked	Soaked and cooked	Soaked, dehulled and cooked
Vegetable peas				
Bonneville	64.41±0.1	74.53±0.03 (+16)	80.20±0.1 (+25)	81.13±0.5 (+26)
Arkel	66.46±0.21	76.33±0.03 (+15)	82.43±0.21 (+24)	83.36±0.09 (+25)
Field peas				
HFP4 (Aparna)	60.40±0.23	70.10±0.02 (+16)	74.50±0.22 (+23)	78.36±0.03 (+30)
Rachna	60.59±0.12	70.50±0.01 (+16)	76.23±0.11 (+26)	77.30±0.14 (+28)
SE (m)	±0.14	±0.15	±1.73	±0.10
CD (P< 0.05)	0.47	0.45	5.64	0.30

Values are means ± S.D. of three independent determinations

Figures in parentheses indicate per cent increase (+) over control values

Table 27 : Effect of autoclaving on in vitro protein digestibility (%) of peas (on dry matter basis)

Varieties	Control	Unsoaked and autoclaved	Soaked and autoclaved	Soaked, dehulled and autoclaved
Vegetable peas				
Bonneville	64.41±0.12	75.83±0.13 (+18)	84.13±0.09 (+31)	84.33±0.13 (+31)
Arkel	66.46±0.21	76.83±0.02 (+16)	86.26±0.05 (+30)	86.33±0.08 (+30)
Field peas				
HFP4 (Aparna)	60.40±0.23	71.40±0.11 (+18)	80.46±0.13 (+33)	81.46±0.12 (+35)
Rachna	60.59±0.12	70.63±0.02 (+17)	79.33±0.08 (+31)	80.33±0.22 (+33)
SE (m)	±0.14	±0.18	±0.21	±0.10
CD (P<0.05)	0.47	0.54	0.65	0.57

Values are means ± S.D. of three independent determinations

Figures in parentheses indicate per cent increase (+) over control values

seeds. The protein digestibility improved tremendously when the unsoaked, soaked and soaked-dehulled pea seeds were autoclaved. On autoclaving of the unsoaked seeds, protein digestibility rose to an extent of 16.0 to 18.0 per cent over the control values Table-27. Soaking of seeds prior to autoclaving was noticed to further increase protein digestibility. Autoclaving of soaked and dehulled seeds was noticed to give an all time high protein digestibility increased to the level of 30.0 to 35.0 per cent in the soaked - dehulled autoclaved pea seeds over the control values.

The increase in protein digestibility of legumes on cooking and autoclaving may be due to inactivation or destruction of trypsin inhibitors (Sharma, 1989; Kataria et al., 1989) and opening up of protein structure through denaturation. Reduction in the content of antinutritional factors like phytates and tannins, brought about by soaking, cooking and autoclaving may also be responsible for increasing protein digestibility (Jood et al., 1987; Kataria, et al., 1988).

Previous workers have also reported the beneficial effect of heating and autoclaving on the protein digestibility (in vitro) in various legumes including peas, faba beans, cow pea, bengal gram, maize and soybean (Saharan, 1991; Sharma, 1989; Laurena et al., 1987; Shrivastav et al., 1990).

There was an appreciable improvement in protein digestibility of sprouted pea seeds, it increased with an increase in the period of germination. After 12 h germination HFP4 and Arkel had the highest and the lowest increase in protein digestibility, respectively. When the sprouting was done for 24 h, 21.0 to 22.0 per cent increase was noticed in protein digestibility over the control values. Further rise in the germination period from 24 to 48 h had pronounced effect on the digestibility of protein. About 24 to 28

Table 28 : Effect of germination on in vitro protein digestibility (%) of peas (on dry matter basis)

Varieties	Control	Period of germination		
		12 h	24 h	48 h
Vegetable peas				
Bonneville	64.41±0.11	78.13±0.21 (+21)	78.30±0.02 (+22)	80.30±0.04 (+25)
Arkel	66.46±0.21	79.20±0.02 (+19)	80.56±0.08 (+21)	82.70±0.08 (+24)
Field peas				
HFP4 (Aparna)	60.40±0.13	73.46±0.11 (+22)	74.13±0.08 (+23)	77.40±0.09 (+28)
Rachna	60.59±0.12	72.33±0.18 (+19)	74.50±0.09 (+23)	76.50±0.13 (+26)
SE (m)	±0.14	±0.13	±0.16	±0.14
CD (P < 0.05)	0.47	0.42	0.52	0.47

Values are means ± S.D. of three independent determinations

Figures in parentheses indicate per cent increase (+) over control values

Table 29 : Correlation co-efficients of antinutritional factors with in vitro digestibility of protein

Treatments	Antinutritional factors			Trypsin inhibitor activity
	Phytic acid	Polyphenols	Saponin	
Raw	0.8943**	-0.8454**	0.8245**	0.9867**
6 h soaking	0.1583	0.5235	-0.9350**	-0.4582
12 h soaking	-0.8215**	-0.1393	-0.9827**	0.9761**
18 h soaking	-0.9195**	-0.1895	0.7510**	0.9885**
Soaked (12 h), dehulled	0.7738**	0.8979**	0.9733**	0.8163**
Unsoaked and cooked	-0.9275**	-0.0490	0.5851*	-0.2425
Soaked (12h) and cooked	0.3512	-0.4903	0.6658*	0.2293
Soaked (12h), dehulled and cooked	-0.3800	-0.2960	-0.7397**	0.9911**
Unsoaked and autoclaved	-0.4089	-0.2068	0.5914*	0.2754
Soaked (12h) and autoclaved	0.3388	0.8628**	0.1650	-0.2905
Soaked (12h), dehulled and autoclaved	-0.3509	0.1008	0.6715*	-0.9130**
12 h sprouting	-0.0168	0.0161	-0.054	-0.0259
24 h sprouting	-0.1818	0.5094	0.6419*	-0.4022
48 h sprouting	0.5245	0.1265	0.7730**	-0.5867*

* Significant at 5% level

** Significant at 1% level

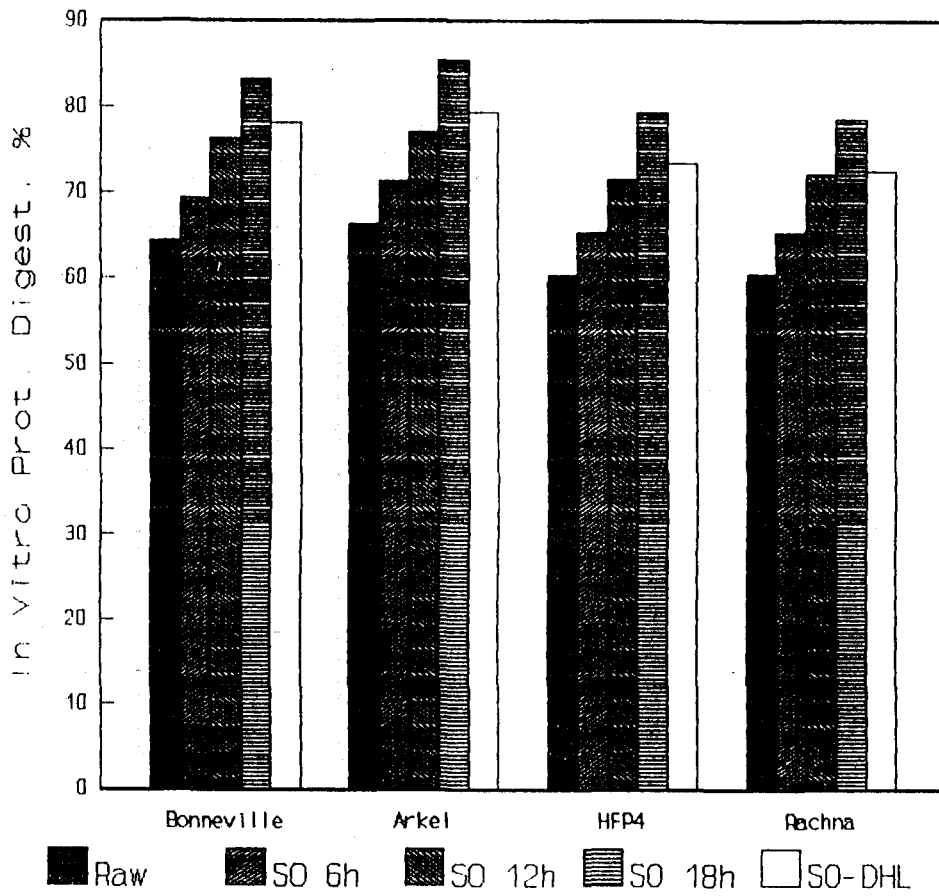


Fig.21: Effect of Soaking (SO) and Dehulling (DHL) of Peas on Protein Digestibility.

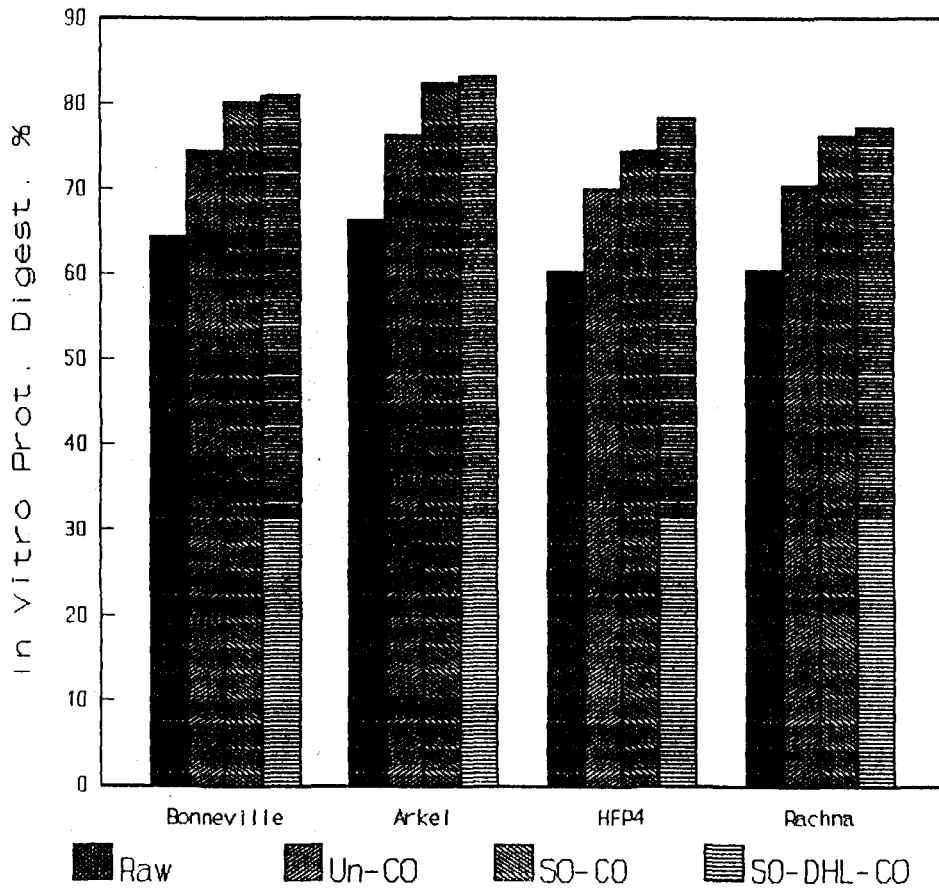


Fig.22: Effect of Cooking (CO) of Unsoaked(Un), Soaked and Soaked+Dehulled Peas on Protein Digestibility.

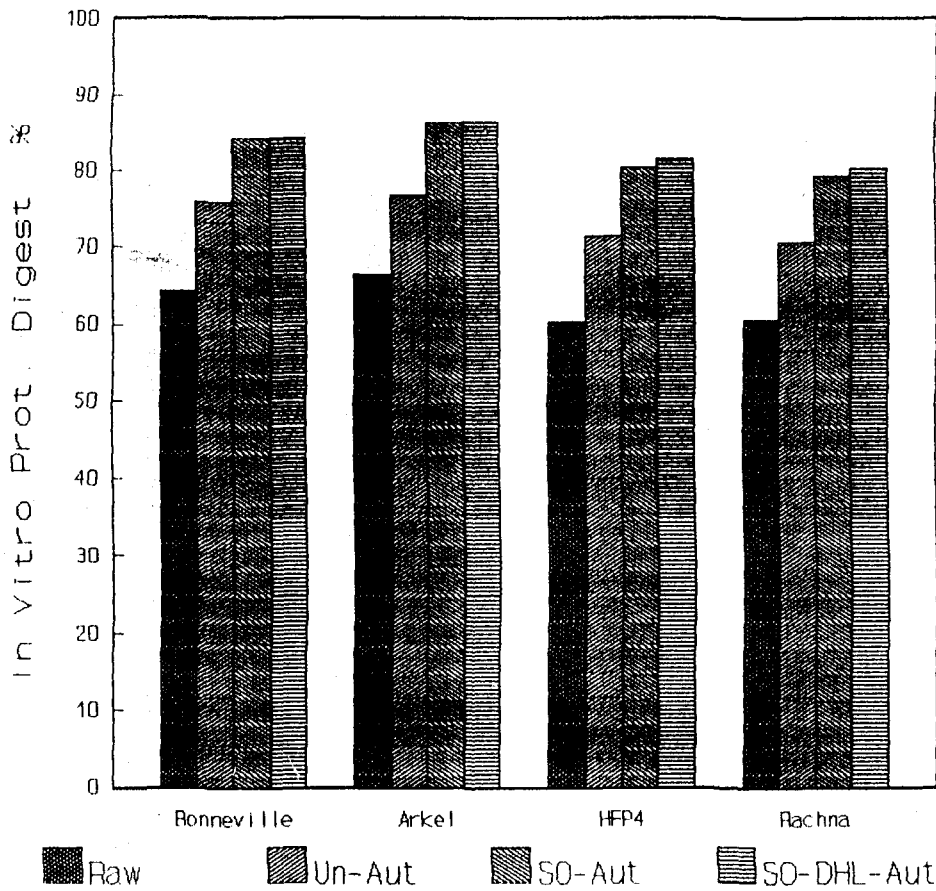


Fig.23: Effect of Autoclaving (Aut) of Unsoaked, Soaked and Soaked+Dehulled peas on Protein Digestibility.

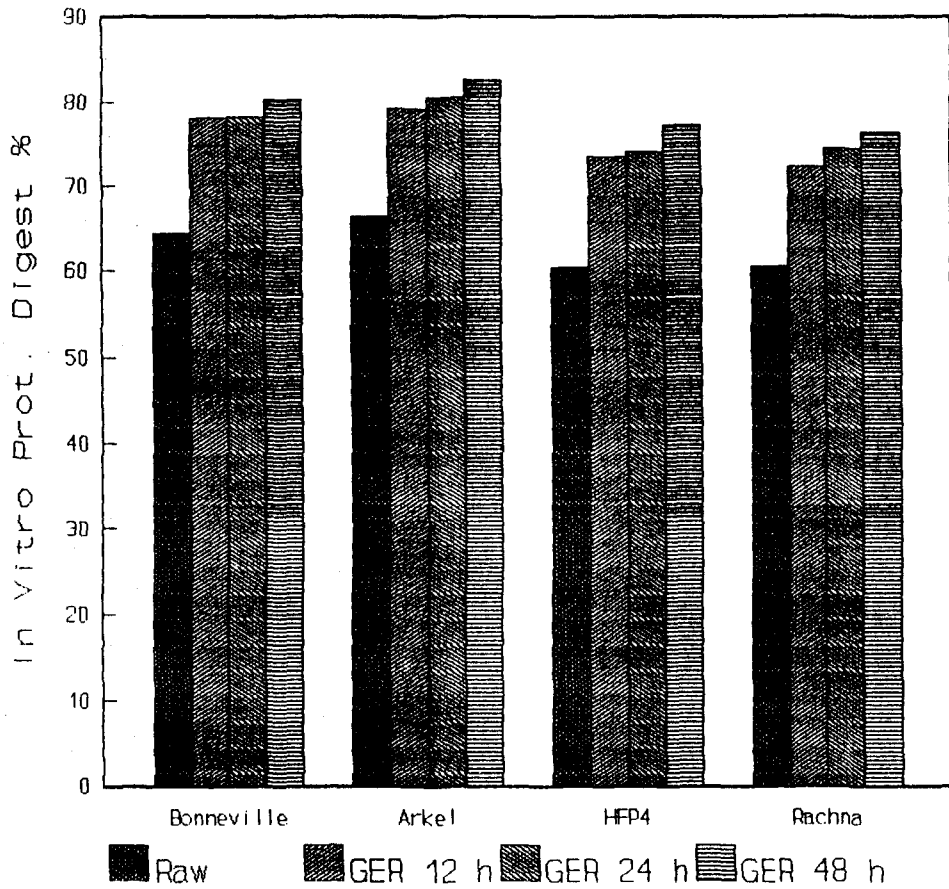


Fig.24 : Effect of Germination (GER) of Peas on Protein Digestibility.

per cent increase was noticed in different pea cultivars when sprouted for 48 h Table-28.

An improvement in protein digestibility upon germination may be because of a decline in antinutritional factors like trypsin inhibitors, tannins, phytates (Kaur, 1986; Sharma, 1989), modification and degradation of storage proteins (Kataria et al., 1989), due to action of hydrolytic enzymes (Hamza, 1983). Sprouting causes immobilization of proteins with the help of proteases leading to the formation of polypeptides, oligopeptides and free amino acids (Youssef, 1987) and hence, leading to improvement in protein digestibility.

4.3.3 Minerals

4.3.3.1 Total minerals

The total calcium and phosphorus content in field and vegetable pea seeds varied from 25.6 to 35.1 and 319.7 to 361.1 mg/100 g, respectively Tables 30, 35. Pea seeds were found to be good sources of iron (10.4 to 12.5 mg/100 g), zinc (3.1 to 5.4 mg/100 g) and copper (1.1 to 1.3 mg/100 g), too Tables 39, 44, 48. With an increase in the period of soaking i.e. 6 to 12 and 12 to 18 h a loss in content of all the minerals studied was noticed to varying extents in different cultivars. In the 18 h soaked pea seeds decrease in calcium, phosphorus, iron, zinc and copper ranged from 17 to 30, 4 to 5, 6 to 29, 5 to 14 and 7 to 12 per cent, respectively Tables 30, 35, 39, 44, 48. Dehulling of the soaked seeds further reduced the mineral content. After soaking and dehulling, maximum (32%) and minimum (23%) loss in calcium content was observed in HFP4 and Rachna, respectively Table-31. There was

significant ($P < 0.05$) difference in the loss of phosphorus content in different soaked and dehulled pea cultivars. The soaked and dehulled seed of HFP4 witnessed maximum phosphorus loss followed by Rachna, Arkel and Bonneville Table-31. Iron, zinc and copper content were reduced by 20 to 40, 10 to 23 and 12 to 26 per cent in the soaked and dehulled pea seeds, respectively Table-40, 49. The loss in the mineral contents on soaking may be attributed to leaching out of these minerals into the soaking water (Kumar et al., 1978). Minerals present in the hulls might have been lost during dehulling, hence, a contributing factor towards less total mineral content in the soaked and dehulled pea seeds.

On ordinary cooking of unsoaked pea seeds a reduction in the total mineral content was noticed but this decrease was further raised when soaked as well as soaked-dehulled seeds were cooked. Cooking of unsoaked peas resulted in 3 to 8 per cent loss of total calcium content, whereas upon cooking of soaked as well as soaked dehulled pea seeds, this decrease was further raised i.e. to the extent of 11 to 24 and 24 to 32 per cent, respectively Table-32. Similarly, the maximum reduction in total phosphorus, iron, zinc and copper in different pea cultivars was noticed when cooking of soaked and dehulled seeds was done followed by ordinary cooking of soaked and unsoaked seeds Table 36, 41, 45, 50.

Loss in phosphorus content of soaked, dehulled and cooked pea seeds was almost twice as that of the soaked and cooked pea seeds. The field pea variety i.e. HFP4 contained 10.86 mg/100 g iron content and it was lowered down to 10.8, 9.8 and 7.0 mg/100 g after cooking of unsoaked, soaked and soaked-dehulled seeds, respectively Table-41. There was significant ($P < 0.05$) varietal differences in the total zinc and copper contents of ordinary cooked peas. The loss in total zinc content of Bonneville, Arkel, HFP4 and Rachna ranged

from 0.1 to 9, 1.0 to 17, 1.0 to 22 and 1.0 to 22 per cent, respectively when unsoaked, soaked and soaked-dehulled seeds were ordinarily cooked Table-45. Similar lowering effect on total copper content was also noticed.

When ordinary cooking and autoclaving was compared on total content of calcium, phosphorus, iron, zinc and copper, these processes were not found to be significantly ($P < 0.05$) different. Autoclaving of the soaked and dehulled peas seeds lowered the total mineral content to the maximum when compared to autoclaving of unsoaked and soaked pea seeds Table 33, 37, 42, 46, 51. As the total mineral content was lowered down to a greater extent in the pea seeds which were unsoaked and soaked or dehulled prior to ordinary cooking or autoclaving, the loss may be attributed mainly to leaching out of minerals into the soaking water than the cooking or the autoclaving.

Sprouting for 12, 24 and 48 h resulted in 15 to 22, 9 to 15 and 6 to 14 per cent decrease in the total calcium content, respectively Table 34. Similar trends were also observed in case of total phosphorus, iron, zinc and copper. After 48 h germination the loss in total phosphorus, iron, zinc and copper ranged from 4 to 5, 0 to 2, 3 to 8 and 0.8 to 12 per cent, respectively. When the germination period was raised from 24 to 48 h, it did not further lower down the total mineral content. Actually germination itself did not contribute to loss of total minerals in peas seeds and therefore, some reduction in the total mineral content in the sprouted seeds may be due to leaching out of these minerals in the soaking medium as sprouting was done after soaking the seeds for 12 h.

Table 30: Effect of soaking on total calcium content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis)

Varieties	Period of soaking					
	Control			6 h		
	Total	Extract-ability	Total	Extract-ability	Total	Extract-ability
					12 h	18 h
Vegetable peas						
Bonneville	34.6±0.43	42.3±0.97	32.6±0.23 (-6)	51.4±0.65 (+22)	29.4±0.13 (-15)	65.9±0.49 (+56)
Arkel	29.3±0.33	37.8±1.33	27.3±0.13 (-7)	45.9±0.68 (+21)	24.1±0.13 (-18)	62.5±0.71 (+65)
Field peas						
HFP4 (Aparna)	25.6±0.23	35.1±1.78	23.6±0.13 (-8)	45.7±0.46 (+30)	20.4±0.12 (-20)	55.9±0.29 (+59)
Rachna	35.1±0.17	40.6±0.43	33.1±0.17 (-6)	46.5±0.41 (+15)	31.9±0.17 (-9)	53.6±0.44 (+32)
SE(m)	±0.42	±1.00	±0.40	±0.46	±0.41	±0.41
CD (P < 0.05)	1.26	3.00	1.20	1.38	1.23	1.23

Values are means ± S.D. of three independent determinations

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

Table 31: Effect of soaking and dehulling on total calcium and phosphorus contents (mg/100 g) and their HCl-extractability (%) in peas (on dry matter basis)

Varieties	Calcium			Phosphorus				
	Control		Soaked and dehulled	Control		Soaked and dehulled		
	Total	Extract-ability	Total	Extract-ability	Total	Extract-ability		
Vegetable peas								
Bonneville	34.6±0.43	42.3±0.97	26.5±0.23 (-23)	69.7±0.11 (+65)	361.1±0.58	54.8±0.43	331.0±0.50 (-8)	63.6±0.13 (+16)
Arkel	29.3±0.33	37.8±1.33	21.2±0.30 (-28)	66.4±0.67 (+76)	349.3±0.55	54.4±0.22	318.9±0.56 (-9)	62.0±0.17 (+14)
Field peas								
HFP4 (Aparna)	25.6±0.23	35.1±1.78	17.5±0.34 (-32)	63.1±0.89 (+80)	319.7±0.26	50.1±0.12	288.9±0.22 (-10)	62.5±0.13 (+25)
Rachna	35.1±0.17	40.6±0.43	27.0±0.15 (-23)	59.6±0.23 (+47)	340.7±0.28	52.9±0.11	310.1±0.20 (-9)	60.9±0.08 (+15)
SE(m)	±0.42	±1.00	±0.30	±0.47	±0.73	±0.21	±0.62	±0.10
CD(P<0.05)	1.26	3.00	0.90	1.41	2.19	0.63	1.86	0.30

Values are means ± S.D. of three independent determinations

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

Table 32 : Effect of ordinary cooking on total calcium content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis)

Varieties	Control		Unsoaked		Soaked		Soaked and dehulled	
	Total	Extract-ability	Total	Extract-ability	Total	Extract-ability	Total	Extract-ability
Vegetable peas								
Bonneville	34.6±0.43	42.3±0.97	33.5±0.20 (-3)	58.3±0.49 (+38)	30.9±0.33 (-11)	67.3±0.52 (+59)	25.8±0.12 (-25)	70.1±0.51 (+66)
Arkel	29.3±0.33	37.8±1.33	28.1±0.18 (-4)	54.5±0.71 (+44)	24.7±0.17 (-16)	65.1±0.80 (+72)	21.1±0.31 (-28)	67.7±0.76 (+79)
Field peas								
HFP4 (Aparna)	25.6±0.23	35.1±1.78	23.5±0.12 (-8)	48.9±0.27 (+39)	19.4±0.16 (-24)	59.6±0.48 (+70)	17.3±0.13 (-32)	63.5±0.35 (+81)
Rachna	35.1±0.17	40.6±0.43	34.2±0.11 (-3)	47.6±1.85 (+17)	30.7±0.36 (-13)	56.3±0.28 (+39)	26.7±0.17 (-24)	60.2±0.17 (+48)
SE(m)	±0.42	±1.00	±0.40	±0.84	±0.06	±0.44	±0.63	±0.41
CD (P < 0.05)	1.26	3.00	1.20	2.52	0.18	1.32	1.89	1.23

Values are means ± S.D. of three independent determinations

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

Table 33: Effect of autoclaving on total calcium content (mg/100g) and its extractability (%) in peas (on dry matter basis)

Varieties	Control		Unsoaked		Soaked		Soaked and dehulled	
	Total	Extract- ability	Total	Extract- ability	Total	Extract- ability	Total	Extract- ability
Vegetable peas								
Bonneville	34.6±0.43	42.3±0.97	33.4±0.10 (-4)	59.8±0.84 (+41)	30.9±0.33 (-11)	68.9±0.41 (+63)	26.1±0.33 (-25)	72.1±0.53 (+71)
Arkel	29.3±0.33	37.8±1.33	28.6±0.30 (-2)	56.0±0.61 (+48)	24.2±0.22 (-17)	68.4±0.66 (+81)	21.2±0.12 (-28)	72.0±0.62 (+90)
Field peas								
HFP4 (Aparna)	25.6±0.23	35.1±1.78	23.1±0.11 (-10)	54.1±0.30 (+54)	19.8±0.15 (-23)	65.1±0.40 (+86)	17.6±0.17 (-31)	66.4±0.31 (+89)
Rachna	35.1±0.17	40.6±0.43	34.6±0.12 (-1)	49.4±0.79 (+22)	30.40±0.17 (-13)	62.1±0.40 (+53)	26.9±0.27 (-23)	63.6±0.31 (+57)
SE(m)	±0.42	±1.0	±0.07	±0.55	±0.05	±0.40	±0.63	±0.38
CD (P< 0.05)	1.26	3.00	0.21	1.65	0.15	1.20	1.89	1.14

Values are means ± S.D. of three independent determinations

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

Table 34: Effect of germination on total calcium content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis)

Varieties	Period of germination							
	Control		12 h		24 h		48 h	
	Total	Extract-ability	Total	Extract-ability	Total	Extract-ability	Total	Extract-ability
Vegetable peas								
Bonneville	34.60±0.43	42.3±0.97	29.3±0.33 (-15)	67.5±0.71 (+60)	30.4±0.28 (-12)	71.0±0.64 (+68)	32.5±0.25 (-6)	79.3±0.55 (+88)
Arkel	29.3±0.33	37.8±1.33	23.9±0.22 (-18)	66.1±0.72 (+75)	24.9±0.33 (-15)	69.4±0.71 (+84)	25.1±0.15 (-14)	76.4±0.67 (+102)
Field peas								
HFP4 (Aparna)	25.6±0.23	35.1±1.78	20.1±0.45 (-22)	62.6±0.46 (+78)	22.3±0.17 (-13)	69.9±0.44 (+99)	23.2±0.41 (-9)	74.5±0.37 (+112)
Rachna	35.1±0.17	40.6±0.43	31.6±0.17 (-22)	61.3±0.31 (+51)	31.8±0.12 (-9)	65.7±0.33 (+62)	32.8±0.23 (-7)	73.7±0.41 (+82)
SE(m)	±0.42	±1.00	±0.41	±0.47	±0.62	±0.45	±0.06	±0.42
CD (P<0.05)	1.26	3.00	1.23	1.41	1.86	1.35	0.18	1.26

Values are means $\pm$ S.D. of three independent determinations

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

Table 35 : Effect of soaking on total phosphorus content (mg/100 g) and its HCl-extractability in peas (on dry matter basis)

Varieties	Period of soaking					
	Control		6 h		12 h	
	Total	Extract-ability	Total	Extract-ability	Total	Extract-ability
Vegetable peas						
Bonneville	361.1±0.58	54.8±0.43	354.3±0.57 (-2)	55.4±0.19 (+1)	347.3±0.53 (-4)	57.9±0.14 (+6)
Arkel	349.3±0.55	54.4±0.22	342.4±0.54 (-2)	55.2±0.15 (+2)	335.5±0.58 (-4)	57.1±0.15 (+5)
Field peas						
HFP4 (Aparna)	319.7±0.26	50.1±0.12	312.7±0.26 (-2)	51.2±0.19 (+2)	305.8±0.20 (-4)	54.0±0.09 (+8)
Rachna	340.7±0.28	52.9±0.11	333.7±0.28 (-2)	53.3±0.07 (+1)	327.0±0.24 (-4)	55.0±0.06 (+4)
SE(m)	±0.63	±0.21	±0.62	±0.13	±0.42	±0.09
CD (P < 0.05)	1.89	0.63	1.86	0.39	1.26	0.27
					2.10	0.30

Values are means ± S.D. of three independent determinations

cent

Figures in parentheses indicate per/ increase (+) or decrease (-) over control values

Table 36: Effect of ordinary cooking on total phosphorus content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis)

Varieties	Control		Unsoaked		Soaked		Soaked and dehulled	
	Total	Extract-ability	Total	Extract-ability	Total	Extract-ability	Total	Extract-ability
Vegetable peas								
Bonneville	361.1±0.58	54.8±0.43	360.2±0.53 (-0.2)	57.6±0.14 (+5)	346.8±0.05 (-4)	61.8±0.11 (+13)	330.4±0.57 (-9)	66.3±0.14 (+21)
Arkel	349.3±0.55	54.4±0.22	348.5±0.57 (-0.2)	56.9±0.15 (+5)	334.3±0.56 (-4)	59.9±0.16 (+10)	317.5±0.53 (-9)	65.8±0.18 (+21)
Field peas								
HFP4 (Aparna)	319.7±0.26	50.1±0.12	319.3±0.23 (-0.1)	53.9±0.09 (+8)	305.9±0.22 (-4)	57.1±0.14 (+14)	288.3±0.24 (-10)	63.9±0.14 (+28)
Rachna	340.7±0.28	52.9±0.11	340.1±0.28 (-0.2)	55.1±0.06 (+4)	326.8±0.20 (-4)	59.3±0.07 (+12)	309.6±0.20 (-9)	64.6±0.08 (+28)
SE(m)	±0.63	±0.21	±0.62	±0.09	±0.08	±0.10	±0.07	±0.11
CD (P<0.05)	1.89	0.63	1.86	0.27	0.24	0.30	0.21	0.33

Value are means ± S.D. of three independent determinations

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

Table 37 : Effect of autoclaving on total phosphorus content (mg/100 g) and its HCl-extractability (%) in peas
(on dry matter basis)

Varieties	Control		Unsoaked		Soaked		Soaked and dehulled	
	Total	Extract- ability	Total	Extract- ability	Total	Extract- ability	Total	Extract- ability
Vegetable peas								
Bonneville	361.1±0.58	54.8±0.43	360.7±0.50 (-0.1)	60.2±0.66 (+10)	346.2±0.55 (-4)	66.3±0.24 (+21)	329.8±0.35 (-9)	72.3±0.18 (+32)
Arkel	349.3±0.55	54.4±0.22	347.9±0.56 (-0.4)	58.7±0.16 (+8)	334.3±0.53 (-4)	64.8±0.16 (+20)	316.9±0.75 (-9)	71.8±1.62 (+32)
Field peas								
HFP4 (Aparna)	319.7±0.26	50.1±0.12	318.1±0.22 (-0.5)	56.1±0.09 (+12)	305.5±0.24 (-4)	61.7±0.08 (+23)	287.6±0.32 (-10)	68.6±0.09 (+37)
Rachna	340.7±0.28	52.9±0.11	339.7±0.20 (-0.3)	57.4±0.07 (+9)	326.3±0.20 (-4)	62.2±0.07 (+18)	307.9±0.82 (-10)	69.1±0.07 (+31)
SE(m)	±0.63	±0.21	±0.01	±0.28	±0.24	±0.13	±0.08	±0.67
CD ($P < 0.05$)	1.89	0.63	0.03	0.84	0.72	0.39	0.24	2.01

Values are means ± S.D. of three independent determinations

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

Table 38: Effect of germination on total phosphorus content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis)

Varieties	Period of germination					
	Control		12 h		24 h	
	Total	Extract-ability	Total	Extract-ability	Total	Extract-ability
Vegetable peas						
Bonneville	361.1±0.58	54.8±0.43	348.3±0.58 (-4)	63.2±0.27 (+15)	347.9±0.29 (-4)	73.7±0.24 (+34)
Arkel	349.3±0.55	54.4±0.22	336.7±0.55 (-4)	62.0±0.10 (+14)	335.8±0.29 (-4)	73.2±0.30 (+35)
Field peas						
HFP4 (Aparna)	319.7±0.26	50.1±0.12	305.7±0.22 (-4)	61.0±0.10 (+22)	305.1±0.12 (-5)	68.5±0.15 (+37)
Rachna	340.7±0.28	52.9±0.11	326.9±0.28 (-4)	60.1±0.23 (+14)	327.4±0.24 (-4)	69.9±0.24 (+32)
SE(m)	±0.63	±0.21	±0.07	±0.16	±0.08	±0.19
CD ($P < 0.05$)	1.89	0.63	0.21	0.48	0.24	0.57
					0.15	0.30

Values are means ± S.D. of three independent determinations

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

Table 39: Effect of soaking on total iron content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis)

Varieties	Period of soaking					
	Control		6 h		12 h	
	Total	Extract-ability	Total	Extract-ability	Total	Extract-ability
Vegetable peas						
Bonneville	10.45±0.09	48.3±0.03	10.41±0.01 (-0.4)	49.5±0.03 (+2)	10.30±0.01 (-1)	52.5±0.01 (+9)
Arkel	12.51±0.04	47.4±0.01	12.40±0.02 (-0.8)	48.6±0.02 (+3)	12.10±0.01 (-3)	51.8±0.06 (+9)
Field peas						
HFP4 (Aparna)	10.86±0.09	46.4±0.10	10.11±0.03 (-7)	47.8±0.07 (+3)	9.39±0.06 (-14)	50.2±0.02 (+8)
Rachna	11.91±0.08	42.4±0.01	10.30±0.05 (-14)	43.6±0.04 (+3)	10.21±0.01 (-14)	45.9±0.04 (+8)
SE(m)	±0.63	±0.01	±0.60	±0.14	±0.60	±0.13
CD(P < 0.05)	1.89	0.03	1.80	0.42	1.80	0.39
					2.10	0.57

Values are means ± S.D. of three independent determinations

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

Table 40: Effect of soaking and dehulling on total iron and zinc contents (mg/100 g) and their HCl-extractability (%) in peas (on dry matter basis)

Varieties	Iron			Zinc				
	Control		Soaked and dehulled	Control		Soaked and dehulled		
	Total	Extract-ability	Total	Extract-ability	Total	Extract-ability		
Vegetable peas								
Bonneville	10.45±0.09	48.3±0.03	8.31±0.06 (-20)	66.3±0.16 (+37)	5.41±0.11	25.5±0.09	4.86±0.01 (-10)	41.2±0.17 (+62)
Arkel	12.51±0.04	47.4±0.01	10.06±0.08 (-20)	64.1±0.03 (+35)	3.86±0.11	24.4±0.21	3.21±0.01 (-17)	38.6±0.44 (+58)
Field peas								
HFP4 (Aparna)	10.86±0.09	46.4±0.10	7.00±0.09 (-40)	61.6±0.08 (+33)	3.15±0.20	21.2±0.27	2.41±0.01 (-23)	36.1±1.10 (+70)
Rachna	11.91±0.08	42.4±0.01	8.51±0.09 (-29)	58.9±0.14 (+39)	3.46±0.10	19.2±0.05	2.71±0.01 (-22)	34.3±0.38 (+79)
SE(m)	±0.63	±0.01	±0.61	±0.19	±0.22	±0.15	±0.20	±0.51
CD(P < 0.05)	1.89	0.03	1.83	0.57	0.66	0.45	0.60	1.53

Values are means ± S.D. of three independent determinations

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

Table 41: Effect of ordinary cooking on total iron content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis)

Varieties	Control		Unsoaked		Soaked		Soaked and dehulled	
	Total	Extract-ability	Total	Extract-ability	Total	Extract-ability	Total	Extract-ability
Vegetable peas								
Bonneville	10.45±0.09	48.3±0.03	10.25±0.00 (-2)	50.5±0.02 (+5)	10.05±0.06 (-4)	54.3±0.03 (+12)	8.25±0.10 (-21)	70.1±0.03 (+45)
Arkel	12.51±0.04	47.4±0.01	12.55±0.00 (-0.3)	50.1±0.01 (+6)	12.36±0.08 (-1)	53.7±0.06 (+13)	9.80±0.11 (-22)	68.3±0.03 (+44)
Field peas								
HFP4 (Aparna)	10.86±0.09	46.4±0.10	10.80±0.00 (-0.5)	48.6±0.25 (+5)	9.81±0.01 (-10)	52.2±0.01 (+13)	7.01±0.21 (-35)	65.9±0.12 (+42)
Rachna	11.91±0.08	42.4±0.01	11.51±0.00 (-3)	46.3±0.19 (+9)	10.9±0.01 (-8)	49.7±0.05 (+17)	8.81±0.21 (-26)	63.4±0.01 (+50)
SE (m)	±0.63	±0.01	±0.15	±0.13	±0.05	±0.18	±0.05	±0.21
CD (P < 0.05)	1.89	0.03	0.45	0.39	0.15	0.54	0.15	0.63

Values are means ± S.D. of three independent determinations

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

Table 42: Effect of autoclaving on total iron content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis)

Varieties	Control		Unsoaked		Soaked		Soaked and dehulled	
	Total	Extract-ability	Total	Extract-ability	Total	Extract-ability	Total	Extract-ability
Vegetable peas								
Bonneville	10.45±0.09	48.3±0.03	10.11±0.02 (-3)	52.9±0.12 (+10)	10.10±0.02 (-3)	59.8±0.12 (+24)	8.25±0.74 (-21)	74.3±0.32 (+54)
Arkel	12.51±0.04	47.4±0.01	12.55±0.27 (-0.3)	51.6±1.01 (+9)	12.06±0.02 (-4)	58.2±0.12 (+23)	9.95±0.71 (-20)	72.6±0.07 (+53)
Field peas								
HFP4 (Aparna)	10.86±0.09	46.4±0.10	10.81±0.41 (-0.5)	50.3±0.10 (+8)	9.46±0.05 (-13)	56.8±0.18 (+22)	6.91±0.67 (-36)	69.2±0.06 (+49)
Rachna	11.91±0.08	42.4±0.01	11.51±0.01 (-3)	49.9±0.16 (+18)	10.61±0.74 (-11)	54.1±0.14 (+28)	8.75±0.61 (-27)	66.8±0.12 (+58)
SE(m)	±0.63	±0.01	±0.05	±0.41	±0.07	±0.24	±0.70	±0.15
CD (P<0.05)	1.89	0.03	0.15	1.23	0.21	0.72	2.10	0.45

Values are means ± S.D. of three independent determinations

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

Table 43: Effect of germination on total iron content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis)

Varieties	Period of germination					
	Control		12 h		24 h	
	Total	Extract-ability	Total	Extract-ability	Total	Extract-ability
Vegetable peas						
Bonneville	10.45±0.09	48.3±0.03	10.35±0.50 (-0.9)	56.3±0.14 (+17)	10.15±0.41 (-3)	64.1±0.37 (+33)
Arkel	12.51±0.04	47.4±0.01	12.10±0.56 (-3)	55.1±0.12 (+16)	12.35±0.76 (-1.2)	62.7±0.01 (+32)
Field peas						
HFP4 (Aparna)	10.86±0.09	46.4±0.10	10.83±0.05 (-0.2)	53.8±0.16 (+16)	10.95±0.61 (-0.8)	59.8±0.46 (+29)
Rachna	11.91±0.08	42.4±0.01	11.50±0.06 (-3)	49.9±0.2 (+18)	11.66±0.07 (-2)	56.4±0.33 (+33)
SE(m)	±0.63	±0.01	±0.05	±0.10	±0.06	±0.28
CD(P<0.05)	1.89	0.03	0.15	0.30	0.18	0.84
					±0.07	±0.99
					0.21	2.97

Values are means ± S.D. of three independent determinations

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

Table 44: Effect of soaking on total zinc content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis)

Varieties	Period of soaking					
	Control		6 h		12 h	
	Total	Extract- ability	Total	Extract- ability	Total	Extract- ability
Vegetable peas						
Bonneville	5.41±0.11	25.5±0.09	5.41±0.01 (-0)	29.3±0.13 (+15)	5.31±0.08 (-2)	34.2±0.16 (+34)
Arkel	3.86±0.11	24.4±0.21	3.71±0.01 (-4)	27.8±0.20 (+14)	3.71±0.01 (-4)	31.9±0.08 (+31)
Field peas						
HFP4 (Aparna)	3.15±0.20	21.2±0.27	2.96±0.01 (-6)	24.8±0.52 (+17)	2.96±0.01 (-6)	30.3±0.08 (+43)
Rachna	3.46±0.10	19.2±0.05	3.26±0.01 (-6)	23.6±0.08 (+23)	3.25±0.01 (-6)	27.6±0.58 (+44)
SE(m)	±0.22	±0.15	±0.21	±0.24	±0.22	±0.25
CD(F < 0.05)	0.66	0.45	0.63	0.72	0.66	0.75
					±0.10	±0.35
					0.30	1.05

Values are means ± S.D. of three independent determinations

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

Table 45 : Effect of ordinary cooking on total zinc content (mg/100 g) and its extractability (%) in peas (on dry matter basis)

Varieties	Control		Unsoaked		Soaked		Soaked and dehulled	
	Total	Extract-ability	Total	Extract-ability	Total	Extract-ability	Total	Extract-ability
Vegetable peas								
Bonneville	5.41±0.11	25.5±0.09	5.40±0.01 (-0.1)	30.2±0.21 (+18)	5.20±0.03 (-4)	37.3±0.54 (+46)	4.90±0.00 (-9)	46.3±0.70 (+82)
Arkel	3.86±0.11	24.4±0.21	3.81±0.01 (-1.3)	28.9±0.30 (+18)	3.80±0.05 (-2)	35.8±0.36 (+47)	3.20±0.00 (-17)	44.5±1.53 (+82)
Field peas								
HFP4 (Aparna)	3.15±0.20	21.2±0.27	3.11±0.01 (-1.3)	25.1±0.19 (+18)	2.90±0.01 (-8)	34.1±0.23 (+61)	2.40±0.01 (-22)	41.2±0.82 (+98)
Rachna	3.46±0.10	19.2±0.05	3.41±0.01 (-1.4)	24.8±0.12 (+29)	3.30±0.00 (-5)	30.9±0.69 (+61)	2.70±0.00 (-22)	38.0±0.48 (+98)
SE(m)	±0.22	±0.15	±0.01	±0.18	±0.01	±0.40	±0.06	±0.79
CD(P < 0.05)	0.66	0.45	0.03	0.54	0.3	1.20	0.18	2.37

Values are means ± S.D. of three independent determinations

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

Table 46: Effect of autoclaving on total zinc content (mg/100g) and its HCl-extractability (%) in peas (on dry matter basis)

Varieties	Control		Unsoaked		Soaked		Soaked and dehulled	
	Total	Extract-ability	Total	Extract-ability	Total	Extract-ability	Total	Extract-ability
Vegetable peas								
Bonneville	5.41±0.11	25.5±0.09	5.40±0.10 (-0.2)	31.4±0.17 (+23)	5.10±0.11 (-6)	39.5±0.21 (+55)	5.00±0.20 (-8)	50.2±1.91 (+97)
Arkel	3.86±0.11	24.4±0.21	3.80±0.20 (-2)	30.1±0.75 (+23)	3.80±0.31 (-2)	38.5±0.37 (+58)	3.10±0.33 (-20)	48.3±0.66 (+98)
Field peas								
HFP4 (Aparna)	3.15±0.20	21.2±0.27	3.10±0.10 (-2)	27.2±0.65 (+28)	2.90±0.20 (-8)	36.9±1.46 (+74)	2.40±0.11 (-84)	44.6±0.11 (+110)
Rachna	3.46±0.10	19.2±0.05	3.40±0.10 (-2)	25.4±0.45 (+32)	3.20±0.11 (-8)	34.6±0.47 (+80)	2.70±0.11 (-22)	43.4±0.47 (+126)
SE(m)	±0.22	±0.15	±0.20	±0.45	±0.11	±0.65	±0.34	±0.85
CD (P < 0.05)	0.66	0.45	0.60	1.35	0.33	1.95	1.02	2.55

Values are means ± S.D. of three independent determinations

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

Table 47: Effect of germination of total zinc content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis)

Varieties	Period of germination					
	Control		12 h		24 h	
	Total	Extract- ability	Total	Extract- ability	Total	Extract- ability
Vegetable peas						
Bonneville	5.41±0.11	25.5±0.09	5.31±0.41 (-2)	36.7±0.90 (+44)	5.25±0.01 (-3)	39.3±0.01 (+54)
Arkel	3.86±0.11	24.4±0.21	3.75±0.10 (-3)	32.3±0.62 (+32)	3.71±0.03 (-4)	38.9±0.69 (+59)
Field peas						
HFP4 (Aparna)	3.15±0.20	21.2±0.27	2.93±0.10 (-7)	31.7±0.29 (+50)	2.91±0.00 (-8)	34.7±0.35 (+64)
Rachna	3.46±0.10	19.2±0.05	3.21±0.41 (-7)	28.3±1.63 (+47)	3.24±0.01 (-6)	33.2±0.12 (+73)
SE (m)	±0.22	±0.15	±0.11	±0.81	±0.11	±0.32
CD(P<0.05)	0.66	0.45	0.33	2.43	0.33	0.96
					±0.01	±0.69
					0.03	2.07

Values are means ± S.D. of three independent determinations

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

Table 48 : Effect of soaking on total copper content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis)

Varieties	Period of soaking					
	Control		6 h		12 h	
	Total	Extract- ability	Total	Extract- ability	Total	Extract- ability
Vegetable peas						
Bonneville	1.24±0.08	79.0±0.86	1.15±0.09 (-7)	81.3±0.07 (+3)	1.15±0.09 (-7)	82.4±1.58 (+4)
Arkel	1.35±0.08	79.8±0.44	1.21±0.01 (-10)	80.1±1.73 (+0.3)	1.21±0.01 (-10)	81.3±2.04 (+2)
Field peas						
HFP4 (Aparna)	1.14±0.01	81.5±1.55	1.13±0.03 (-0.8)	82.3±1.15 (+1.0)	1.00±0.08 (-12)	83.0±1.73 (+2)
Rachna	1.13±0.03	78.8±0.58	1.10±0.08 (-3)	79.0±0.01 (+0.3)	1.10±1.15 (-3)	80.6±0.24 (+2)
SE(m)	±0.14	±0.78	±0.50	±0.41	±0.30	±0.32
CD (P<0.05)	0.42	2.34	1.50	1.23	0.90	0.96
					±0.60	±0.53
					1.80	1.59

Values are means ± S.D. of three independent determinations

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

Table 49 : Effect of soaking and dehulling on total copper content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis)

Varieties	Control		Soaked and dehulled	
	Total	Extract-ability	Total	Extract-ability
Vegetable peas				
Bonneville	1.24±0.08	99.0±0.86	1.07±0.03 (-14)	87.8±0.38 (+11)
Arkel	1.35±0.08	79.8±0.44	1.00±0.09 (-26)	85.3±2.73 (+7)
Field peas				
HFP4 (Aparna)	1.14±0.01	81.5±1.55	0.94±0.06 (-18)	86.0±1.92 (+6)
Rachna	1.13±0.03	78.8±0.58	1.00±1.15 (-12)	83.1±0.51 (+5)
SE (m)	±0.14	±0.78	±0.20	±0.63
CD (P<0.05)	0.42	2.34	0.60	1.89

Values are means ± S.D. of three independent determinations

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

Table 50 : Effect of ordinary cooking on total copper content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis)

Varieties	Control		Unsoaked		Soaked		Soaked and dehulled	
	Total	Extract-ability	Total	Extract-ability	Total	Extract-ability	Total	Extract-ability
Vegetable peas								
Bonneville	1.24±0.08	79.0±0.86	1.10±0.26 (-11)	81.3±4.73 (+3)	1.07±0.4 (-14)	83.1±4.34 (+5)	1.07±0.00 (-14)	85.4±1.68 (+8)
Arkel	1.35±0.08	79.8±0.44	1.30±0.16 (-4)	81.8±1.15 (+3)	1.10±0.66 (-19)	82.3±3.46 (+3)	1.00±0.00 (-26)	83.6±1.5 (+5)
Field peas								
HFP4 (Aparna)	1.14±0.01	81.5±1.55	1.10±0.26 (-4)	82.6±2.62 (+1)	1.10±0.06 (-4)	83.4±2.00 (+2)	0.94±0.00 (-18)	85.8±1.9 (+5)
Rachna	1.13±0.03	78.8±0.58	1.03±0.13 (-9)	80.3±5.92 (+2)	1.00±0.06 (-12)	81.6±0.58 (+4)	1.00±0.00 (-12)	84.0±5.0 (+7)
SE(m)	±0.14	±0.78	±0.15	±0.83	±0.25	±0.53	±0.20	±0.60
CD(P < 0.05)	0.42	2.34	0.45	2.49	0.75	1.59	0.60	1.80

Values are means ± S.D. of three independent determinations

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

Table 51 : Effect of autoclaving on total copper content (mg/100 g) and its HCl-extractability (%) in peas
(on dry matter basis)

Varieties	Control		Unsoaked		Soaked		Soaked and dehulled	
	Total	Extract- ability	Total	Extract- ability	Total	Extract- ability	Total	Extract- ability
Vegetable peas								
Bonneville	1.24±0.08	79.0±0.86	1.13±0.23 (-9)	82.1±3.97 (+4)	1.00±0.66 (-19)	84.4±1.15 (+7)	1.00±0.00 (-19)	86.2±4.00 (+9)
Arkel	1.35±0.08	79.8±0.44	1.33±0.13 (-1)	82.4±1.85 (+3)	1.10±0.66 (-19)	83.9±0.37 (+5)	1.00±0.00 (-26)	85.4±2.46 (+7)
Field peas								
HFP4 (Aparna)	1.14±0.01	81.5±1.55	1.03±0.23 (-10)	82.0±7.1 (+0.6)	1.10±0.10 (-4)	83.4±0.58 (+2)	1.00±0.00 (-12)	86.1±3.64 (+6)
Rachna	1.13±0.03	78½8±0.58	1.00±0.10 (-12)	81.3±7.9 (+3)	1.00±0.12 (-12)	82.6±0.80 (+5)	1.00±0.00 (-12)	84.7±4.59 (+7)
SE(m)	±0.14	±0.78	±0.17	±0.23	±0.13	±0.12	±0.10	±0.21
CD (P < 0.05)	0.42	2.34	0.51	0.69	0.39	0.36	0.30	0.63

Values are means ± S.D. of three independent determinations

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

Table 52 : Effect of germination on total copper content (mg/100 g) and its HCl-extractability (%) in peas (on dry matter basis)

Varieties	Period of germination					
	Control		12 h		24 h	
	Total	Extract-ability	Total	Extract-ability	Total	Extract-ability
Vegetable peas						
Bonneville	1.24±0.08	79.0±0.86	1.23±0.03 (-0.8)	83.1±1.40 (+5)	1.23±0.12 (-0.8)	85.2±1.53 (+8)
Arkel	1.35±0.08	79.8±0.44	1.35±0.01 (0)	82.8±2.3 (+4)	1.35±0.20 (0)	84.1±1.82 (+5)
Field peas						
HFP4 (Aparna)	1.14±0.01	81.5±1.55	1.07±0.03 (-6)	83.6±1.25 (+3)	1.07±0.11 (-6)	84.0±1.04 (+3)
Rachna	1.13±0.03	78.8±0.58	1.13±0.03 (0)	81.7±1.16 (+4)	1.13±0.10 (0)	82.3±0.29 (+ 4)
SE(m)	±0.14	±0.78	±0.10	±0.16	±0.15	±0.11
CD (P < 0.05)	0.42	2.34	0.30	0.48	0.45	0.33
					±0.10	±1.1
					0.30	3.3

Values are means ± S.D. of three independent determinations

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

4.3.3.2 Extractability of minerals

Different domestic processing and cooking methods had significantly ($P < 0.05$) enhancing effect on the HCl-extractability of dietary essential minerals including calcium, phosphorus, iron, zinc and copper. As a result of soaking, dehulling, ordinary cooking, autoclaving and germination HCl-extractability in 0.03N HCl, an index of the bioavailability of the minerals, improved to varying extents.

On 6 h soaking, the extractability of calcium improved to the extent of 30 per cent in HFP4 Table-30. Arkel and HFP4 had similar calcium extractability values after 6 h soaking. As the period of soaking was prolonged i.e. from 6 to 12 and 12 to 18 h an enhancement in calcium extractability was also witnessed; after 18 h soaking calcium extractability almost doubled in HFP4.

The extractability of phosphorus improved after soaking the pea seeds for varying periods i.e. 6, 12 and 18 h Table-35. There were significant ($P < 0.05$) variations in the extractability of phosphorus of different raw as well as soaked pea cultivars. Bonneville, the vegetable pea variety had the maximum extractability of phosphorus followed by Arkel, Rachna and HFP4. After 18 h soaking the phosphorus extractability varied significantly ($P < 0.05$) in pea varieties; the maximum (14%) and minimum (7%) being observed in HFP4 and Bonneville, respectively.

The extractability of iron in vegetable peas was significantly ($P < 0.05$) higher than that of field peas. The raw seeds of Bonneville had the maximum iron extractability i.e. 48.3 and it was raised to 54.1 after 18 h soaking. On 18 h soaking, there were significant ($P < 0.05$) varietal differences in iron

extractability; an improvement in iron extractability ranged from 12 to 13 per cent in vegetable and field pea varieties Table-39.

The unsoaked seeds of vegetable peas had significantly ($P < 0.05$) higher zinc extractability than that of field peas where as copper extractability did not varied significantly ($P < 0.05$) among different unprocessed pea cultivars Table 44, 48. After 6 h soaking an increase to the extent of 23 per cent was witnessed in Rachna. As the period of soaking was increased 18 h, further enhancement in zinc extractability was noticed Table-44. Similar beneficial effect of soaking on the extractability of copper was observed. The per cent improvement in copper extractability varied from 4 to 6 in different pea varieties Table-48.

Soaking followed by dehulling, further caused an increase in the HCl extractability of minerals. An increase to the extent of 47 to 80, 14 to 25, 33 to 39, 58 to 79 and 5 to 11 per cent occurred in extractability of calcium, phosphorus, iron, zinc and copper, respectively Table 31, 40, 49.

On ordinary cooking and autoclaving of unsoaked, soaked and soaked dehulled seeds, there were significant varietal differences in the extractability of minerals in pea seeds. Ordinary cooking as well as autoclaving could enhance the extractability of minerals of unsoaked pea seeds but it was obviously less than that of soaked as well as soaked-dehulled seeds. Bonneville had the highest calcium extractability i.e. 42.3 per cent which was increased to 58.3, 67.3 and 70.1 per cent when unsoaked, soaked and soaked and dehulled pea seeds were ordinarily cooked, respectively Table-32. Maximum extractibility of calcium occurred in soaked, dehulled and cooked seeds of HFP4. Moist heating i.e. autoclaving could improve the calcium extractability of pea seeds to

a greater extent than ordinary cooking. The calcium extractability was almost doubled in the soaked, dehulled and autoclaved pea seeds of Arkel variety.

A significant ($P < 0.05$) difference in the extractability of phosphorus was found in the pea varieties on ordinary cooking and autoclaving of unsoaked soaked and soaked-dehulled seeds Table 36, 37. In unsoaked, soaked and soaked-dehulled pea seeds, the per cent increase in phosphorus extractability varied from 4 to 8, 10 to 14 and 21 to 28 per cent Table 36.

Similar beneficial effect of ordinary cooking and autoclaving could be seen in the extractability of iron, zinc and copper. Iron extractability was found to be maximum in unprocessed Bonneville followed by Arkel, HFP4 and Rachna. Ordinary cooking and autoclaving could improve iron extractability to the extent of 5 to 9 and 8 to 18 per cent in unsoaked pea seeds, respectively whereas in soaked seeds the improvement varied from 12 to 17 and 22 to 28 per cent, respectively. The highest (50%) extractability of iron occurred in the seeds of Rachna when these were soaked-dehulled and ordinarily cooked Table 41. As compared to ordinary cooking, autoclaving was noticed to be a better processing method for enhancing the iron extractability.

Zinc extractability of the soaked-dehulled and cooked pea seeds was about 3-4 times higher than that of unsoaked and cooked seeds. Rachna had 19.2 per cent zinc extractability and it was raised to 24.8, 30.9 and 38 per cent after cooking of unsoaked, soaked and soaked-dehulled seeds Table-45. Soaked-dehulled and autoclaved pea seeds had more than double the zinc extractability Table-46.

The raw seeds of HFP4 had the highest copper extractability i.e. 81.5 per cent followed by Arkel, Bonneville and Rachna. There were no

significant ($P < 0.05$) variations in the copper extractability of unprocessed Bonneville, Arkel and Rachna. Ordinary cooking could increase the copper extractability by 1 to 3, 2 to 5 and 5 to 8 per cent in unsoaked, soaked and soaked-dehulled seeds, respectively Table-50. Autoclaving had also similar enhancing effect on copper extractability of peas. An increase to the extent of 6 to 9% was observed in soaked-dehulled and autoclaved seeds of different pea cultivars Table-51.

The extractability of minerals was improved during germination of soaked seeds. Different pea cultivars showed significant ($P < 0.05$) differences in the extractability of calcium on 12, 24 and 48 h sprouting.. Increase in the sprouting period significantly ($P < 0.05$) affected the calcium extractability of field as well as vegetable peas. When the period of sprouting was increased from 12 to 24 h, the per cent increased in calcium extractability rose from 60 to 88, 75 to 102 and 78 to 112 and 51 to 82 in Bonneville, Arkel, HFP4 and Rachna, respectively Table-34. After 48 h germination calcium extractability was almost doubled in Arkel and HFP4.

Germination could improved the phosphorus extractability to varying extents in different pea varieties. Higher the period of germination, more was the improvement in phosphorus extractability. After 48 h germination the maximum increase i.e. 52 per cent occurred in HFP4 and the minimum i.e. 48 per cent in Arkel Table-38.

The sprouted pea seeds had higher extractability of iron than that of controls. There were significant ($P < 0.05$) varietal differences in iron extractability of pea seeds sprouted for varying periods. When the period of germination was increased from 24 to 48 h the per cent improvement i.e.

29 to 33 was raised by 58 to 71 in different varieties of field and vegetable peas Table 43.

Germination had beneficial effect on the extractability of zinc and copper too. Zn extractability was $2\frac{1}{2}$ times higher over the control values in HFP4 and Rachna sprouted for 48 h Table-47. The zinc extractability of Bonneville and Arkel was also doubled when sprouting was done for 48 h Table-47. There were no significant ($P < 0.05$) differences in the zinc extractability when Bonneville, Arkel and HFP4 were sprouted for 48 h Table-47. An increase to the varying extent in copper extractability occurred in the sprouts of seeds. After 48 h germination, Arkel, HFP4 and Rachna had comparable level of copper extractability.

As the divalent cations including calcium, iron, zinc, copper etc. are generally present in association with the phytic acid in plant foods which may be responsible for lower extractability of these divalent cations. Decrease in the level of phytic acid by various domestic and processing methods viz. soaking, dehulling, ordinary cooking, autoclaving and sprouting, as reported by previous workers (Kataria, 1986; Sharma, 1989) and in this study too Table 4 to 7 may possibly release these metallic ions in free form and may account for their increased HCl-extractability. The anti-nutrients including phytic acid in the processed peas were found to have a significant negative correlation with extractable calcium, phosphorus, iron, zinc and copper Table-53 to 57 which ascertained the role of phytic acid in lowering the extractability of the divalent cations in plant foods.

SUMMARY AND CONCLUSION

In the present study, four high yielding varieties of vegetable (Bonneville and Arkel) and field peas (HFP4 and Rachna), were assessed for their physico-chemical properties, nutrient composition, in vitro starch and protein digestibility and level of antinutritional factors. Effect of domestic processing and cooking methods viz. soaking, dehulling, ordinary cooking, autoclaving and sprouting on in vitro starch and protein digestibility, extractability of minerals and antinutritional factors was investigated.

Density among the four varieties of peas ranged from 1.18 to 1.30 g/ml; the highest being in Rachna and the lowest being in Arkel. Rachna (field pea) had the minimum hydration capacity (0.18 g/seed) whereas Arkel (Vegetable pea) had the maximum (0.24 g/seed) hydration capacity. The hydration index of Arkel was the highest followed by Bonneville, HFP4 and Rachna. Rachna, having the lowest hydration capacity had the minimum hydration index too. Swelling capacity and swelling index of Arkel was significantly ($P < 0.05$) higher than those of Bonneville, HFP4 and Rachna. Among all the varieties, Arkel had the highest hydration capacity, hydration index, swelling capacity and swelling index and it should be preferred over the field peas as it requires less cooking time and hence, will save fuel energy.

Among different pea cultivars Bonneville required the minimum cooking time i.e. 83 minutes whereas HFP4 and Rachna, the field pea, took 106 minutes.

Protein content of peas varied from 19.5 to 20.5 per cent the highest being in Arkel and the lowest in HFP4 (Aparna). Vegetable pea varieties (Bonneville and Arkel) had significantly ($P < 0.05$) higher levels of fat, ash and crude fibre than those of field peas.

Carbohydrate content was found to be maximum i.e. 64.9 in HFP4 followed by Rachna (64.6%), Bonneville (57.1%) and Arkel (56.7%). Peas had 5.81 to 6.98 g/100 g total soluble sugar content. Vegetable peas had significantly ($P < 0.05$) higher levels of total soluble sugars than those of field peas. There were significant ($P < 0.05$) varietal differences in the total available carbohydrates, starch, reducing and non-reducing sugar content of four pea cultivars.

The phytic acid and polyphenol of peas varied from 630.3 to 780.3 and 1.8 to 2.1 mg/100 g, respectively. Vegetable peas had significantly ($P < 0.05$) higher concentration of saponins than field peas. Peas contained varying amounts of trypsin inhibitor activity i.e. 922.4 to 989.5 TIU/g.

Starch digestibility (in vitro) expressed as mg maltose released/g flour was 30.53 to 36.53 in raw unprocessed seeds of different pea cultivars. The raw unprocessed pea had 60.4 to 66.4 per cent protein digestibility (in vitro) . Field pea cultivars viz. HFP4 and Rachna had significantly ($P < 0.05$) lower in vitro starch as well as protein digestibility than those of vegetable peas.

Pea seeds were found to be good sources of calcium (25.6 to 35.1 mg/100 g), phosphorus (319.7 to 361.1 mg/100 g), iron (10.4 to 12.5 mg/100 g), zinc (3.1 to 5.4 mg/100 g) and copper (1.1 to 1.3 mg/100 g).

All the domestic processing and cooking treatments had a significant ($P < 0.05$) lowering effect on antinutrients including phytic acid, polyphenol, saponin and trypsin inhibitor activity in vegetable as well as field peas. There was a successive and significant ($P < 0.05$) decrease in phytic acid and polyphenols

with increase in soaking period in all the pea cultivars. Dehulling of the soaked pea seeds was found to be more effective in lowering down the content of phytic acid, polyphenols and saponins. The concentration of these antinutrients declined following ordinary cooking, autoclaving and sprouting too. Longer the germination period, more was the decline in phytic acid, polyphenols and saponins. Among all the processing and cooking methods, germination could lower the content of antinutrients including phytic acid, polyphenols and saponins to maximum. After 48 h germination phytic acid and polyphenols were lost to the extent of 67 to 83 and 84 to 96 per cent, respectively. Autoclaving of soaked and dehulled pea seeds could decrease the trypsin inhibitor activity to the extent of 90 to 95 per cent over the control values. Autoclaving and ordinary cooking of soaked seeds was much more effective in decreasing all these antinutrients than that of unsoaked seeds.

All the treatments (soaking, ordinary cooking, autoclaving and sprouting) improved the in vitro digestibility of starch and protein. The treatment autoclaving involving heat processing after soaking and dehulling had the most marked effect on the digestibility of starch and protein.

Different processing and cooking methods had varying effects on the mineral composition of pulses. With an increase in the period of soaking, a loss in total content of calcium, phosphorus, iron, zinc and copper was noticed to varying extents in different pea cultivars. Dehulling of the soaked seeds further reduced the total mineral content. The losses of total mineral content were less when the unsoaked rather than soaked seeds were ordinarily cooked or autoclaved. Germination itself did not seem to alter the total mineral

composition. Some decrease in the total mineral content of sprouted pea seeds was due to fact that soaking of seeds for 12 h was done prior to germination.

As a result of soaking, dehulling, ordinary cooking, autoclaving and germination HCl-extractability of minerals in 0.3 N HCl, an index of their bioavailability improved to varying extents. On 6 h soaking, the extractability of calcium improved to the extent of 30% in HFP4. As the period of soaking was prolonged i.e. from 6 to 12 and 12 to 18 h an enhancement in calcium extractability was also witnessed. Soaking followed by dehulling, further caused an increase in the calcium extractability. Bonneville had the highest calcium extractability i.e. 42.3 per cent which was increased to 51.4, 65.9 and 69.8 per cent when unsoaked, soaked and soaked-dehulled pea seeds were ordinarily cooked, respectively. Moist heating i.e. autoclaving could improve the calcium extractability of pea seeds to a greater extent than ordinary cooking. Germination for 48 h could improve the calcium extractability by 112 per cent.

The extractability of phosphorus improved after soaking the pea seeds for varying periods i.e. 6, 12 and 18 h. On dehulling the soaked seeds there was 14 to 25 per cent increase in the phosphorus content. A significant ($P < 0.05$) difference in the extractability of phosphorus was found in the pea varieties on ordinary cooking and autoclaving of unsoaked, soaked and soaked-dehulled seeds. Higher the period of germination, more was the improvement in phosphorus extractability.

The iron extractability of vegetable peas was significantly ($P < 0.05$) higher than that of field peas. The raw seeds of Bonneville had 48.3 per cent

iron extractability which was raised to 54.1 per cent after 18 h soaking. Soaking followed by dehulling further caused an increase in the iron extractability to the extent of 33 to 39 per cent. As compared to ordinary cooking, autoclaving was noticed to be a better processing method for enhancing the iron extractability. There were significant ($P < 0.05$) varietal differences in iron extractability of pea seeds sprouted for varying periods.

Soaking and dehulling increased the zinc and copper extractability by 58 to 79 and 5 to 11 per cent, respectively. Zinc extractability of the soaked-dehulled and cooked pea seeds was about 3-4 time higher than that of unsoaked and cooked seeds. Soaked-dehulled and autoclaved pea seeds had more than double the zinc extractability.

Ordinary cooking could increase the copper extractability by 1 to 3, 2 to 5 and 5 to 8 per cent of unsoaked, soaked, soaked-dehulled seeds, respectively. Autoclaving had also a similar enhancing effect on copper extractability of peas. An increase to the extent of 6 to 9 per cent was observed in soaked-dehulled and autoclaved seeds of different pea cultivars. Germination had beneficial effect on the extractability of zinc and copper too.

Thus, the nutrient composition of peas is excellent in respect of protein, digestible carbohydrates and dietary essential minerals. They have a potential as a protein concentrate and can be processed to produce high-protein containing products. As the nutritive value of pea seeds is limited by antinutrients including phytic acid, polyphenols, saponin and trypsin inhibitor activity which are present in considerable amounts, can be reduced by domestic processing methods.

As a result of soaking, dehulling, ordinary cooking, autoclaving and sprouting a significant ($P < 0.05$) reduction occurred in the content of antinutrients viz. phytic acid, polyphenol, saponin, trypsin inhibitor activity. Starch and protein digestibility (in vitro) improved considerably in vegetable as well as field peas. HCl extractability of calcium, phosphorus, iron, zinc and copper was also enhanced during different processing and cooking methods. hence, the processed peas have a better potential as protein concentrate for the production of high protein containing food supplements, the consumption of which can lead to better nutritional status of the masses.

BIBLIOGRAPHY

- Abdus Sattar, Durrani, S.K., Mahmood, F., Admad, A. and Khan, I. (1989). Effect of soaking and germination temperature on selected nutrients and antinutrients of mung bean . Food Chem. **34**(2): 111-120. [En., 30 ref.] Nuclear Inst. Food and Agric., Peshawar, Pakistan.
- Ahmad, M. and Shehata, EL. T. (1982). Cooking quality of faba beans. In "Faba bean Improvement" (Hawtin, G. and Webb, C. ed.). ICARDA, Aleppo, Syria, pp. 355-362.
- Akeson, W.E. and Stahmann, M.A. (1964). A pepsin-pancreatin digest index of protein quality evaluation. J. Nutr. **83** : 257-259.
- Akinyele, I.O. (1989). Effects of traditional methods of processing on the nutrient content and some antinutritional factors in cowpeas (Vigna unguiculata). Food Chem. **33** : 291-299.
- A L.-Baker, A.Y. Sachde, A.G. and Naoum, I.E. (1982). Occurrence and stability of trypsin inhibitor in Iraqi local legumes. J. Agric. Food Chem. **30** : 1184-1185.
- Albrecht, W.J., Mustakas, C.G., McGhee, J.E. and Griffin, E.L. (Jr.) (1967). A simple method for making full fat soy flour cereal. Sci. Today. **12** : 81-83.
- Ali, H.I. and Harland, B.F. (1991). Effects of fibre and phytate in sorghum flour on iron and zinc in weanling rats : A pilot study. Cereal Chem. **68**(3).
- Ali-Khan, S.T. and Youngs, C.G. (1973). Variation in protein content of field peas. Can. J. Plant Sci. **53** : 37-41.

- Anderson, J.W. and Bridges, S.R. (1988). Dietary fibre content of selected foods. *Am. J. Clin. Nutr.* **47**: 440.
- Anonymous. (1973). Nutritional improvement of food legumes by breeding
Ed. Max. Milner, PAG, Italy. pp. 61-68.
- Antunes, P.L. and Sgarbieri, V.C. (1980). Effect of heat treatment on the toxicity and nutritive value of dry bean (Phaseolus vulgaris) protein. *J. Agric. Food Chem.* **28** : 935.
- AOAC (1980). Official Methods of Analysis of the Association of Official Agricultural Chemists. Association of Analytical Chemists. Washington, D.C. pp. 125-139.
- Augustin, J., Beck, C.B., Kalbfleish, G., and Kagel, L.C. (1981). Variation in the vitamin and mineral contents of raw and cooked commercial Phaseolus vulgaris classes. *J. Food Sci.* **46** : 1701.
- Aw, T.L. and Swanson, B.G. (1985). Influence of tannins on Phaseolus vulgaris protein digestibility and quality. *J. Food Sci.* **50**: 67.
- Aykroyd, W.R. and Doughty, J. (1964). Legumes in Human Nutrition. FAO. National Studies. 19.
- Bansal, K.K., Dhindsa, K.S. and Batra, V.I.P. (1988). Trypsin inhibitor and haemagglutinin activities in chick pea (Cicer arietinum L.) *J. Food Sci. Technol. India* **25**(1) : 46-48.
- * Barre, R. (1965). Influence of phytic acid on peptic digestion of various proteins. *Annales Pharmaceutiques Francaises.* **14**: 182-193.

- *Bednarski, W., Jomasik, J and Piatkowska, B. (1985). Processing and nutritive values of Vicia faba minor beans after sprouting. *Przemyslyspozywezy* **39**(6) : 222-225 (Cited from *FSTA* **18**(12), 12J (83).
- Bender, A.E. (1972). Processing damage to protein foods. In "Protein Advisory Group Bulletin", United Nations, New York. **2**: 10.
- *Benken, I.I. and Budanova, V.I. (1976). Trypsin inhibitor in seeds of Phaseolus sp. *Trudy PO. Prikladnoi Botanika Genetica i Selekcii*. **56**: 67-73.
- Bhatty, R.S. (1974). Chemical composition of some faba bean cultivars. *Can J. Plant Sci.* **54**: 413-421.
- Biliaderis, C.G., Grant, D.R., Vose, J.R. (1981). Structural characterization of legume starches. 1. Studies on amylose, amylopectin, and beta-limit dextrins. *Cereal Chem.* **58**: 496-502.
- Birk, Y. (1969). Saponins. In "Toxic Constituents of Plant Foodstuff". [Liener, I.E. (ed.)]. Academic press, New York, pp. 169-210.
- Bond, D.A. (1976). Field bean. In "Evolution of crop plants", [Simmonds, N.W. (ed.)]. Longman, London, pp. 179-182.
- Borade, V.P., Kadam, S.S. and Salunkhe, D.K. (1984). Changes in phytic phosphorus and minerals during germination and cooking of horse gram and moth bean. *Qual. Plant. Plant Foods Hum. Nutr.* **34**(2): 151.
- Boralkar, M. and Reddy, S.N. (1985). Effect of roasting, germination and fermentation on the digestibility of starch and protein present in soybean. *Nutr. Rep. Int.* **31**(4): 833-835.
- Boulter, D. (1982). The composition and nutritional value of legumes in relationship to crop improvement by breeding. *Proc.Nutr.Soc.***41**: 1-6.

- Bramsnaes, F., Olsen, H.S. (1979). Development of field pea and faba bean proteins. *J. Am. Oil Chem. Soc.* **56**: 450-453.
- Bressani, R. (1973). Nutritional improvement of legumes by breeding. Ed. Max. Milner Academic Press, New York. pp. 15.
- Bressani, R. and Elias, L.G. (1979). The nutritional role of polyphenols in beans. In "Proc. Symp. Polyphenols in Cereals and Legumes". Institute of Food Technologists, St. Louis, M.O.
- Bressani, R. and Elias, L.G. (1980). Polyphenols. In "Cereals and Legumes" (J.H.Hulse, ed.) IDRC, Ottawa, Canada, pp. 61.
- Burkitt, D.P. (1973). Epidemiology of large bowel disease: the role of fibre. *Proc. Nutr. Soc.* **32** : 145-149.
- Burkitt, D.P., Trowell, H.C. (1975). Refined carbohydrate foods and disease. London, U.K., Academic Press.
- * Cain, R.F. (1950). Relation of time and temperature of blanch to tenderness. *The Canner.* **111**: 10.
- Calloway, D.H., Hickey, C.A., Murphy, E.L. (1971). Reduction of intestinal gas-forming properties of legumes by traditional and experimental food processing methods. *J. Food Sci.* **36**: 251-255.
- * Canus, M.C. , Laporte, J.S. (1976). *Ann. Biol. Anim., Biochem., Biophys.* **16**: 719-729.
- Carnovale, E., Lugaro, E. and Lombardi-Boccia, G. (1988). Phytic acid in faba bean and pea : Effect on protein availability. *Cereal Chem.* **65**(2): 114-117.

- Cerning, J. and Guilhot, J. (1973). Changes in carbohydrate composition during maturation of wheat and barley kernel. *Cereal Chem.* **50**: 220.
- Chang, C.W. (1967). Study of phytase and flouride effects in germinating corn seeds. *Cereal Chem.* **44**: 129-130.
- Cheeke, P.R. (1976). Nutritional and Physiological properties of saponins. *Nutr. Rep. Int.* **13**: 315-324.
- Chen, P.S., Tosibara, T.Y. and Warner, H. (1956). Micro determinations of phosphorus. *Anal. Chem.* **28**: 1756-1759.
- Cheryan, M. (1980). Phytic acid interaction in food systems. *CRC Crit. Rev. Food Sci. Nutr.* **13**: 297-335.
- Chitra, R., Sadasivam, S. (1986). A study on the trypsin inhibitor of black gram (Vigna mungo L.) Hepper). *Food Chem.* **21**: 315-320.
- Chompreeda, P.T. and Fields, M.L. (1984). Effects of heat and fermentation on the extractability of minerals from soybean meal and corn meal blends. *J. Food Sci.* **49**: 566-568.
- Chompreeda, P.T. and Fields, M.L. (1984). Effect of heat and natural fermentation on amino acids, flatus producing compounds, lipid oxidation and trypsin inhibitor in blends of soybean and cornmeal. *J. Food Sci.* **49**: 563.
- Clegg, K.M. (1956). The application of the anthrone reagent to the estimation of starch in cereals. *J. Sci. food Agric.* **7**: 40.
- Coffey, D.G., Uebersax, M.A., Hosfield, G.L. and Brunner, J.R. (1985). Evaluation of the haemagglutinating activity of low temperature cooked kidney beans. *J. Food Sci.* **50**: 78-81.

- * Cole, S. (1961). Neolithic revolution. Ed. 2. London, U.K., British Museum of Natural History.
- Collins, J.L. and Saunders, G.G. (1976). Changes in trypsin inhibitor activity in some soybean varieties during maturation and germination. *J. Food Sci.* **41**: 168-171.
- Crapo, P. (1984). Theory Vs fact : The glycemic response to foods. *Nutr. Today.* **14**: 6-11.
- Cummings, J.H. (1978). Nutritional implication of dietary fibre. *Am. J. Clin. Nutr.* **31**: 521.
- Deniels, D.G.H. and Fisher, N. (1981). Hydrolysis of the phytate of wheat flour during bread making. *Brit. J. Nutr.* **46**: 1-6.
- Davies, N.T. and Nightingale, R. (1975). The effects of phytate on intestinal absorption and secretion of zinc, whole body retention of zinc, copper, iron and manganese in rats. *Brit. J. Nutr.* **34**: 243-246.
- Davies, N.T. and Reid, H. (1979). An evaluation of phytate, zinc, copper, iron and manganese content and zinc availability from soy-based textured vegetable protein meat substitutes or meat extrudes. *Brit. J. Nutr.* **41**: 579-589.
- de Boland, A.R., Garner, G.B. and O'Dell, B.L. (1975). Identification and properties of phytate in cereal grains and oil seed products. *J. Agric. Food Chem.* **23**: 1186-1190.
- * de Espana, M.E.F. (1977). Estudio Sobre las posibles relaciones entre parametros fisicos, quimicos y nutricionales on Phaseolus vulgaris B.S. Thesis (ESNA/INCAP).

- Deo, S. (1987). Chemical composition and nutritive value of mung, pigeonpea, urd, lentils and peas. M.Sc. Thesis. Lincoln College, University of Canterbury, New Zealand.
- Deosthale, Y.G. (1984). Food processing and nutritional value of legumes. In "Pulse production constraints and opportunities". Ed. Shrivastava, S.C., Bhaskaran, S., Menon, K.K.G., Ramanujan, S. and Rao, M.V. Oxford and IBH Publishing Company, New Delhi.
- Desphande, S.S. and Cheryan, M. (1983). Changes in the phytic acid, tannins and trypsin inhibitor activity on soaking of dry beans. (P. vulgaris L.) Nutr. Rep. Int. **27**: 371-378.
- Deshpande, S.S. and Cheryan, M. (1984). Effect of phytic acid, divalent cations and their interactions on alpha amylase activity. J. Food Sci. **49**: 516-519.
- Deshpande, S.S. and Salunkhe, D.K. (1982). Interaction of tannic acid and catechin with legume starches. J. Food Sci. **47**: 2080-2081.
- Drumm, T.D., Gray, J.I., Hosfield, G.L. and Uebersax (USA), M.A. (1990). Lipid, saccharide, protein, phenolic acid and saponin contents of four market classes of edible dry beans as influenced by soaking and canning. J. Sci. Food Agric. **51**: 425-435.
- Duhan, A., Chauhan, B.M., Punia, D. and Kapoor, A.C. (1989). Phytic acid content of chick pea (Cicer arietinum) and black gram (Vigna mungo): Varietal differences and effect of domestic processing and cooking methods. J. Sci. Food Agric. **49**: 449-435.
- Ekfenyong, T.E. (1985). Effect of cooking on polyphenolic content of some Nigerian legumes and cereals. Nutr. Rep. Int. **31**(3): 561-565.

- Ekfenyong, T.E. and Brochers, R.L. (1979). Digestibility of protein of winged bean seed. *J. Food Sci. Technol.* **16**: 92-95.
- Ekfenyong, T.E. and Brochers, R.L. (1982). Effect of processing on some nutritional properties of protein in winged bean. *Nutr. Rep. Int.* **25**: 877-885.
- Elbert, E.M. and Witt, R.L. (1968). Gelatinization of starch in the common dry bean. *J. Home Econ.* **60**: 186.
- El-Faki, H.A., Venkataraman, L.V., Desikachar, H.S.R. (1984). Effect of processing on the in vitro digestibility of protein and carbohydrates in some Indian legumes. *Qual. Plant. Plant Foods Hum. Nutr.* **34**: 127-133.
- Elias, L.G., de Fernandez, D.G. and Bressani, R. (1979). Possible effects of seed coat polyphenols on the nutritional quality of bean protein. *J. Food Sci.* **44**: 524-527.
- Elkowicz, K., Sosulski, F.W. (1982). Antinutritive factors in eleven legumes and their air-classified protein and starch fractions. *J. Food Sci.* **47** : 1301-1304.
- El-Refai, A.A., Gouda, M.S., Ammar, K.A. (1987). Effect of processing and storage on protein and lipid composition of peas. *Food Chem.* **23** : 117-127.
- Erdman, J.W., Jr. (1979). Oilseed phytates: Nutritional implications. *J. Am. Oil. Chem. Soc.* **56**: 736-741.
- Erdman, J.W., Jr. (1981). Bioavailability of trace minerals from cereals and legumes. *Cereal Chem.* **58**: 21.

- Erdman, J.W.Jr., Forbes, R.M. (1977). Mineral bio-availability from phytate-containing foods. *Foods Product Development*. **11**: 46-48.
- Eskin, N.A.M., Johnson, S., Vaisey-Genser, M., McDonald, B.E. (1980). A study of oligosaccharides in selected group of legumes. *Can. Inst. Food Sci. Technol. J.* **13**: 40-42.
- * Etchevers, G.G.de.(1980). Chemical composition of some legumes and chenopodiaceas grown in the provincia of Nuble. *Ciencia e Investigacion Agraria*. **7**: 191-196.
- Evans, I.M. and Boulter, O. (1980). Crude protein and sulphur amino acid content of some commercial varieties of peas and beans. *J. Sci. Food Agric.* **31**: 238-242.
- Evans, R.J., Bauer, D.H., Adams, M.W. and Saettler, A.W. (1978). Methionine and cysteine contents of bean (Phaseolus seeds). *J. Agric. Food Chem.* **26**: 1234-1237.
- Fenwick, D.E. and Oakenfull, P. (1983). Saponin content of food plants and some prepared foods. *J. Sci. Food Agric.* **34**: 186-191.
- Fleming, S.E. (1981). A study of relationships between flatus potential and carbohydrate distribution in legume seeds. *J. Food Sci.* **46**: 794-798.
- Fleming, S.E. (1981). Flatulence activity of the smooth-seeded field peas as indicated by hydrogen production in the rat. *J. Food Sci.* **47**: 12.
- Fleming, S.E. (1981). Influence of cooking method on digestibility of legume and cereal starches. *J. Food Sci.* **47**: (1): 1-7.
- Fleming, S.E., Reichert, R.D. (1983). A comparison of flatulence potential of field pea and soybean seed fraction. *Can. Inst. Food Sci. Technol. J.* **16**: 30-34.

- Friedman, M., Brandon, D.L., Bates, A.H. and Hymowitz, T. (1991). Comparison of a commercial soybean cultivar and an isoline lacking the kunitz trypsin inhibitor: Composition, nutritional value and effect of heating. *J. Agric. Food Chem.* **39**(2): 327-335.
- * Gallardo, F., Araya, H., Pak, N. and Togle, M.A. (1974). Toxic factors in chilean legumes. II. Trypsin inhibitor activity. *Archivos Latinoameri-Canas de Nutricion* **24**: 183-191.
- Ganesh Kumar, K. and Venkataraman, L.V. (1976). Studies on the in vitro digestibility of starch in some legumes before and after germination. *Nutr. Rep. Int.* **13**: 115.
- Geervani, P. and Theophilus, F. (1980). Studies on digestibility of selected legumes carbohydrates and its impact on the pH of the gastro intestinal tract in rats. *J. Sci. Food Agric.* **32**: 71-75.
- * George, A.J. (1965). Legal status and toxicity of saponins. *Food Cosmet. Toxicol.* **3**: 85-87.
- Gestetner, B., Birk, Y., Bondi, A. and Tencer, Y. (1966). Method for the determination of sapogenin and saponin contents in soybeans. *Phyto Chem.* **5**: 803-806.
- Gibbins, L.N. and Norris, F.N. (1963). Phytase and acid phosphatase in the dwarf bean (P. vulgaris). *Biochem. J.* **86**: 67-71.
- Gopalan, C., Ram Shastri, B.V. and Balasubramanian, S.C. (1984). Nutritive value of Indian foods. Indian Council of Medical Research, New Delhi. pp. 131.
- Gorski, P.M. (1985). Variation in tannin content of faba bean (Vicia faba) seed coat. *FABIS, News Letter.* **11**: 26-28.

- Green, N.W. and Neurath, H. (1953). The effects of divalent cations on trypsin. *J. Biol. Chem.* **204**: 379-389.
- Greenwood, C.T. and Thompson, J. (1962). The properties of the components of starches from smooth and wrinkled seeded peas. *Biochem. J.* **82**: 156.
- Griffiths, D.W. (1979). Inhibition of digestive enzymes by extracts of field beans (Vicia faba). *J. Sci. Food Agric.* **30**: 458-462.
- Griffiths, D.W. (1984). The trypsin and chymotrypsin inhibitor activities of various pea (Pisum sp.) and field bean (Vicia faba) cultivars. *J. Sci. Food Agric.* **35**: 481-486.
- Griffiths, D.W. and Moseley, G. (1980). The effect of diets containing field beans of high or low polyphenolic contents on the activity of digestive enzymes in the intestine of rats. *J. Sci. Food Agric.* **31**: 255-259.
- Griffiths, D.W. and Thomas, T.A. (1981). Phytate and total phosphorus content of field beans (Vicia faba L.). *J. Sci. Food Agric.* **32**: 187-192.
- Griminger, P. and Fisher, H. (1958). dietary saponin and plasma cholesterol in the chicken. *Proc. Soc. Exp. Biol. Med.* **99**: 424.
- Gross, R. (1983). Composition and protein quality of winged bean. *Qual. Plant. Plant Foods Hum. Nutr.* **32**: 117-124.
- Gueguen, J. and Barbot, J. (1988). Quantitative and qualitative variability of pea (Pisum sativum) protein composition. *J. Sci. Food Agric.* **42**: 209-224.

- Gupta, K. and Wagle, D.S. (1980). Changes in antinutritional factors during germination in Phaseolus mungoreous. A cross between Phaseolus mungo (M₁₋₁) and Phaseolus aureus (T₁). J. Food Sci. **45**: 394-397.
- Gupta, Y.P. (1987). Antinutritional and toxic factors in food legumes. Qual. Plant. Plant Foods Hum. Nutr. **37**: 201.
- *Hamza, M.H. (1983). Electrophoretic studies on seed protein of some Egyptian and German legume seeds. Ph.D. Thesis. Faculty of Agriculture, University of Alexandria (Cited from Youssef et al., 1987).
- Haslam, E. (1974). Polyphenol - protein interactions. Biochem. J. **139**: 285-289.
- Hellendoorn, E.W. (1978). Fermentation as the principal cause of the physiological activity of indigestible food residues. In:"Topics in Dietary Fibre Research" pp. 127-167. Plenum Press, New York, N.Y.
- Henderson, H.M. and Ankrah, S.A. (1985). The relationship of endogenous phytase, phytic acid and moisture uptake with cooking time in Vicia faba minor cultivar. Aladin. Food Chem. **17**(1) : 1-11.
- Hernández, T., Hernández, A. and Martinez, C. (1991). Polyphenols in alfalfa leaf concentrates. J. Agric. Food Chem. **38**(6) : 1120-1122.
- Hoff, J.E. and Nelson, P.E. (1966). Methods for accelerating the processing of dry beans. Eight Dry Bean Research Conference. Bellair, M.I. Aug. 11-13.
- Hove, E.L., King, S. (1979). Trypsin inhibitor contents of lupin seeds and other grain legumes. New Zealand J. Agric. Res. **22**: 41-42.

- Hove, E.L., King, S., Hill, G.D. (1978). Composition, protein quality and toxins of seeds of the grain legumes. Glycine max, Lupins sp. Phaseolus sp. , Pisum sativum and Vicia faba. New Zealand J. Agric. Res. **21**: 457-462.
- HSu, S.H. and Hadley, H.H. and Hymowitz, T. (1973). Changes in carbohydrate content of germinating soybean seeds. Crop Sci. **13**: 407.
- Hulse, H.J., Laing, E.M., and Pearson, D.E., ed. (1980). Sorghum and millets: Their composition and nutritional value. Academic Press, New York.
- Iyer, V., Salunkhe, D.K., Sathe, S.K. and Rockland, L.B. (1980). Quick cooking beans (P. vulgaris L.) II Phytate, oligosaccharides and anti-enzymes. Qual. Plant. Plant FoodsHum. Nutr. **30**: 45-46.
- * Jacorzyski, B. Filutowicz, H. Wronowski, S. (1981). The effect of cooking on the mono and oligosaccharides in the seeds of pulse crop. Acta Alimentaria Polonica. **7**($\frac{1}{2}$). 3-11.
- * Jaffe, W.G. (1950). Estudio sobre la inhibicion del ercimiento de ratas esusada por algunas semillas de leguminosas. Acta Cient Venezolana **1**: 62 (Cited from from "Toxic Constituents of Plant Foodstuffs" by Liener, I.E. 1976).
- Jaffe, W.G. (1980). Haemagglutinins (lectins). In "Toxic Constituents of Plant Foodstuffs : Liener, I.E., ed., Academic Press, New York.
- Janardanan., K. and Lakshmanan, K.K. (1985). Studies on the pulse Mucuna utilis : Chemical composition and antinutritional factors. J. Food Sci. Tech. **22**(5) : 369.
- Janoria, M.P., Gour, V.K. and Singh, C.B. (1984). Perspectives in grain legumes. National Seminar on New Dimensions in Pulse Research and Development. April. Jabalpur.

- Jaya, T.V. and Venkataraman, L.V. (1980). Effect of germination on the nitrogenous constituents, essential amino acid, carbohydrates, enzymes and antinutritional factors in chick pea and green gram. *Indian Food Packer*. **34**: 3-11.
- Jenkins, D.J.A., Jepson, E.M. (1982). Leguminous seeds and their constituents in the treatment of hyperlipidaemia and diabetes. In *lipoprotein and coronary atherosclerosis*, Nosedar, G., Graglia como, C., Fumagalli, R., Paoletti, R., ed., Elsevier Biomedical Press, New York.
- Jenkins, D.J.A., Wolever, T.M.S., Jenkins, A.L., Thompson, L.U., Rao, A.V., Francis, T. (1986). The glycemic index: Blood glucose response to foods. In *Dietary Fibre : Basic and chemical Aspects*; Vahouny, G.V., Kritchevsky, D. ed., Plenum Press: New York.
- Jenkins, D.J.A., Wong, G.S., Patten, R.P., Bird, J., Hall, M., Buckley, G., McGuire, V., Reichert, R., Little, A. (1983). Leguminous seeds in the dietary management of hyperlipidaemia. *Am. J. Clin. Nutr.* **38**: 567-573.
- Johns, D.C. (1986). Trypsin inhibitors in peas. *Proc. Nutr. Soc. New Zealand*. **11**: 100.
- Johns, D.C. (1987). Influence of trypsin inhibitors in four varieties of peas (*Pisum sativum*) on the growth of chickens. *New Zealand. J. Agric. Res.* **30**: 169-175.
- Jood, S., Chauhan, B.M. and Kapoor, A.C. (1986). Saponin content of chick pea and black gram: Varietal differences and effects of processing and cooking methods. *J. Sci. Food Agric.* **37**: 1121-1124.
- Jood, S., Chauhan, B.M. and Kapoor, A.C. (1987). Polyphenols in chick pea and black gram as affected by domestic processing and cooking methods. *J. Sci. Food Agric.* **38**: 145-149.

- Jood, S., Chauhan, B.M. and Kapoor, A.C. (1988). Contents and digestibility of carbohydrates of chick pea and black gram as affected by domestic processing and cooking. *Food Chem.* **30** : 113-127.
- Jood, S., Chauhan, B.M. and Kapoor, A.C. (1989). Protein digestibility (in vitro) of chick pea and black gram as affected by domestic processing & cooking. *Qual. Plant. Plant Foods Hum. Nutr.* **39**(2): 149-154.
- Jood, S., Mehta, U. and Singh, R. (1986). Effect of processing on available carbohydrates in legumes. *J. Agric Food Chem.* **34**: 417-422.
- Jood, S., Mehta, U., Singh, R. and Bhatt, C.M. (1985). Effect of processing on flatus producing factors in legumes. *J. Agric. Food Chem.* **33**: 268-271.
- Kadam, S.S., Gorpade, U.M., Adsule, R.N. and Salunkhe, D.K. (1986). Trypsin inhibitors in moth bean: Thermal stability and changes during germination and cooking. *Qual. Plant. Plant Foods Hum. Nutr.* **36** : 43-46.
- Kadwe, R.S., Thakre, K.K. and Badhe, N.N. (1974). A note on the protein per cent and mineral composition on twenty five varieties of pulses. *Indian J. Nutr. Dietet.* **11**: 83-84.
- Kakade, M.L. (1969). Nutritive value of field beans (Dolichos lablab). I. In vitro digestibility of raw and autoclaved beans. *J. Sci. Indust. Res.* **21** C: 155-158.
- Kakade, M.L. and Evans, R.J. (1963). Effect of heat on the in vitro digestion of navy beans (Phaseolus vulgaris). *J. Agric. Food Chem.* **13** : 45-49.
- Kakade, M.L. and Evans, R.J. (1966). Effect of soaking and germination on the nutritive value of navy beans. *J. Food Sci.* **31**: 781.

- Kamalakannan, V., Safhyamoorshy, A.V. and Motlang, D.B. (1981). Studies on black gram (Vigna mungo) trypsin inhibitor. J. Sci. Food Agric. **32**: 1172-1176.
- Kapoor, A.C. (1972). Studies on the nutritional and protein quality and on the metabolism of nitrogen and phosphorus of soybean (Glycine max L. Marriell). Ph.D. Thesis. Indian Agricultural Research Institute, New Delhi. India.
- Kataria, A. (1986). Studies on nutrient composition and antinutritional factors of amphidiploids (green gram x black gram). M.Sc. Thesis. Haryana Agricultural University, Hisar.
- Kataria, A., Chauhan, B.M. and Gandhi, S. (1988). Effect of domestic processing and cooking on the antinutrient of black gram. Food. Chem. **30** (2) : 149-156.
- Kataria, A., Chauhan, B.M. and Punia, D. (1989). Antinutrients and protein digestibility (in vitro) of mungbean as affected by domestic processing and cooking. Food Chem. **32**: 9-17.
- Kataria, A., Chauhan, B.M. and Punia, D. (1989). Antinutrients in amphidiploids (black gram x mung bean). Varietal differences and effect of domestic processing and cooking. Qual. Plant. Plant Foods Hum. Nutr. **39**(3) : 257-266.
- Kataria, A., Chauhan, B.M. and Punia, D. (1990). Effect of domestic processing and cooking methods on the contents of carbohydrates of amphidiploids (black gram x mung bean). Food Chem. **36**(1) : 63-67.
- Kaur, D. (1986). Studies on nutrient composition and antinutritional factors of rice bean (Vigna umbellata). M.Sc. Thesis. Haryana Agricultural University, Hisar.

- Kaur, D. and Kapoor, A.C. (1990). Some antinutritional factors in rice bean (Vigna umbellata). Effects of domestic processing and cooking methods. Food Chem. **37**: 171-179.
- Kaur, D. and Kapoor, A.C. (1990). Starch and protein digestibility of rice bean (Vigna umbellata). Food Chem. **38**: 263-272.
- Khalil, J.K., Sawaya, W.N. and Ali-Mohammad, H.M. (1986). Effects of experimental cooking on the yield and proximate composition of three selected legumes. J. Food Sci. **51**: 233-234.
- Khan, N.A. and Ghafoor, A. (1978). The effect of soaking, germination and cooking on the protein quality of mash beans (Phaseolus mungo) J. Sci. Food Agric. **29**: 461.
- Khokhar, S. (1984). Studies on nutrient composition and antinutritional factors of moth bean (Vigna aconitifolia). M.Sc. Thesis. Haryana Agricultural University, Hisar.
- Khokhar, S. and Chauhan, B.M. (1986). Antinutritional factors in moth bean (Vigna aconitifolia): Varietal differences and effects of methods of domestic processing and cooking. J. Food Sci. **51**(3) : 591-594.
- Khokhar, S. and Chauhan, B.M. (1986). Effect of domestic processing and cooking on in vitro protein digestibility of moth bean. J. Food Sci. **51**(4): 1083-1084.
- Khokhar, S. and Chauhan, B.M. (1986). Nutrient composition, protein fraction and antinutritional factors of moth beans (Vigna aconitifolia). Bull. Grain Technol. **24**(1): 3.
- Khokhar, S. and Chauhan, B.M. (1986). Saponins in food - their physiological and nutritional significance. Sci. culture **52**(a): 287-291.

- *King, T.P., Pusztai, A., Clarke, A.M.V. (1982). Kidney bean (Phaseolus vulgaris) lectin - induced lesions of the rat small intestine 3. Ultrastructural studies. J. Comp. Pathol. **92** : 357-373.
- Knuckles, B.E., Kuzmicky, D.D. and Batachart, A.A. (1985). Effect of phytate and partially hydrolyzed phytate on in vitro protein digestibility. J. Food Sci. **50**(4) : 1080-1082.
- Koehler, H.H. and Burke, D.W. (1981). Nutrient composition, sensory characteristics, and texture measurements of seven cultivars of dry beans. J. Am. Soc. Hort. Sci. **106**: 313.
- Koller, D., Mayer, A.M., Poljakoft Mayber, A. and Klein, S. (1962). Seed germination. Ann. Rev. Plant Physiol. **13**: 437.
- Kooistra, E. (1962). On the differences between smooth and three types of wrinkled peas. Euphytica. **11**: 357-373.
- *Koreleski, J., Rys, R. Kubicz, M. (1977). Effect of heating and autoclaving of field pea and yellow lupin seeds on the protein value. Roczniki Naukowe Zootechniki. **4**: 203-208.
- Kruger, J.E. (1976). Changes in the polyphenol oxidase of wheat during kernel growth and maturation. Cereal Chem. **53**: 201-203.
- Kumar, K.G. and Venkataraman, L.V. (1976). Studies on the in vitro digestibility of starch in some légumes before and after germination. Nutr. Rep. Int. **13**: 115-120.
- Kumar, K.G. and Venkataraman, L.V., Jaya, T.V. and Krishnamurthy, K.S. (1978). Cooking characteristics of some germinated legumes: Changes in phytins, Ca⁺⁺, Mg⁺⁺ and pectins. J. Food Sci. **43**: 85.

- Kumar, V., Kapoor, A.C. (1983). Availability of zinc as affected by phytate. *Nutr. Rep. Int.* **28** : 103-111.
- Kumar, V. and Kapoor, A.C. (1984). Trace mineral composition of different varieties of cereal and legumes. *Indian J. Nutr. Dietet.* **21**: 137-143.
- Latunde -Dada, G.O. (1991). Some physical properties of ten soybean varieties and effect of processing on iron levels and availability. *Food Chem.* **42**: 89-98.
- Laurena, A.C., Garcia, V.V. and Mendoza, E.M.T. (1987). Effect of heat on the removal of polyphenols and in vitro protein digestibility of cowpea (Vigna unguiculata L.) *Qual. Plant. Plant Foods Hum. Nutr.* **37**(2): 183-192.
- Lee, C.K. and Karunanithy (Singapore) (1990). Effects of germination on the chemical composition of Glycine and Phaseolus Beans. *J. Sci. Food Agric.* **51**: 437-445.
- Liener, I.E. (1962). Toxic factors in legumes and their elimination. *Am. J. Clin. Nutr.* **77**: 281-286.
- Liener, I.E. (1976). Legume toxins in relation to protein digestibility - a review. *J. Food Sci.* **41**: 1076-1081.
- Lindgren, E. (1975). The nutritive value of peas and field beans for hens. *Swedish J. Agric. Res.* **5**: 159-161.
- Lindsey, W.L. and Norwell, M.A. (1969). A new DPTA- TEA soil test for zinc and iron. *Agron. Abst* **61**: 84.
- Lolas, G.M. and Markakis, P. (1975). Phytic acid and other phosphorus compounds of beans (P. vulgaris L.) *J. Agric. Food Chem.* **23**: 13-15.

Lopez, A.A., Williams, H.L. and Cooler, F.W. (1986). Essential elements and cadmium and lead in fresh and canned peas (Pisum sativum L.). J. Food Sci. **51**: 604-607.

Lowry, D.H., Rosebrough, N.J., Farr, A.L. and Randall, R.J. (1951). Protein measurement with Folin - Phenol reagent. J. Biol. Chem. **103**: 265-275.

Lynch, S.R., Beard, J.L., Dassenko, S.A., Cook, J.D. (1984). Iron absorption from legumes in humans. Am. J. Clin. Nutr. **40**: 42-47.

Mabry, T., Markaham, K.R., Thomas, M.B. (1970). The systemic identification of flavonoids; Springer - Verlag, New York.

Maga, J.A. (1982). Phytate, its chemistry, occurrence, food interactions, nutritional significance and methods of analysis (A Review) J. Agric. Food Chem. **30**: 1-9.

* Magar, J.A., Sizer, C.E. (1978). Mineral levels in various legume products. Lebensmittel Wissenschaft and Technologie . **11**: 257-258.

Malhotra, S., Malik, B. and Dhindsa, K.S. (1988). Proximate composition and antinutritional factors in rice bean (Vigna umbellata) . Qual. Plant. Foods Hum. Nutr. **38**: 75-81.

* Malinow, M.R., Mclaughlin, P., Kohler, G.O. and Livingstone, A.L. (1977). Prevention of elevated cholesterolemia in monkeys. Steroids **29**: 105.

Manan, F., Hussain, T., Ali, I., Iqbal, P. (1987). Effect of cooking on phytic acid content and nutritive value of Pakistani peas and lentils. Food Chem. **23**: 81-87.

- Mandal, N.C., Burman, S. and Biswas, B.B. (1972) . Isolation, purification and characterizations of phytase from germinating mung beans. *Phyto Chem.* **11**: 495-502.
- Manorma, R. and Sarojini, G. (1982). *Effect of different heat treatments on the trypsin inhibitor activity of soybeans*, *Indian J. Nutr. Dietet.* **19**: 8-13.
- Marickar, Y. and Pattabiraman, T.N. (1988). Changes in protease inhibitory activity in plant seeds on heat processing. *J. Food Sci. Technol.* **25**(2) : 59-62.
- Marquardt, R.R., Mckirky, J.A. and Ward, A.T. (1978). a. Comparative cell wall constituent levels of tannin free and tannin containing cultivars of field beans (Vicia faba L.). *Can. J. Plant Sci.* **58**: 753-760.
- Martson, E.V. and de Omana, E. (1979). Effects of sodium salt solution on the chemical composition and morphology of black beans (Phaseolus vulgaris). *J. Food Sci.* **44**(2): 531-536.
- * Mattson, S. (1946). The cookability of yellow peas. *Acta Agric. Scand.* **2**: 185.
- Maxson, E.D. and Rooney, L.M. (1972). Evaluation of methods for tannin analysis in sorghum grain. *Cereal Chem.* **49** : 719-729.
- McLean, L.A., Sosulski, F.W., Youngs C.G. (1974). Effects of nitrogen and moisture on yield and protein in field peas. *Can. J. Plant Sci.* **54**: 301-305.

Meiners, C.R., Derise, N.L., Lau, H.C., Crews, M.G., Ritchey, S.J.,
Murphy, E.W. (1976). The content of nine mineral elements in
raw and cooked mature dry legumes. *J. Agric. Food Chem.* **24**:
1126-1129.

Meiners, C.R., Derise, N.L., Lau, H.C., Ritchey, S.J. and Murphy, E.W.
(1976). Proximate composition and yield of raw and cooked
mature dry legumes. *J. Agric. Food Chem.* **24**: 1123-1126.

*Merck Index (1976). Ed. 9. Merck Rahway, P. 8120. New Zersey, U.S.A.,
Merck and Co. Ltd. (cited from Saponins in food. a reivew by
Oakenfull, D. 1981).

Metche, M., Girardin, M. (1980). In *Les polimères Végétaux*, Costes, C., Ed.;
Bordes: Paris.

Michael Eskin, N.A. and Wiebe, S. (1983). Changes in phytase activity
and phytate during germination of two faba bean cultivars. *J.*
Food Sci. **48**: 270-271.

Monties, B., Rambourg, J.C. (1978). *Ann. Technol. Agric.* **27**: 629-654.

Mubarak, A.A. EL., Salih, F.A., Huda Abdul Galiel, N.E.L. and Ghorashi,
Am. (1988). Effect of time and harvest on physical and chemical
composition, cookability and yield of faba bean FABIS News letter
20: 30-36.

Muneta, P. (1964). The cooking time of dry beans after extended storage.
Food Technol. **18**: 130-131.

Naivikal, O. (1978). The carbohydrates present in flour obtained from
various types of legumes. *Dissertation Abstracts International B.*
38: 3112.

- Nakata, S., Kimura, T. (1985). Effect of ingested toxic bean lectins on the gastro-intestinal tract of the rat. *J. Nutr.* **115**: 1621-1629.
- Newman, H.A., Kummirov, F.A. and Scott, H.H. (1957). Dietary saponin, a factor which may reduce liver and serum cholesterol levels. *Poultry Sci.* **37**: 42.
- Nigam, V.N. and Giri, K.V. (1961). Sugar in pulses. *Can. J. Biochem. Physiol.* **39**: 1847-1853.
- Nitsan, Z. (1971). Vicia faba beans Vs soybean meal as a source of protein. *J. Sci. Food Agric.* **22**: 252-255.
- Nnanna, I.A. and Phillips, R. Dixon. (1990). Protein and starch digestibility and flatulence potential of germinated cowpeas (Vigna unguiculata). *J. Food Sci.* **55** (1): 151-153.
- Oakenfull, D.G. (1981). Saponins in food - a review. *Food Chem.* **6**: 19-40.
- Oakenfull, D.G., Fenwick, D.E., Hood, R.L., Topping, D.L., Illman, R.J. and storer, G.B. (1979). Effect of saponins in bile acids and plasma lipids in the rat. *Brit. J. Nutr.* **42**: 209-216.
- Oberleas, D., Muhrer, M.E. and O'Dell, B.L. (1966). Dietary metal complexing agents and zinc bioavailability in the rat. *J. Nutr.* **90**: 56.
- O'Dell, B.L. (1969). Effect of dietary components upon zinc availability (Review). *Am. J. Clin. Nutr.* **22**: 13-15.
- O'Dell, B.L. and de Boland, A. (1976). Complex action of phytate with proteins and cations in corn germ and oil seed meals. *J. Agric. Food Chem.* **24**: 804.

- Ologhobo, A.D. and Fetuga, B.L. (1982). Chemical composition of promising cowpea (Vigna unguiculata) varieties. Nutr. Rep. Int. 25: 913-919.
- Ologhobo, A.D. and Fetuga, B.L. (1982). Polyphenols, phytic acid and other phosphorus compounds of lima bean (Phaseolus limatus). Nutr. Rep. Int. 26(4): 605.
- Ologhobo, A.D. and Fetuga, B.L. (1983). Trypsin inhibitor activity in some lima bean (P. lunatus) varieties as affected by different processing methods. Nutr. Rep. Int. 27: 41-49.
- Ologhobo, A.D. and Fetuga, B.L. (1984). Distribution of phosphorus and phytate in some Nigerian varieties of legumes and some effects of processing. J. Food Sci. 49(1): 199-201.
- Oh, H.I., Hofb, J.E., Armstrong, G.S. (1980). Hydrophobic interaction in tannin - protein complexes. J. Agric. Food Chem. 28: 394-398.
- Pandey, S., Gritton, E.T. (1975). Protein levels in developing and mature pea seeds. Can. J. Plant Sci. 55: 185-190.
- Pandhye, V.W., Salunkhe, D.K. (1980). Studies on black gram (Phaseolus mungo L.) trypsin inhibitor. J. Food Biochem. 4: 119-138.
- Panse, Y.G. and Sukhatme, P.V. (1961). Statistical methods of agricultural workers. 2nd ed. Indian Council of Agricultural Research, New Delhi, pp. 12: 87.
- Papadopoulos, C.H., Tsaffaris, A.S. and Roupakias, D.G. (1985). Correlation between tannin content and testa colour in faba bean (Vicia faba L.) FABIS News letter. 11: 38-40.

- * Pesola, V.A. (1955). Protein content of field pea seeds as a varietal character. *Acta Agralia Fennica*. **83**: 125-132.
- Peterson, W.H., Skinner, J.T. and Strong, F.M. (1943). *Elements of Food Biochemistry*. Prentice Hall, Inc. New York. pp. 73.
- Pierpoint, W.S. (1983). Reactions of phenolic compounds with proteins, and their relevance to the production of leaf protein. In *Leaf Protein Concentrates*. Télek, L., Graham, H.D., Ed., AVI. Publishing Westport, CT.
- Potter, J.D., Topping, D.L. and Oakenfull, D. (1979). Soya products, saponins and plasma cholesterol. *Lancet* i : 223.
- Price, K.R., Curl, C.L. , Fenwick, G.R. (1986). The saponin content and sapogenal composition of seed of 13 varieties of legume. *J. Sci. Food Agric.* **37**: 1185-1191.
- Quest, D.C. and de Silva, S.D. (1977). Temperature dependence of cooking rate of dry legumes. *J. Food Sci.* **42**: 370-374.
- Rackis, J.J. (1974). Biological and Physiological factors in soybean. *J. Am. Oil Chem. Soc.* **51**: 161A-174A.
- * Rahma, E.H., EL-Bedawey, A.A., EL Adawy, T.A. and Gowe, M.A. (1987). Changes in chemical and antinutritional factors and functional properties of faba bean during germination. *Lebensmittel wissenschaft und technologie* **20**(6): 271-276. (Cited from *Food Technol. Abs.* **23**(12): 736.
- Ranhotra, G.S. (1972). Hydrolysis during bread making of phytic acid in wheat protein concentrate. *J. Food Sci.* **37**: 12-13.

- Rao, B.S.N., Prabhavathi, T. (1982). Tannin content of food commonly consumed in India and its influence on ionisable iron. *J. Sci. Food Agric.* **33**: 89-96.
- Rao, K.H. and Subramanian, N. (1970). Essential amino acid composition of commonly used Indian pulses by paper chromatography. *J. Food Sci. Technol.* **7** : 31-34.
- Rao, P.S. (1969). Studies on the digestibility of carbohydrates in pulses. *Indian J. Med. Res.* **57** (11): 215.
- Rao, P.S. (1976). Nature of carbohydrates in pulses. *J. Agric. Food Chem.* **24**: 958.
- Rao, P.U. and Belavady, B. (1978). Oligosaccharides in pulses : Varietal differences and effects of cooking and germination. *J. Agric. Food Chem.* **26**: 316-319.
- Rao, P.U. and Deosthale, Y.G. (1982). Tannin content of pulses : Varietal differences and effects of germination and cooking. *J. Sci. Food Agric.* **33**: 1013-1016.
- Ray, P.K. (1969). Nutritive value of horse gram (Dolichos biflorus).
I. Effect of feeding raw and treated seed flour on the growth of rats. *J. Nutr. Dietet.* **6**: 329.
- Ray, P.K. (1969). Nutritive value of horse gram (Dolichos biflorus). II In vitro digestibility of raw and autoclaved seeds. *Indian J. Nutr. Dietet.* **6**: 329.
- Rea, R.L., Thompson, L.U., Jenkins, D.J.A. (1985). Lectins in foods and their relation to starch digestibility. *Nutr. Res.* **5** : 919-929.

- Reddy, M.U. and Reddy, D.N. (1985). Effect of home processing on the biological quality of cluster bean (Cymopsis tetragonoloba) protein. J. Food Sci. Technol. **22** (6) : 415.
- Reddy, N.R., Balakrishnan, C.V., Salunkhe, D.K. (1978). Phytate phosphorus and mineral changes during germination and cooking of black gram (Phaseolus mungo L.) seeds. J. Food Sci. **43** : 540-543.
- Reddy, N.R., Pierson, M.D., Sathe, S.K., Salunkhe, D.K. (1985). Dry bean tannins; A review of nutritional implications. J. Am. Oil. chem. Soc. **62** (3) : 541-549.
- Reddy, N.R., Salunkhe, D.K. (1980a). Alpha amylase inhibitor and phytohaemagglutinins of black gram (Phaseolus mungo L.) . J. Food Biochem. **4**(4) : 273-276.
- Reddy, N.R., Salunkhe, D.K. (1980b). Changes in oligosaccharides during germination and cooking of black gram and fermentation of black gram/rice blend. Cereal Chem. **57**: 356-360.
- Reddy, N.R., Salunkhe, D.K. (1980c). Effect of fermentation on phytate phosphorus and mineral content in black gram and rice blends. J. Food Sci. **45** : 1708-1712.
- Reddy, N.R., Salunkhe, D.K. (1981). Interactions between phytate, protein and minerals in whey fractions of black gram. J. Food Sci. **46**: 564-567.
- Reddy, N.R., Sathe, S.K. and Salunkhe, D.K. (1982). Phytates in legumes and cereals. Adv. Food Res. **28** : 1-9.
- Reichert, R.D. (1981). Quantitative isolation and estimation of cell wall material from dehulled pea (Pisum sativum) flours and concentrates. Cereal Chem. **58**: 266-270.

- Reichert, R.D. and Mackenzie, S.L. (1982). Composition of peas (Pisum sativum). Varying widely in protein content. J. Agric. Food Chem. **30**: 312-317.
- Renu and Bhattacharya, L. (1989). Proximate composition of improved genotype of peas (Pisum sativum). Bull. Grain Technol. **27**: 118-123.
- Rockland, L.B., Zaragosa, E.M. and Oracca-Tettch, R. (1979). Quick cooking winged beans (Psophocarpus tetragonolobus). J. Food Sci. **44**: 1004-1007.
- *Raneo, M., Escobar, B., Masson, L., Mella, M.A. (1983). Chemical composition of raw and precooked legumes. Alimentos. **8**: 3-10.
- Rossi, M., Germondori, I. and Lasini, P. (1984). Comparison of chick pea cultivars. Chemical composition, nutritional evaluation and oligosaccharide content. J. Agric. Food Chem. **32**: 811-814.
- Roy, D.N. and Rao, P.S. (1971). Evidence, isolation, purification and some properties of a trypsin inhibitor in Lathyrus sativus. J. Agric. Food Chem. **19**: 257-259.
- Ryan, C.A. and Santarius, K. (1976). Immunological similarities of proteinase inhibitors from potatoes. Plant Physiol. **58** : 683-685.
- Saharan, K. (1991). A study on chemical and biological evaluation of protein quality of peas (Pisum sativum). M.Sc. Thesis, Haryana Agricultural University, Hisar.
- Saini, H.S. (1989). Thermal stability of protease inhibitors in some cereals and legumes. Food Chem. **32**: 59-67.
- Sartirana, M.L. and Bianchetti, R. (1967). The effects of phosphate on the development of phytase in the wheat embryo. Physiol. Plant. **20**: 1066-1067.

- Sathe, S.K. and Salunkhe, D.K. (1981). Studies on trypsin and chymo trypsin inhibitory activities, haemagglutinating activity, and sugars in the Great Northern beans (Phaseolus vulgaris L.). J. Food Sci. **46**: 626.
- Satwadhar, P.N., Kadam, S.S. and Salunkhe, D.K. (1981). Effects of germination and cooking on polyphenols and in vitro protein digestibility of horse gram and moth bean. Qual. Plant. Plant Foods Hum. Nutr. **31**: 71-76.
- Satyapriya, V.S. (1989). Pulses in India : Growth, Regional Distribution and Area Responses. Oxford and IBH Publishing Co. Delhi, Bombay, Calcutta. pp. 1-4.
- Savage, G.P. and Deo, S. (1989). The nutritional value of mung bean and urd (Vigna radiata var. aureus and var. mungo) Nutr. Abst. Rev. (Series A). **59**(9) : 640-662.
- Savage, G.P. and Deo, S. (1989). The nutritional value of peas (Pisum sativum): A literature review. Nutr. Abst. Rev. (Series A). **59**: 66-83.
- Serraino, M.R., Thompson, L.U., Savoie, L. and Parent, G. (1985). Effect of phytic acid on the in vitro rate of digestibility of rapeseed protein and amino acids. J. Food Sci. **50**: 1689-1692.
- Sharma, A. (1989). Effect of processing and cooking methods on nutrient composition and antinutritional factors of Bakla (Vicia faba). M.Sc. Thesis. Haryana Agricultural University, Hisar.
- Sharma, S.N. and Pant, R.C. (1979). Starch, soluble sugars and amylolytic enzymes in the germinating pigeon pea (Cajanus cajan L.) seeds. Indian J. Plant Physiol. **22**: 219-222.
- Shia, G., Slinkard, A.E. (1977). Relationship of seed shape and cotyledon colour to percent protein of peas. Crop Sci. **17**: 183-184.

- Shrivastava, P.P., Das, H. and Prasad, S. (1990). Effect of roasting process variables on in vitro protein digestibility of bengal gram, maize and soybean. Food Chem. **35**: 31-37.
- Shrivastava, S.K. and Bajpai, R.K. (1981). Some chemical characteristic of new varieties of pigeon peas. Indian J. Nutr. Dietet. **18**: 166-170.
- Silva, H.C. and Braga, G.L. (1982). Effect of soaking and cooking on the oligosaccharide content of dry beans (Phaseolus vulgaris L.). J. Food Sci. **47**: 924-929.
- Singh, B. and Sedeh, H.G. (1979). Characteristics of phytase and its relationship to acid phosphatase and certain minerals in triticale. Cereal Chem. **56**: 267-269.
- Singh, K.B. Erskine, W., Robertson, L.D., Nakoul, H. and Williams, P.C. (1988). Influence of pre-treatment on cooking quality parameters of dry legumes. J. Sci. Food Agric. **44**: 135-142.
- Singh, M. and Krikorian, A.D. (1982). Inhibition of trypsin activity in vitro by phytate. J. Agric. Food Chem. **32**: 799-800.
- Singh, S.P., Misra, B.K., Sikka, K.C., Chandel, K.P.S. and Pant, K.C. (1985). Studies on some nutritional aspects of rice bean (Vigna umbellata). J. Food Sci. Technol. **22**(3): 180.
- Singh, T.P., Soni, G.L. and Singh, R. (1977). Biochemical evaluation of the common pulses of the Punjab state. J. Res., P.A.U. **14**(3): 318-322.
- Singh, U. (1984). The inhibition on digestive enzymes by polyphenols of chick pea and pigeon pea. Nutr. Rep. Int. **29**(3): 745-753.

- Singh, U. and Jambunathan, R. (1981). Studies on desi and kabuli chick pea cultivars. The levels of protease inhibitors, level of polyphenolic compounds and in vitro digestibility. J. Food Sci. **46**: 1364-1367.
- Singh, U., Kherdekar, M.S. and Jambunathan, R. (1982). Studies on desi and kabuli chick pea (Cicer arietinum L.) cultivars. V The level of amylase inhibitors, level of oligosaccharides and in vitro starch digestibility. J. Food Sci. **47**: 510-512.
- *Sobolev, A.M. (1963). Enzymatic hydrolysis of phytin in vitro and in germinating seed. Soviet Plant Physiol. **9**: 236-240.
- Somogyi, M. (1945). a new reagent for the determination of sugars. J. Biol. Chem. 160-161.
- Sosulski, F.W. (1979). Organoleptic and nutritional effects of phenolic compounds on oilseed protein products. A review. J. Am. Oil Chem. Soc. **56**: 711-715.
- Sosulski, F.W., Elkowicz, L., Reichert, R.D. (1982). Oligosaccharides in eleven legumes and their air - classified protein and starch fractions. J. Food Sci. **47** : 498-502.
- Srinivasa, R.P. (1976). Nature of carbohydrate in pulses. J. Agric. Food Chem. **24** : 958-961.
- Steinke, R.D., Paulson, M.C. (1964). The production of steam-volatile phenols during the cooking and alcoholic fermentation of grain. J. Agric. Food Chem. **12**: 381.

- Subba Rao, G.N. and Subramanyan, V. (1950). Processing of pulses. Proc. Soc. Biol. Chem. India. **9** : 22-23.
- Subbulakshmi, G., Kumar, K.G. and Venkataraman, L.V. (1976). Effect of germination on the carbohydrates, proteins, trypsin inhibitors, amylase inhibitors and haemagglutinins in horse gram and moth bean. Nutr. Rep. Int. **13** : 19-31.
- Swain, T. and Hills, W.E. (1959). The phenolic constituents of pramus domestica L. The qualitative analysis of phenolic constituents. J. Sci. Food Agric. **10**: 63.
- Tabekhia, M.M. and Luh, B.S. (1980). Effect of germination, cooking and canning on phosphorus and phytate retention in dry beans. J. Food Sci. **45** : 406-408.
- Tamir, M. and Alumot, E. (1969). Inhibition of digestive enzymes by condensed tannins from green and ripe carobs. J. Sci. Food Agric. **20** : 199-202.
- Tan, N., and Wong, K.C. (1982). Thermal stability of trypsin inhibitor activity in winged bean (Psophocarpus tetragonolobus). J. Agric. Food Chem. **30** : 1140-1143.
- Tannous, R.I., Ullah, M. (1969). Effects of autoclaving on nutritional factors in legume seeds. Tropical Agriculture **46** : 123-129.
- Tan, N., Rahim, Z.H.A., Khar, H. and Wong, K.C. (1983). Winged bean (Psophocarpus tetragonolobus) tannin level, phytate content and haemagglutinin activity. J. Agric. Food Chem. **31** : 916-917.

- Tan, N., Wong, K.C. and de Lumen, B.O. (1984). Relationship of tannin levels and trypsin inhibitor activity with the in vitro protein digestibility of raw and heat treated winged beans. J. Agric. Food Chem. **32** (9): 819-821.
- Tas, N.H., Wong, K.C., Luman, B.O. (1984). Relationship of tannin levels and trypsin inhibitor activity with the in vitro protein digestibility of raw and heat treated winged beans. J. Agric. Food Chem. **32** : 819-822.
- Thompson, L.U. (1988). Antinutrients and blood glucose. Food Technol. **42** : 123-132.
- Thompson, L.U. and Yoon, J.H. (1984). Starch digestibility as affected by polyphenols and phytic acid. J. Food Sci. **49**(4): 1228-1229.
- Thompson, L.U., Gabon, J. (1987). Effect of lectins on salivary and pancreatic alpha-amylase activities and the rate of starch digestion. J. Food Sci. **52** : 1050-1053.
- Topping, D.L., Storer, G.B., Golvert, G. D., Illman, R.J., Oakenfull, D.G. and Weller, R.A. (1980). Effect of dietary saponins on fecal bile acids and neutral sterols, plasma lipids and lipoprotein turn over in the pig. Am. J. Clin. Nutr. **33** : 783-786.
- Tressl, R., Bahri, D., Molzer, M., Kossa, T. (1977). Formation of flavour components in asparagus. 2. Formation of flavour components in cooked asparagus. J. Agric. Food Chem. **25** : 459-463.
- Udayasekhara, R.P. and Deosthale, Y.G. (1982). Tannin content of pulses; Varietal differences and effect of germination and cooking. J. Sci. Food Agric. **33** : 1013-1016.

- Valdebouze, P., Bergeron, E., Gaborit, T., Delort-Laval, J. (1980). Content and distribution of trypsin inhibitors and haemagglutinins in some legume seeds. *Can. J. Plant Sci.* **60**: 695-701.
- Varner, J.E. (1965). Seed development and germination in plants. In "Plant Biochem." pp. 763, Academic Press, New York.
- Verma, P. and Mehta, U. (1988). Study on physical characteristics, sensory evaluation and the effect of sprouting, cooking and dehulling on the antinutritional factors of rice bean (Vigna umbellata). *J. Food Sci. Technol.* **25**(4): 197-200.
- Vogel, A. (1962). Text Book of Quantitative Inorganic Analysis. 3rd ed. Longmans.
- Walker, A.F. and Kochhar, N. (1983). Effect of processing including domestic cooking on nutritional quality of legumes. *Proc. Nutr. Soc.* **41** :41-51.
- Warsey, A.S., Norton, G. and Stein, M. (1974). Inhibitors from broad bean : Isolation and purification. *Phytochem.* **13** : 2481-2486.
- *Weiss, H. (1952). Heve Utersu Chung Uber Zusammensetzung Und Ent Bitterung Von Sojabohnen. *Cretreids Mehl Und Brot.* **3** : 1.
- Welch, R.W., Griffiths, D.W. (1984). Variation in the oil content and fatty acid composition of field beans (Vicia faba) and peas (Pisum sp.). *J. Sci. Food Agric.* **35** : 1282-1289.
- Welch, C.A., Lachance, P.A., Wasserman, B.P. (1989). Dietary phenolic compounds: Inhibition of Na⁺ - dependent D-glucose uptake in rat intestinal brush border membrane vesicles. *J. Nutr.* **119**: 1698-1704.
- Williams, P.C., Nakoul, H. and Singh, K.B. (1982). International Centre for Agricultural Research in the Dry Areas (ICARDA). Aleppo, Syria.

- Wills, R.B.H., Evans, T.J., Lim, J.S.K., Seriven, F.M., Greenfield, H. (1984).
Composition of Australian foods. 25. Peas and beans. Food technology
in Australia. **36**: 512-514.
- Wise, A. (1983). Dietary factors determining the biological activities of
phytate. Review in clinical nutrition. Nutr. Abst. Rev. **53** : 791.
- Yannai, S. and Zimmermann, G. (1970). Influence of controlled storage of
some staple foods and their protein nutritive value in lysine limited
diets. II Protein nutritive value and antitryptic activity in soybeans
and chick peas. J. Food Sci. Technol. **7** : 185.
- Yemm, E.W. and Willis, A.J. (1954). The estimation of carbohydrates in plant
extracts by anthrone. Biochem. J. **57** : 508.
- Youssef, M.M., Abd-El-Ael, M.H., Laila, A.E.S. and Ziena, H.M. (1987). Effect
of dehulling, soaking and germination on chemical composition,
mineral element and protein pattern of faba bean (Vicia faba L.)
Food Chem. **23** : 129-138.
- Youssef, M.M., Hamza, M.A., Abd-EL-Ael, M.H., Shekib, L.A. and El-Bauna,
A.A. (1986). Amino acid composition and in vitro digestibility of
some Egyptian food made from faba bean (Vicia faba L.). Food
Chem. **22**(3): 225-233.

* Original not seen

