STUDIES ON THE DEVELOPMENT OF PRODUCTS FROM RICEBEAN AND FABABEAN : THEIR SENSORY AND NUTRITIONAL EVALUATION

By

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D E D I C A T E D

TO MY

VENERABLE PARENTS

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Hisar
August 17 , 1994

[KAMLESH SAHARAN]

CERTIFICATE - I

This is to certify that this dissertation entitled, "Studies on the development of products from ricebean and fababean : their sensory and nutritional evaluation" submitted for the degree of Ph.D. in the subject of Foods and Nutrition of the Chaudhary Charan Singh Haryana Agricultural University, is a bonafide research work carried out by Kamlesh Saharan under my supervision and that no part of this dissertation has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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CERTIFICATE - II

This is to certify that this dissertation entitled, "Studies on the development of products from ricebean and fababean : their sensory and nutritional evaluation" submitted by Kamlesh Saharan to the Chaudhary Charan Singh Haryana Agricultural University in partial fulfilment of the requirements for the degree of Ph.D., 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.

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CHAPTER - 1

INTRODUCTION

Grain legumes due to their high protein content are important constituents of predominantly vegetarian diet of population of subtropical and tropical areas. Mature legume seeds mixed with the staple for the main dish and the sauce accompanying it have played an important part in traditional dietary patterns. Legumes not only bring to the cereal staple a variety of taste and texture but add nutrients to staple dish which ensure a balanced diet, meeting all nutrient requirements.

India is the largest pulse growing country in the world, both in terms of area and production, covering 43.3 per cent area and 35.15 per cent of total production of pulses. The productivity of pulse crops in the world and India is 807 and 534 kg/ha, respectively (Yadav and Kumar, 1994). In early 1990's the world production of pulses was about 54 million tonnes of which 35.5 million tonnes was from developing countries. During the last 45 years, the population has increased by 160.8 per cent, whereas pulse production has increased by 76.3 per cent only.

Over past four decades the area, production and productivity of pulses remained almost static whereas the population has increased manifolds. Therefore, the per capita availability of pulses has declined sharply from 64 g in 1951 to 36.5 g in 1990's as against NIN recommendation of 80 g/day (Bangal et al., 1994).

Legume production in the lesser developed countries is far below than that of cereal grains. The reason being that cereals are much more productive than legumes. In India, the ratio of cereal to pulses which was just about 5:1 in early 50's has increased to almost 10:1 in late 70's and then further to 12:1 in last 80's. Share of pulses in the total food grain production which was over 16 per cent during 50's decreased to just about 8 per cent in more recent period (Lal et al., 1994). Since the dietary legume to cereal ratio for optimum protein quality should be approximately 1:2, it is readily apparent that legume production should be stimulated.

The three basic strategies to fill up the gap between demand and supply could be an increase in area under pulses, an increase in yield potential of improved varieties of pulses and diversification in terms of crop species of pulses (Bhagmal and Joshi, 1994). Keeping the third strategy in mind, the Department of Plant Breeding, CCS Haryana Agricultural University, Hisar has evolved some high yielding varieties of non-conventional pulses like fababean (VH-82-1) and ricebean (RB-32). Fababean genotype VH-82-1 recorded the yield of 3433 kg/ha against 2682 kg/ha, 2460 kg/ha and 2307 kg/ha of

chickpea, lentil and peas, respectively. Moreover, the difference between the yields of fababean and the highest yielding chickpea variety "Gaurav" were found to be significant (Singh, 1990).

Fababean is believed to be originated in mediterraneen West Asian region (Bond, 1976), is also a early maturer (90-120 days) and can withstand high water tables and soil salinity (Lokermen et al., 1983). Ricebean occurs as a cultigen in India, Burma, Malayasia, Korea, Indonesia and Philippines. Its genotypes, RB-32 was found to be an early maturer, resistant to yellow mosaic virus infection which is commonly found in urd, mung and cowpea's and RB-32 gave the highest average yield of 14.45 g/ha against 10.30 g/ha of mung (Singh, 1990).

Fababean and ricebean are the potential suppliers of protein. they have been reported to contain 28.6 to 29.3 per cent and 17.5 to 23 per cent protein, respectively (Sharma, 1989; Kaur, 1986). They are good source of carbohydrates and minerals. Inspite of good nutritional profile, fababean and ricebean have several nutritional and processing problems such as the presence of antinutrients, prolonged cooking time, hard to cook phenomenon and poor digestibility.

Studies carried out in Department of Foods and Nutrition, CCS Haryana Agricultural University, Hisar as well as at other places have shown that various domestic processing and cooking methods viz., soaking, germination, fermentation, etc., improve the nutritive value of legumes including ricebean and fababean probably by lowering the contents of antinutrients (Kaur and

Kapoor, 1990a; Sharma and Sehgal, 1992b). Using these processing methods, a variety of legume products are prepared and consumed depending upon the cultural and taste preferences and it is of paramount importance to assess their nutritive value which is lacking.

Information on the nutritive value of various legume products which are in their final shape and ready for eating after undergoing processing and cooking methods is lacking but very important as it reflects the actual intake and availability of different nutrients. Moreover, it is advantageous to assess the nutritive value of any food after it is cooked as considerable amount of nutrients get lost during cooking and processing.

Keeping these facts in view, the present study was planned to standardize and develop various products based upon indigenous processing methods, viz., soaking, germination, fermentation, roasting, baking, frying, etc., from the high yielding varieties of fababean (VH-82-1) andricebean (RB-32), their organoleptic acceptability and the nutritional analysis of the developed products. The objectives of the study were as follow:

1. To assess the physico-chemical characteristics and nutrient composition of unprocessed seeds of ricebean and fababean
2. To standardize and develop the products from these unconventional legume and their sensory evaluation
3. To carry out the nutritional analysis of most acceptable developed products at different stages involved in the process of preparation of the final legume

CHAPTER - 2

REVIEW OF LTIERATURE

Pulses are rich source of protein in our diets. Traditional pulses are being grown continuously but their yield has been almost static during the last 25 years. Consequently, with increasing population, the per capita availability of pulses has declined sharply. So, to meet the growing demands of population, the availability of pulses could be increased through effective utilization of unconventional pulses like ricebean, fababean, etc., through their use in development of different products.

Very few studies have been reported on incorporation of these pulses in different recipes. The literature available regarding the effect of different processings on nutrients and the development of different products from pulses and their nutritional evaluation has been suitably reviewed under the following heads and sub-heads:

2.1 Physico-chemical properties

2.2 Effect of domestic processing and cooking

2.2.1 Proximate composition

2.2.1.1 Crude protein, fat, ash and fibre

2.2.1.2 Carbohydrates

2.2.2 *In vitro* digestibility

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2.3 Development of products, their organoleptic and nutritional evaluation

2.1 Physico-Chemical Properties

Physico-chemical parameters such as density, hydration capacity, swelling capacity and cooking time, etc., of pulses are the important parameters which ultimately play an important role in their behaviour for cooking and processing. Williams *et al*. (1982) observed that hydration capacity was highly correlated with seed size in chickpea and also the seed volume and swelling capacity per seed were related to cooking time. They reported that seed volume, density, swelling capacity and

hydration capacity of Kabuli type chickpea was 0.247 ml, 1.29 g/ml, 0.344 ml and 0.356 g, respectively.

Latunde-Dada (1991) observed that swelling capacity and seed density of ten Nigerian soyabean varieties ranged from 99.3 to 197.7 per cent and 1.82 to 2.36 g/cm^2, respectively. Bishnoi and Khetarpaul (1993a) reported that swelling capacity and density of different varieties of peas ranged from 0.43 to 0.55 ml/seed and 1.18 to 1.30 g/ml, respectively.

Ahmad and Shehata (1982) analysed 93 fababean samples and observed that hydration coefficient varied from 172 to 219. Both the consumers as well as processors prefer fababean samples that have high hydration and swelling coefficients. Mubarak et al. (1988) reported that fababean grown in two different areas of Sudan had 187.2 to 202.6 hydration coefficients.

Cooking time is defined as the time from commencement of boiling until 90-100 per cent seeds are cooked. Cooking time is an important property as most of the legume require hours of cooking, if not soaked. Muneta (1964) cooked fababean in boiling water for five different cooking times with 10 min 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) used kramer peas to determine he degree of cooking in fababeans. Sharma (1989) reported that the

cooking time of two varieties of fababean was 116 and 70 min. Cooking time of different pea varieties varied from 83 to 106 min (Bishnoi and Khetrapaul, 1993a).

Singh et al. (1988) reported that soaking reduced cooking time in fababeans. Cooking time of dry and soaked seeds was highly correlated in fababean. Soaking of the legumes before cooking can provide many beneficial attributes to the final cooked products. Soaking removes foreign material, facilitates cleaning of beans, aids in can filling through uniform expansion, ensures product tenderness and improves colour (Cain, 1950; Hoff and Nelson, 1966).

2.2.1 Proximate Composition

2.2.1.1 Crude protein, fat, ash and fibre

Legumes constitute an important source of dietary protein in developing countries due to non-availability of animal protein. Marked variation exists in the contents of crude protein, ether extract and ash in different pulses.

Protein content of ricebean varied from 14 to 26 per cent (Chatterjee and Dana, 1977; Chandel et al., 1978; Singh et al., 1980; Bhatnagar, 1986). Singh et al. (1980) reported that ash and ether extract of six strains of ricebean varied from 3.81 to 4.31 and 1.0 to 1.6 per cent, respectively. Thirteen promising strains of ricebean were analysed by Malhotra et al. (1988). They reported that crude protein, ash, fat and crude fibre contents in these ricebean strains ranged from 17.5 to 23.1, 3.06 to 4.48, 2.4 to 3.9 and 1.70 to 4.25, respectively.

Protein content in fababean ranged from 23-35 per cent (Gorski, 1985; Sammour, 1987; Sharma and Sehgal, 1991b). Barratt (1982) reported that crude protein content in cotyledons and whole seeds of thirty cultivars of fababean ranged from 26 to 38 and 26 to 39 per cent, respectively. Fat and ash content in fababean varied from 0.8 to 4.5 per cent and 2.5 to 3.5 per cent, respectively (Eden, 1968; Mubarek et al., 1988 and Sharma and Sehgal, 1991b).

Youssef et al. (1987) studied the effect of dehulling, soaking and germination on chemical composition of fababean. They reported that whole seed, husked, soaked and germinated (3 days) fababean contained crude protein 31.6, 31.1, 30.9 and 30.4 per cent, true protein 28.6, 27.7, 27.1 and 26.9 per cent, fat 1.27, 1.33, 1.35 and 1.26 per cent, crude fibre 1, 5, 1.0, 1.0 and 1.0 per cent and ash 3.3, 3.2, 3.0 and 3.7 per cent, respectively.

Cooking brought a slight decrease in crude protein, ether extract and fibre contents in chickpea grains as compared to raw grains (Kosson and Bakowski, 1986). According to Savage and Deo (1989), cooked peas had slightly lower crude protein contents, whereas Sotelo et al. (1987) observed no difference in cooked and raw chickpea grains with respect to protein, fat and fibre content.

Autoclaving for more time resulted in decreased insoluble fibre content (Schweizer and Wilrich, 1979). On contrary to this, Hughes and Swanson (1990) reported a slight decrease in soluble dietary fibre but a marked increase in insoluble

dietary fibre after autoclaving which resulted in 15-30 per cent increase in total dietary fibre in Phaseolus vulgaris.

Boiling of vegetables resulted in a significant breakdown of pectins (Waldron and Selvendran, 1990). Vidalvalverde and Frias (1991) reported that pressure cooking of soaked cowpeas showed a decrease in NDF, ADF, cellulose and lignin provided cooking water is removed. In lentils, no difference in these values was observed as cooking water was retained.

Legume seeds have been reported to undergo pronounced metabolic changes during germination and the structural profile of various components is altered in sprouts. Increase in crude protein, decrease in fat and an increase or decrease in ash content occurs during germination. Increase in NDF, ADF and protein content of sprouted peas has been reported by Beal et al. (1984). According to Ndzondzi-Bokuango et al. (1989), increase in total N, non-protein nitrogen and decrease in ash contents with increasing time period of germination of fababean has been reported.

Increase in the protein content during germination may occur due to the loss in dry weight, loss of leachable sugars and seed coat, protein synthesis and decrease in protein content could be attributed to the loss of low molecular weight nitrogenous compounds during soaking and rinsing of seeds (Chavan and Kadam, 1989).

The decrease in fat content could be due to the result of metabolism in order to meet the increased energy requirement of the developing plant tissues (Ghazali and Cheng, 1991). No

change in ash content during germination may occur as the effect of leaching out of minerals during soaking is nullified by the loss of non-mineral dry matter.

The contents of crude protein and fat in various legumes change during fermentation. A decrease by 6 to 8 per cent in crude protein content of bengal gram and green gram have been reported by Aliya and Geervani (1981) whereas Eka (1980) showed an increase in protein from 30.6 to 38.5 per cent and fat content from 15.2 to 31.2 per cent in fermented locust beans. In the cereal-legume blends using rice, barley, green gram dal and defatted soyaflour, fermentation either decreased or did not altered the crude protein content of blends (Goyal, 1991). Ash content did not change during fermentation (Goyal, 1991; Yadav, 1992). No change in the ash and fat contents of autoclaved dehulled soyabeans and soybean sprouts occurred during rabadi fermentation whereas protein content decreased after 12 h fermentation, but remained unchanged thereafter (Grewal, 1992).

Some strains of micro-organisms are known to be fat producing and their likely participation in fermentation may account for increased amount of fat in fermented products. Since no addition or deletion of mineral source is involved hence, no change in ash content during fermentation has been observed (Chaudhary, 1993).

Dehusking of seeds reduces the fibre content as most of the fibre is found in testa. A little decrease in ash content in most dehusked legumes has been reported (Savage, 1988;

Savage and Deo, 1989; Griffiths and Savage, 1991) as higher levels of ash are found in testa in pigeonpea resulting in 13 per cent loss in ash content. According to Hamilton and Thompson (1992), flame roasting of corn resulted in higher nitrogen content whereas ash and fibre fraction were not affected by roasting.

2.2.1.2 Carhohydrates

Total soluble sugar, non-reducing and reducing sugars varied from 62.5 to 91.3, 38.0 to 72.7 and 10.4 to 24.0 mg/g flours, respectively among blackgram and greengram parents and amphidiploids (Gupta and Wagle, 1980). Kataria (1986) reported that the total soluble, reducing and non-reducing sugars and starch among amphidiploids and parents (greengram and blackgram) ranged from 7.6 to 9.6; 0.311 to 0.516; 7.2 to 8.9 and 44.0 to 49.9 g, respectively.

According to Kaur (1986), the total soluble, reducing and non-reducing sugars and starch content in different varieties of ricebean varies from 3.5 to 3.6, 0.159 to 0.517, 3.4 to 5.3; and 52.4 to 55.1 per cent, respectively. Carbohydrate content in flours of navy bean, pinto bean, fababean and lentil was analysed by Naivikal (1978). He reported that the total sugars ranged from 4.99 to 7.22 per cent, reducing sugar from 0.71 to 1.81 per cent and non-reducing sugar from 2.53 to 3.08 per cent and amylose from 15.3 to 19.5 per cent. Starch contents were almost similar (50.9 to 52.9%) in all the flours.

Soaking and cooking decreased soluble sugars by 16 per cent in peas, 43 per cent in white beans and 80 per cent in

soyabeans (Jacorzymski et al., 1981). 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 sugars. The greater losses of sugars during longer period of soaking may be because of enhanced solubility of sugars (Jood et al., 1988; Kataria et al., 1990; Bishnoi, 1991).

Cooking brought a significant increase in the oligosaccharide contents of all pulses (Rao and Belavady, 1978). According to Reddy and Salunkhe (1980), the total sugars reduced from 78.5 to 52.6 per cent during 40 minute cooking of blackgram. Hydrolysis of starch to oligosaccharides and that of oligosaccharide to monosaccharides during cooking may be responsible for increased concentration of sugars in pulses (Kataria et al., 1990).

With the increase in germination period, the total soluble carbohydrates and non-reducing sugars increased in chickpea and greengram (Jaya and Venkataraman, 1980). According to Gupta and Wagle (1980), germination of Phaseolus mungo, Phaseolus mungoreous and Phaseolus aureus for 4 days decreased the soluble and reducing sugars. Jood et al. (1988) reported a decrease in non-reducing sugars of blackgram, bengalgram, red gram and P.vulgaris after 24 h germination. 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. Longer the period of germination, more may be hydrolysis of starch, thereby resulting in more release and concentration of soluble sugars (Jood et al., 1988; Kataria et al., 1990).

2.2.2 In vitro digestibilities

2.2.2.1 Starch digestibility (in vitro)

Among the legume carbohydrates, starch is the major constituent (Nigam and Giri, 1961) which possesses low digestibility (Geervani and Theophilus, 1980; El-Faki et al., 1984a). The low starch digestibility in food legumes results from the presence of amylase inhibitors (Singh et al., 1982), phytate and polyphenols (Thompson and Yoon, 1984) and chain length (Rao, 1976; Srinivasa, 1976). Starch digestibility among different legumes varies from 22 to 80 per cent (Khokhar and Chauhan, 1986; Sharma and Sehgal, 1991; Yadav, 1992 and Chaudhary, 1993).

Different processing and cooking methods viz., soaking, cooking, germination, fermentation have been reported to improve the starch digestibility of legumes.

Starch digestibility (in vitro) was increased after soaking (12 h) followed by germination (24, 36 and 48 h) in soyabean (Boralker and Reddy, 1985). Germination of cowpeas for 24 h increased the starch digestibility from 23 to 46 mg maltose/g flour (Chavan et al., 1989). Cooking in boiling water significantly increased the starch digestibility of both ungerminated and germinated seeds of cowpeas (Nnanna and Philips, 1990).

Bishnoi and Khetrapaul (1993b) studied the effect of soaking and sprouting in four varieties of peas. A significant improvement in starch digestibility occurred with an increase in the period of soaking. Maximum improvement was observed after 18 h of soaking. The increase in starch digestibility over control values in different pea cultivars after 24 h and 48 h sprouting ranged from 55 to 75 and 76 to 103 per cent, respectively. According to Duhan (1992), soaking (12 h) and sprouting (24 h) improved the starch digestibility from 22 to 31 per cent, 252 to 416 per cent in different pigeonpeas cultivars.

Kataria et al. (1990) reported an increase of 35 to 48 per cent in starch digestibility of amphidiploids (blackgram x mungbean) when the seeds were soaked for 18 h. Cooking of unsoaked as well as soaked seeds and germination improved significantly the starch digestibility.

Sharma and Sehgal (1991a) studied the starch digestibility of two varieties viz., VH-131 and WF of fababean. They observed that starch digestibility increased upto 10 to 26 per cent in soaked, 21 to 42 per cent in soaked and dehulled, 34 to 36 per cent in soaked and cooked and 35 to 121 per cent in germinated fababean. According to Parihar et al. (1993) , starch digestibility varied from 38 to 47 mg maltose released/g from in different fababean cultivar. All the processing methods improved the starch digestibility significantly but most effective was germination followed by boiling, soaking and pressure cooking. Kaur and Kapoor (1990b) reported that soaking

of ricebean for 12 h increased the starch digestibility from 46.9 to 52.8 per cent in different cultivars.

The activity of certain enzymes like amylase present in seed increases during germination as a result of which the seeds undergo pronounced metabolic changes and the structural profile of various organic component is altered (Koller et al., 1962). Hence, starch digestibility of sprouted legumes increases. A significant rise in alpha amylolytic activity during germination improves the starch digestibility of fababean (Bednarski et al., 1985). Various processing and cooking methods have been reported to reduce the level of phytates, tannins and amylose inhibitors which may be responsible for an improvement in starch digestibility of legume grains during soaking (Bishnoi and Khetarpaul, 1993b; Duhan, 1992).

Heat treatment increases the rate of amylosis by three times when compared to that of raw sample of moth bean and horse gram (Subhalakshmi et al., 1976) and hence, causes an enhancement in starch digestibility. El-faki et al. (1984b) observed an increase in starch digestibility on boiling, pressure cooking and germination.

Kaur and Kapoor (1990b) stated 4 to 7 fold increase in starch digestibility of unsoaked cooked seeds of ricebean cultivars. An increase in starch digestibility on cooking has been reported in case of peas (Bishnoi and Khetarpaul, 1993b), cowpeas (Duhan, 1992) and in amphidiploids (Kataria et al., 1990).

Enhanced digestibility of cooked legume starches by alpha-amylase could be attributed to the swelling and rupturing of starch granules which facilitate more randomized configuration for alpha-amylase to affect hydrolysis, the disintegration of various bean components during cooking and inactivation of α-amylase inhibitors. Differences in starch digestibility during heat treatment may occur due to differences in extent of starch gelatinisation.

An increase in starch digestibility (*in vitro*) during fermentation in various food grains including sorghum (Kazanas and Fields, 1981), pearl millet (Khetarpaul and Chauhan, 1991), soyabean (Grewal, 1992) has been reported.

Ramachandran and Bolodia (1984) reported an increase in starch digestibility of *tef* due to partial breakdown of soluble starch. An increase in starch digestibility of different cereal legume blends when fermented with butter milk at 25, 30 and 35°C for 12, 18 and 24 h has been reported by Goyal (1991). Starch digestibility increased with increase in temperature of fermentation.

Chaudhary (1993) observed the beneficial effect of indigenous fermentation on starch digestibility of blackgram sprouts.

2.2.2.2 Protien digestibility (*in vitro*)

Due to the presence of several factors like saponins, glycoside, tannins, oxalates and phytates, legumes possess low protein digestibility (*in vitro*) (Anon, 1973; Gupta, 1987). The low protein digestibility of legumes may also be attributed to

the resistance of globulins, a major pulse seed protein to the proteolytic enzymes (Walker and Kochhar, 1983).

Various processing techniques have been reported to significantly improve the protein digestibility of several legumes including blackgram (Khan and Ghafoor, 1978), northern bean (Sathe and Salunkhe, 1981); cowpeas (Chavan et al., 1989), field and vegetable peas (Bishnoi and Khetarpaul, 1994b), pigeonpea (Duhan, 1992), fababean (Sharma and Sehgal, 1991a), ricebean (Kaur, 1986) and soyabean (Grewal, 1992).

Soaking of mothbean seeds for 12 h in plain water significantly increased the protein digestibility (Khokhar and Chauhan, 1986). Bishnoi and Khetarpaul (1994b) observed 6 to 8 per cent increase in protein digestibility (in vitro) in soaked peas (3 h). Sharma and Sehgal (1991a) observed an increase of 14 and 17 per cent in protein digestibility in two varieties, i.e., VH-131 and WF, respectively of fababean. According to Parihar et al. (1993), protein digestibility was increased from 50 to 60 per cent on overnight soaking of fababean seeds. In case of ricebean, an increase of 15.1 to 17.7 per cent was observed on soaking the seeds for 12 h (Kaur, 1986).

Increased protein digestibility due to soaking is attributed to leaching of phytates, trypsin inhibitors, polyphenols and other factors affecting the protein content in seed (Deshpande and Cheryan, 1983; Reddy et al., 1982).

Cooking and heat treatment improved the protein digestibility of chickpea, horse gram, cowpea (El-faki et al., 1984b), peas (Bishnoi and Khetarpaul, 1994b) and pigeonpea (Duhan,

1992). Wet heat treatment like boiling at atmospheric pressure and pressurized boiling above 100°C temperature increased the protein digestibility by 6 to 26 per cent in cowpea while pressurized steaming increased the protein digestibility only by 1.1 to 4.2 per cent (Laurena et al., 1987). An increase of 39 to 45 per cent was observed upon cooking of soaked fababean seeds (Sharma and Sehgal, 1991a). Parihar et al. (1993) observed that among different heat treatments protein digestibility improved maximum due to autoclaving in fababean followed by pressure cooking and boiling. Kaur and Kapoor (1990b) reported an increase of 10.2 to 13.0 per cent on cooking of ricebean. According to Mehta et al. (1993), protein digestibility was increased upto 13.3 per cent on cooking of ricebean.

Roasting of soyabean for five and ten minutes caused only a slight increase in the in vitro digestibility of protein (Reddy et al., 1985). Protein digestibility was slightly enhanced in roasted bengal gram, maize and soybean (Shrivastava et al., 1990). They showed that effect of time of roasting on protein digestibility value of bengal gram and maize was more than that of temperature of roasting whereas an opposite trend was observed in case of soyabean.

Beneficial effect of germination has been reported to improve in vitro protein digestibility of various legumes viz., mothbean (Subhulakshmi et al., 1976; Satwadhar et al., 1981; Khokhar and Chauhan, 1986b), chickpea, cowpea and horse gram (El-faki et al., 1984b; Chavan et al., 1989), peas (Bishnoi and Khetarpaul, 1994b) and soybean (Boralker and Reddy, 1985; Grewal, 1992).

Kaur (1986) studied the effect of germination on protein digestibility of 5 varieties of ricebean. She reported that germination for 40 h and 60 h resulted in an increase of 77.5 to 82.8 and 80.8 to 84.1 per cent, respectively in the protein digestibility.

The effect of germination on protein pattern of fababean was studied by Youssef et al. (1986). They reported that germination of soaked fababeans reduced the number and changed the intensity of high molecular weight units to low molecular weight proteins. Hence, germination leads to increase in protein digestibility due to action of hydrolytic enzymes during germination (Hamza, 1983). Other worker (Sharma and Sehgal, 1991a) had also observed an increase in protein digestibility on germination of fababeans. Sharma and Sehgal (1991a) studied two varieties of fababean and reported an increase of 15 to 17, 23 to 26 and 33 to 39 per cent in the protein digestibility of both the varieties after 24, 36 and 48 h of germination, respectively.

Nnanna and Philips (1990) observed that in vitro protein digestibility was not improved significantly by germination nor by decortication but was improved by cooking cowpeas whereas Chavan et al. (1989) showed that germination for 24 h enhanced the protein digestibility from 60.4 to 67.3 per cent. The improvement in protein digestibility occurs due to modification and degradation of storage proteins (Kataria et al., 1989b).

Fermentation also improves the protein digestibility. The reason being the microflora during fermentation produce

proteinases which are responsible for proteolytic activity of microflora. During the fermentation, the bacteria increased the proteolytic activity and degraded protein into peptides and aminoacids which are readily utilisable by bacteria (Zamora and Fields, 1979). Synthesis of aminoacids from metabolic intermediates during growth cycle of bacteria also occur.

An increase in protein digestibility due to fermentation has been observed in corn meal (Neumann et al., 1984), pearl millet (Mahajan and Chauhan, 1988), wheat and barley flour (Gupta, 1989), sorghum meal (Kazanas and Fields, 1981), rabadi prepared from pearlmillet (Dhanker and Chauhan, 1987b) and soyabean (Grewal, 1992).

The blends prepared from rice, bengal gram flours, barley and defatted soyabean flours showed significant increase in protein digestibility with an increase in temperature and period of fermentation (Goyal, 1991). Chaudhary (1993) studied the cumulative effect of germination and fermentation on black gram. She reported that fermentation caused an appreciable enhancement in protein digestibility of different black gram sprout slurries. Improved protein digestibility varied from 53 to 83 per cent in different sprout slurries fermented at 30°C for 12 h. When the period of fermentation was prolonged, i.e., 12 to 24 h protein digestibility almost doubled in 48 h sprouts.

Antinutrients like phytic acid and polyphenols having an adverse effect on protein digestibility are decreased during fermentation (Lopez et al., 1983; Dhanker and Chauhan, 1987b;

Khetarpaul and Chauhan, 1991; Gupta et al., 1991) and may be responsible for an increase in protein digestibility.

2.2.3 Antinutritional factors

2.2.3.1 Phytic acid

The biological role of phytic acid in seeds includes as a phosphorus store; as an energy store and possibly as an agent for preventing aflatoxin production in soyabean seed by making zinc unavailable to the mold. Phytates are widely distributed in plant seeds.

Duhan et al. (1989) reported that phytic acid content of blackgram seeds ranged from 6.47 to 6.68 g kg^{-1}. Phytic acid content of black gram was reported to be 645 mg/100 g and that of amphidiploids (green gram x black gram) to range from 697 to 750 mg/100 g (Kataria, 1986). Kaur and Kapoor (1990a) observed that the phytic acid content of different ricebean cultivars varied from 1875.4 to 2270 mg/100 g. Phytic acid content of fababean ranged from 977.7 to 980.0 mg/100 g (Sharma and Sehgal, 1992b). Yadav (1992) observed the phytic acid content of blackgram and greengram to be 1004.4 and 897.4 mg/100 g, respectively.

Phytic acid (myo-inositol 1, 2, 3, 4, 5, 6-hexakis inositol dihydrogen phosphate) occurs primarily in the seed coat and germ of plant seeds. At acidic pH, phytate forms a binary protein-phytate complex by binding to basic residues of protein. In the presence of cations at alkaline pH, phytic acid forms a ternary protein-mineral-phytate complex (Cheryan, 1980) which inhibits enzymatic degradation of protein (Serraino

et al., 1985) and, therefore, affects the protein digestibility.

Phytic acid, a powerful chelating agent for divalent cations interferes with the mineral availability by formation of insoluble phytates (Reddy and Salunkhe, 1981). Phytin, the mixed Ca-mg salt of phytic acid reduces bioavailability of dietary minerals, especially Zn (Davies and Reid, 1979; Daniels and Fisher, 1981). An insoluble Zn-Ca phytate complex formed in presence of cation and zinc at pH 6, is the mechanism by which phytate reduces the availability of divalent minerals.

Phytate phosphorus is not generally available to humans and monogastric animals. Phytate is hydrolysed to inositol and few orthophophate by enzyme phytase. This enzyme has been reported in soyabean, corn seed, fababean, mungbean, triticale and wheat (Singh and Sedeh, 1979; Michael Eskin and Wiebe, 1983).

The nutritive value of legume seeds could be improved if phytate is reduced or hydrolysed before consumption. Various domestic processing methods as soaking, germination, and fermentation, etc., and other autolytic treatments are known to reduce or eliminate phytic acid content (Duhan et al., 1989; Bishnoi et al., 1994; Yadav, 1992; Grewal, 1992).

Soaking of dry beans in water for 12 h at 24°C resulted in slight decrease in phytate (Tabekhia and Luh, 1980). Cowpea and limabean when soaked for 3 days at 27°C in deionized water showed a loss of 1.45 to 1.04 per cent and 1.07 to 0.96 per cent, respectively in phytic acid content (Ologhobo and Fetuga, 1984). Soaking of chickpea and blackgram seeds at 37°C for 12 h

lowered phytic acid by 10.1 per cent and 24.0 per cent, respectively (Duhan et al., 1989). Kataria et al. (1989a) reported that phytic acid level decreased by 2 to 3 per cent when seeds of amphidiploids were soaked in water for 6 h. The loss was higher when period of soaking was increased to 12 and 18 h. Similar trends has been reported in pigeonpea (Duhan, 1992), soyabean (Grewal, 1992), peas (Bishnoi et al., 1994) and mungbean (Abdus-Sattar et al., 1989).

Youssef et al. (1987) observed that phytic acid content of soaked fababean was reduced by 4 to 10 per cent. According to Sharma and Sehgal (1992b), soaking of fababean reduced phytic acid to only 3 per cent. Kaur and Kapoor (1990) reported that soaking of ricebean in tap water for 6, 12 and 18 h showed a loss of 14.8, 23.8 and 36.7 per cent, respectively. They reported that phytic acid decreased with increasing soaking times.

The loss in levels of phytic acid of legume seeds occurs because leaching out of this antinutrient into soaking water under the influence of concentration gradient. Such losses may be taken as a function of changed permeability of seed coat (Bishnoi et al., 1994).

A longer cooking time is required to destroy phytate in dry beans (Tabekhia and Luh, 1980). Ologhoboo and Fetuga (1984) reported that autoclaving at 105°C for 20 min decreased phytate content of cowpea and limabean from 1.45 to 1.36 and 1.07 to 1.01 per cent, respectively. Khokhar and Chauhan (1986) reported a loss of 1 to 2 per cent in ordinary cooking and 1 to

4 per cent in pressure cooking of seeds in plain water in mothbean.

Chickpea and blackgram showed a loss of 7 to 11 per cent and 6 to 9 per cent, respectively when unsoaked seeds were cooked whereas the losses were further increased when cooking was done after soaking (Duhan et al., 1989). Akinyele (1989) observed a decrease of 21 and 46 per cent in phytic acid in two varieties of cowpea after cooking. Kakkar (1992) reported a loss of 17.8 per cent in phytic acid content of cooked chickpea.

Kumar et al. (1978) suggested that insoluble complexes between phytate and other components were formed during cooking and hence, the phytic acid content was decreased. Verma and Mehta (1988) showed that phytic acid of ricebean was decreased upon cooking. Kaur and Kapoor (1990a) reported that cooking of unsoaked seeds of ricebean showed loss of 21 to 28 per cent whereas that of soaked seeds showed a loss of 28 to 41.3 per cent. Sharma and Sehgal (1992b) reported that fababean which were soaked prior to cooking showed a loss of 10 to 12 per cent in phytic acid content whereas soaking and autoclaving for 15 min exhibited a loss of 16 to 18 per cent.

Germination too causes a significant reduction in phytic acid content of cowpea and limabean (Ologobo and Fetuga, 1984), horse gram and mothbean (Borade et al., 1984; Khokhar and Chauhan, 1986b), chickpea and blackgram (Duhan et al., 1989; Kakkar, 1993), mungbean (Abdullah et al., 1984; Abdus-Sattar et al., 1989; Kataria et al., 1989), Phaseolus bean (Lee, 1990)

and soyabean (Grewal, 1992). Bishnoi et al. (1994) reported a loss of 67 to 83 per cent when peas were germinated for 48 h.

Kaur and Kapoor (1990a) reported that germination of ricebean for 40 h decreased the phytic acid level by 13.5 to 52 per cent. Phytate was reduced to a level of 71 to 77 per cent at the end of 10 days germination in fababean (Michael Eskein and Wiebe, 1983). Similarly, Sharma and Sehgal (1992b) reported a loss of 46 to 48 per cent and 66 to 69 per cent in phytic acid after 36 and 48 h of germination. Verma and Mehta (1988) had noticed that sprouting decreased the phytate phosphorus of ricebean by 11.3 per cent. Youssef (1987) observed that 3 days of germination of fababean reduced the phytic acid only from 425 to 411 mg/g.

The loss in phytic acid during germination of legumes occurs because it is used as a source of phosphorus. Secondly, activity of phytase is enhanced during germination which leads to the hydrolysis and ultimately affects the phytic acid content. Phytase activity has been reported in germinated fababean (Michael Eskein and Weibe, 1983) and mungbean (Mandal et al., 1972).

Khan et al. (1988) reported a loss of 36.1 per cent in phytic acid in brown gram after roasting. Soaking of seeds in water prior to roasting increased phytic acid losses. Khan et al. (1988) reported that seeds of five chickpea cultivars had phytic acid content of 344 and 308 mg/100 g in the whole seed and cotyledons, respectively. This was decreased to 215 and 162 mg/100 g after conventional roasting in an iron pan.

Loss of phytate in different cultivars during roasting ranged from 16.1 to 60.5 per cent in whole seeds and from 17 to 68.8 per cent in the cotyledons.

Reddy and Salunkhe (1980) reported that unprocessed, soaked and fermented cotyledons of blackgram had 4.80, 4.66 and 4.16 mg/g phytate, respectively. Phytic acid content of locust bean decreased from 51 mg to 31 mg/100 g in fermented samples (Eka, 1980).

Goyal (1991) reported a loss upto 51 per cent in rice and bengal gram dal blend fermented at 35°C for 24 h. According to Chaudhary (1993), reduction in phytic acid content varied from 35 to 79 per cent when different sprout slurries were fermented for varying periods at 30°C, whereas at 35°C the loss ranged from 35 to 81 per cent in different blackgram sprouts.

Reduction in phytic acid content during fermentation may be attributed to the presence of wide range of microflora which possess phytase activity (Daniels and Fisher, 1981; Lopez et al., 1983). The inherent phytase activity reported in legumes may also be responsible for decreasing the phytic acid.

2.2.3.2 Polyphenols

Polyphenols, also termed as tannins are mainly present in the seed coat of legumes and interfere with the biological value of grains. Tannin content of dry beans depends upon the bean species and colour of seed coat. Tannins are mainly, i.e., 81-85 per cent are located in the testa while only 15-18 per cent located in kernal (Barroga et al., 1985). Griffiths and Jones (1977) reported that testa of fababeans with coloured

flowers had 4 to 8 per cent tannins against less than 0.6 per cent in white flowered varieties. Gorski (1985) showed that seed coat of coloured varieties of fababean contained traces of polyphenols while coloured seed contained 1.69 to 3.13 per cent of polyphenols (Elias et al., 1979; Papadopoulos et al., 1985). Tanin content of fababean was more related to flower colour than to testa colour.

Contrary to this, Price et al. (1986) did not find any association between colour of the seed coat and the tannin content of the varieties of cowpea, chickpea, pigeonpea and mungbean.

The polyphenol contents of various legumes have been reported to range from 6.3 to 7.5 mg/g in beans (Tan et al., 1983), 24-25 mg/kg ink peas (Savage and Deo, 1989), 4.92 mg/kg in pigeonpeas (Souza et al., 1991), 122 mg/g in lima beans (Egbe and Akinyele, 1990) and 998.4 to 1000.5 mg/100 g in black gram (Yadav, 1992; Chaudhary, 1993).

The polyphenol content of raw ricebean varied from 1287 to 1482 mg/100 g in ricebean cultivars (Kaur and Kapoor, 1990a). Sharma and Sehgal (1992a) reported that polyphenol content of fababean varied from 226.8 to 208.2 mg/100 g.

Tannins are known to inhibit the proteolytic enzymes as they form insoluble complexes with food proteins which ultimately lower the digestibility and so also the protein quality. Digestibility has been reported to be reduced in fababean with high tannin concnetration (Bond, 1976; Marquardt et al., 1978).

Salunkhe et al. (1982) have shown the harmful effect of polyphenols on the availability of minerals and vitamins. The availability of ionizable iron is decreased by tannins due to their natural iron chelating agent action (Rao and Prabhavathi, 1982).

The tannin content in different legumes can be reduced by various processing methods, e.g. dehulling, soaking, cooking and germination, etc. According to previous workers (Rao and Deosthale, 1982; Udayshekharan and Deosthale, 1982), soaking of of pigeonpea and chickpea for overnight resulted in 50 per cent loss of tannin whereas in blackgram and green gram, the losses were 25 per cent. A loss of 17, 41 and 49 per cent in the tannin content of beans was observed when soaked in water for 6, 12 and 18 h, respectively (Deshpande and Cheryan, 1983). Similar losses in tannin have been reported in amphidiploids (Kataria, 1986), mothbean (Khokhar and Chauhan, 1986a), ricebean (Kaur and Kapoor, 1990a), fababean (Sharma and Sehgal, 1992a), pigeonpea (Duhan, 1992), chickpea (Jood et al., 1987; Kakkar, 1993) and peas (Bishnoi et al., 1994).

A decrease in total phenolic acid content of dry beans occurred on processing, showing a significant difference between raw bean, soaked and canned beans (Drumm et al., 1990). This reduction may occur due to oxidation and decarboxylation of phenolic acid to their respective phenols, hydrolysis of the esterified and insoluble phenolic acid to the free acids and solubilization and leaching of free phenolic acid (Tressl et al., 1977).

Upon cooking, 30-49 per cent decrease occurs in polyphenols. Rao and Deosthale (1982) reported a loss of 70 per cent in chickpea and 59 per cent in pigeonpea in polyphenol on cooking. Similar losses in polyphenol content has been reported in cooked mothbean and horse gram (Satwadhar et al., 1981), cowpea and pigeonpea (Ekpenyong, 1985), mungbean (Kataria et al., 1989a), black, white and red coloured beans (Reddy et al., 1985) and pigeonpea (Duhan, 1992).

Ordinary cooking of soaked fababean showed a decrease of 58 to 65 per cent in polyphenolic contents whereas cooking of soaked, dehulled seeds further reduced the level by 76 to 81 per cent (Sharma and Sehgal, 1992a). Dehulled seeds showed a decline in tannin content by 70 to 83 per cent in the beans. Moneam (1990) studied the effect of presoaking prior to cooking on polyphenol content in the hulls of 8 different varieties of fababean. Tannin content of bean hulls before and after soaking for 18 h and then cooking for 1 h at 121°C ranged from 1.2 to 4.4 and 0.39 to 0.93 mg of catechin equivalent/g of hull, respectively. Cooking after soaking lowered the tannin content of seed hulls by 64.8 to 78.9 per cent. Dehulling of cowpeas reduced the polyphenol content by 70 per cent (Shinde et al., 1991).

Kaur and Kapoor (1990a) studied 3 varieties of rice bean and reported that autoclaving of unsoaked and soaked seeds brought 21.5 to 34.7 and 42.3 to 53.4 per cent reductions in polyphenol content, respectively whereas ordinary cooking of unsoaked and soaked seed brought a reduction of 12.4 to 23.0 and 32.8 to 42.8 per cent, respectively.

A decreased amount of polyphenols in cooked seeds could result from their reduced extractability or change in chemical reactivity (Satwadhar et al., 1981). The destruction of polyphenols on cooking may be due to the formation of some insoluble complexes between proteins and tannins (Jood et al., 1987).

Germination has also been reported to reduce the level of polyphenol in various legumes like mothbean (Khokhar and Chauhan, 1986a), pigeonpea, chickpea and greengram (Jood et al., 1987; Kataria, 1986; Duhan, 1992; Kakkar, 1992). Udayshankar and Deosthale (1982) reported a loss of 60 per cent of tannin in pigeonpea and chickpea and 50 per cent in blackgram and greengram. More than 50 per cent tannins are lost in chickpea, blackgram and greengram after overnight soaking in water followed by germination for 40 h (Reddy et al., 1985).

Kaur and Kapoor (1990a) reported that germination of ricebean seeds for 40 h resulted in 31.8 to 40.5 per cent losses in the polyphenol content. Verma and Mehta (1988) showed a loss of 30.8 per cent in tannin on sprouting. It was further reduced by 53 per cent when sprouted ricebean were dehulled. Sharma and Sehgal (1992a) osberved 80 to 83 and 90 to 91 per cent losses in tannin content of fababean after 36 and 48 h sprouting, respectively.

The loss of polyphenols in legumes during germination may be attributed to the presence of polyphenol oxidase and enzymatic hydrolysis (Rao and Deosthals, 1982; Jood et al.,1987).

Fermentation also reduced the polyphenol content in plant foods viz., pearlmillet (Dhankar and Chauhan, 1987a; Khetarpaul and Chauhan, 1990b), wheat and barley (Gupta, 1987), soyabean (Grewal, 1992) and blackgram (Yadav, 1992; Chaudhary, 1993).

Contradictory to the above finding, Goyal (1991) reported a gradual increase in level of polyphenol with increase in temperature and period of fermentation in various cereal legume blends. Similar trend has been shown in studies done by Mahajan (1986) and Khetarpaul and Chauhan (1990b).

2.2.3.3 Saponin

Saponins are sterol or triterpene glycosides, which on hydrolysis yield one or more sugar units and sugar free glycan termed as sapogenins. Due to amphiphilic nature, saponins are strongly surface active, forming stable foams and acting as emulsifying agent (Oakenfull, 1981).

Although saponins are non-toxic in gastro-intestinal tract of human beings but in larger amount they cause gastro-intestinal leisons, enter blood stream and haemolyse the red blood cells. They may cause respiratory failure, convulsions and coma (Martindale, 1972). Saponin intake through food may be beneficial as they lower plasma cholesterol level and may reduce the risk of heart attack (Potter et al., 1979; Topping et al., 1980).

Saponins are present in abundance in chickpea, soyabean and kidney bean (Fenwick and Oakenfull, 1983). Khokhar and Chauhan (1986a) reported a variation of 5.6 to 2.0 per cent of

saponin in various legume. Different pigeonpea cultivars contained 2164 to 3493 mg/100 g of saponin (Duhan, 1992).

Different processing treatment like soaking, cooking, germination and fermentation could reduce the saponin level in some legumes. Jood et al. (1986) reported that soaking of chickpea and blackgram grains in plain water for 12 h reduced the saponin content by 6 to 10 per cent. Similar decrease has been observed in mothbean (Khokhar and Chauhan, 1986a). Soaking of peas for 12 h reduced the level of saponin by 7 to 17 per cent (Bishnoi and Khetarpaul, 1994a).

Kaur (1986) reported that in three different varieties of ricebean, the reduction in the level of saponin content after 12 h soaking ranged from 3.6 to 6.1 per cent. Sharma and Sehgal (1992b) showed a reduction of 20 to 23 per cent in saponin in soaked fababean seeds. The losses may be attributed to leaching out of these antinutrients into soaking water under the influence of concentration gradient.

Fenwick and Okenfull (1983) suggested that heat treatment improves the bitter taste due to saponins in the legumes but the saponin content was not reduced by cooking and processing. On the other hand, Khokhar and Chauhan (1986a) found that cooking as well as germination reduced the saponin level in mothbean. Similar trend has been reported in chickpea and blackgram (Jood et al., 1986), blackgram (Kataria et al., 1989b), pigeonpea (Duhan, 1992), fababean (Sharma and Sehgal, 1992b). Loss of saponin during cooking may be attributed to the thermolabile nature of saponins.

Germination significantly reduces the level of saponins in the legumes. Khokhar and Chauhan (1986a) found that germination of mothbean reduced the saponin content upto 56 to 66 per cent. Saponin content was declined to 44 to 51 per cent in chickpea and 37 to 40 per cent in blackgram (Jood et al., 1986). Longer the period of germination, more was the loss in saponin content.

Sharma and Sehgal (1992b) reported a loss of 30, 64 and 77 per cent in the saponin content of fababean after 24, 36 and 48 h germination. The reduction in the saponin level during germination may be due to enzymatic degradation (Kataria et al., 1989b).

Fermentation also tends to decrease the saponin content of legumes. According to Fenwick and Oakenfull (1983), fermented soyabean product tempeh had less than half the saponin content of raw soyabean.

2.2.3.4 Trypsin inhibitor activity

Trypsin inhibitors, widely present in all legumes possess a growth inhibitory property (Gupta, 1987). They have the ability to inhibit the trypsin activity of stomach and also other enzymes like chymotrypsin and subtilisin (Liener and Kakade, 1980). Trypsin inhibitor functions combining with active enzyme to form tightly bound enzyme-substrate like complex which is very stable. The extent to which the trypsin inhibitor is destroyed by heat is the function of temperature, duration of heating, particle size and moisture conditions in general.

Trypsin inhibitor contents of various legumes were reported as soyabean, 26.2; P.vulgaris, 3.4 to 11.6 ; P.lunatus, 20.2; Vicia faba, 2.7 and peas, 0.7 to 3.5 units (Benken and Budanovi, 1976). Trypsin inhibitor content in field and vegetable pea varieties ranged from 922.4 to 989.5 TIU/g (Bishnoi and Khetarpaul, 1994) and 832 to 1487 TIU/g in greengram and blackgram parents (Kataria et al., 1989), Trypsin inhibitor activity in soyabean was 2370 units (Grewal, 1992).

A six fold difference in trypsin inhibitor activity among different varieties of fababean has been observed by Bhatty (1974). Sharma and Sehgal (1992b) reported that trypsin inhibitor activity in fababean ranged from 903.6 to 912.3 TIU/g. The grist, embryo, seed coat and cotyledon of three horse bean varieties (Vicia faba) contained TIA 16.7 to 21.8, 0, 14.9 to 15.4 and 12.0 to 15.0 TIU/mg, respectively (Haraszti et al., 1986).

Singh et al. (1985) reported that TIA ranged from 15.30 to 28.04 TIU/ml in ricebean. Kaur (1986) studied 3 varieties of ricebean and observed that TIA of these ranged from 45.6 to 56.8 TIU/g. It is reported that in thirteen promising strains of ricebean, TIA ranged from 112.6 to 164.0 units/g (Malhotra et al., 1988).

Various processing methods are known to reduce the level of trypsin inhibitor activity in legumes to varying extents. A loss of 2 to 10 per cent in TIA in mothbean occurred on soaking in plain water (Khokhar and Chauhan, 1986b) whereas Kadam

et al. (1986) noticed a loss of 20 per cent in mothbean which were soaked for 8 h. Bishnoi and Khetarpaul (1994a) reported that TIA reduced to half in soaked peas (18 h). Sharma and Sehgal (1992b) reported that in soaked fababeans, TIA reduced by 4 to 5 per cent over the control value. Since, trypsin inhibitors are low molecular weight proteins, these are likely to pass out from the seed to the soaking medium easily, therefore, trypsin inhibitor are lost during soaking (Despande and Cheryan, 1983).

Complete destruction of trypsin inhibitor activity in cowpea and limabean on boiling for 20 min was observed by Bansal et al. (1988) and Egbe and Akinele (1990). Kadam et al. (1986) reported that trypsin inhibitor extracted from winged bean meal was stable at 60°C for 60 min. At 80°C activity of extracted inhibitor decreased by 25 per cent within 5 min and continued to decline gradually to a loss of 45 per cent activity after 30 min. Autoclaving treatment (120°C, 15 psi) for 10 min inactivated trypsin inhibitor almost completely. Cooking of pre-soaked beans in boiling water for 30 min was effective in destroying most of trypsin inhibitor. Autoclaving at 120°C for 30 min brought 77.7 to 92.5 per cent losses in different cowpea lines (Gatte et al., 1989).

Saini (1991) reported that heat treatment above 100°C in presence of water could remove residual TIA completely and on other hand, cooking, dry heating or deep frying could inactivate only 40 to 50 per cent of trypsin inhibitor. Heating

under pressure decreased original TIA by 81.7 per cent after 5 min and 85.9 per cent after 10 min in cowpea (Ros and Collins, 1992). Roasting of raw soyabean caused 90 per cent loss in TIA (Aletor and Ojo, 1989). According to Sangle et al. (1993) autoclaving and roasting resulted in 90.3 and 70.4 per cent, loss in TIA of soyabean, respectively.

Trypsin inhibitor found in fababean are heat labile in nature (Bhatty, 1974; Rahma et al., 1987). Heating of fababean for 1 h at 70°C and at pH 12 completely destroyed TIA (Warsey et al., 1974; Marquardt, 1975). According to Hussein (1986), TIA of fababean was destroyed by autoclaving at 120°C for 20 min, extrusion cooking at 152°C or microwave radiation at 107°C for 30 min. Sharma and Sehgal (1992b) reported a loss of 51 to 56 per cent in TIA in soaked and cooked fababean and a loss of 85 to 88 per cent in fababean autoclaved after soaking. Trypsin inhibitors in protein isolates from fababeans were reduced maximally when fababean were initially processed at 100°C for 5 min (Borowska, 1993).

Germination significantly reduces the TIA in legume seeds. Kadam et al. (1986) reported a loss of 70 per cent in mothbean germinated for 24 h and it was completely lost when germination period was extended to 48 h. TIA was lost to the extent of 85 to 88 per cent in blackgram seeds sprouted for 48 h (Kamalakannan et al., 1981; Chitra and Sadasivam, 1986). Complete destruction of TIA was observed in chickpea after germination of 8 days (Bansal et al., 1988).

Verma and Mehta (1988) reported a loss of 30 per cent in trypsin inhibitor activity upon germination of ricebean. Germination of fababean was carried till 8 mm sprout length at pH range of 3 to 7 by Bednarski et al. (1985). They reported that maximum decline in trypsin inhibitor activity was at pH 5.0 to 5.5. According to Rahma et al. (1987), trypsin inhibitor activity of fababean declined to 10.05 and 14.50 per cent after 24 and 48 h of germination. Sharma and Sehgal (1992b) reported a loss of 46 to 49, 56 to 59 and 64 to 65 per cent in trypsin inhibitor activity of fababean when germinated for 24, 36 and 48 h, respectively.

The mobilisation and breakdown of chemical constituents including trypsin inhibitor may be responsible for reduction in TIA during germination (Sharma and Sehgal, 1992b). Secondly, leaching out of some elements during soaking and germination may also be responsible for decrease in TIA (Collins and Saunders, 1976).

Wang et al. (1975) reported complete elimination in TIA during fermentation with Rhizopus. Fungal proteases are rather insensitive to inhibitor and are capable of using it as a source of amino acids. However, oleic, linoleic and linolineic acid liberated by fungal lipases may also show anti-tryptic activity.

Kaul and Bajwa (1987) reported a decrease of 87 and 89 per cent in TIA upon fermentation for 2 and 4 h, respectively in blackgram whereas fermentation of soybean corn blends did

not bring about any change in its trypsin inhibitor activity (Chompreeda and Fields, 1984b).

Chaudhary (1993) reported that trypsin inhibitor activity of blackgram sprouts germinated for 24 h decreased by 50 per cent when fermentation was carried at 35°C for 12 h.

2.2.4 Minerals

2.2.4.1 Total minerals

Legumes have fairly good amount of minerals. Commonly consumed pulses contain phosphorus, potassium, calcium and magnesium as major minerals whereas zinc, copper, iron and manganese are the minor minerals present in legumes (Singh et al., 1976).

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

According to Singh et al. (1985), the calcium, iron and phosphorus content of six strains of ricebean varied from 315 to 450 mg/100 g, 0.0 to 2.0 mg/100 g and 197 to 393 mg/100 g, respectively. Ricebean contained 302 mg/100 g calcium and 297 mg/100 g phosphorus as studied by Gopalan et al. (1984). Different varieties of ricebean were found to contain calcium, phosphorus and iron ranging from 286.7 to 326.8, 233.7 to 248.8 and 5.3 to 7.7 mg/100 g, respectively (Kaur, 1986).

Fababeans are also good source of some of the mineral elements (El-Shimi, 1980). According to Rani and Hira (1993), the calcium, phosphorus and iron contents of raw fababean were found to be 180, 424 and 4 mg/100 g , respectively.

Different processing and cooking methods are known to have a pronounced effect on the mineral content of legumes. According to Meiners et al. (1976), minerals in cooked legumes are reduced to about one-third and one-half of the values in raw beans, with Mg, P and K leaching into cooking water.

Cooking of blackgram for 5 min at 10 psi brought considerable losses of Ca, Mg, Fe and Zn into cooking water due to leaching. When cooking time was increased by 40 min the mineral content of beans were increased presumably due to reabsorption of minerals in cooked beans (Reddy et al., 1978).

Similarly, losses in calcium content of blackgram, greengram and chickpea as a result of cooking were noticed by Kumar et al. (1978). The losses occurring during cooking may be because cooking involves a complex reaction system. Thereby the Ca^{++} which is concentrated in parenchymal cell migrates into the interior of cell and complexes with phytate ion. Further 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.

Savage and Deo (1989) reported that cooked peas contained lower levels of iron. Cooking of lentil kernels resulted in a marked increase of all mineral elements (Savage, 1988). Cooking

resulted in 23 per cent loss of iron in bengal gram seed (Annapurani and Murthy, 1985).

According to Rani and Hira (1993), pressure cooking and roasting resulted in significant loss of phosphorus in fababean. Reduction in phosphorus content might be due to leaching of mienrals in cooking water. Iron content was also significantly reduced after pressure cooking. On the contrary, Borade et al. (1984) and Chompreede and Fields (1984a) reported non-significant changes in Mg, Fe and Zn content of legumes after cooking and autoclaving. It is generally believed that minerals are not sensitive to heat processing, but are susceptible to leaching into cooking water.

Roasting brought only a slight change in Ca, Mn, Fe, Cu and Zn content of soyabean (Ologhobo, 1989). Kakkar (1992) reported that roasted chickpea grains had significantly higher iron content as compared to raw grains.

Cooking and autoclaving only slightly decreased the total phosphorus content in some Nigerian varieties of legumes (Ologhobo and Fetuga, 1984). They observed that among the different processes, germination had the most pronounced effect on loss of total phosphorus in all varieties of cowpeas, followed by soaking while cooking and autoclaving only slightly decreased. 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). A significant loss of calcium was found in

later stages of germination in all legumes and this may be due to leaching of inorganic compounds during germination (Kumar et al., 1978).

Giri et al. (1981) reported that total calcium content was decreased in germinated legumes, whereas iron and phosphorus remained constant. Annapurani and Murthy (1985) observed that iron content after 48 h germination was increased by 10 per cent in bengal gram. Further increase in germination, period resulted in increased total iron content. Sprouting of fababean for 36 h brought significant reduction is calcium content (Rani and Hira, 1993). On the contrary, sprouting caused moderate losses of divalent metals like Ca, Fe and Mg probably becuase of the ability of divalent cation to bind to protein to form protein-cation phytate complexes (Lee and Karunanithy, 1990).

Removal of husk had a marked effect on Ca level as it was mainly (61.4%) found in testa (Newsome, 1986). Dehusking of fababean seeds resulted in significant loss of calcium (Rani and Hira, 1993). Annapurani and Murthy (1985) observed 10 per cent increase in total iron values of dehusked seeds as compared to raw seeds of bengal gram.

Fermentation did not alter total mineral content of various cereals and legumes including pearlmillet (Dhanker and Chauhan, 1989; Khetarpaul and Chauhan, 1989) and soyabean (Grewal, 1992).

2.2.4.2 HCl extractability

Extractable minerals in a food are those which are

soluble in 0.03 N HCl, the concentration of HCl found in human stomach. The amount of HCl-extractable minerals in food is an index of their bioavailability from foods (Chompreeda and Fields, 1984a).

Singh and Banerjee (1955) reported an increase in iron extractability after 48 h of germination in different pulses. An increase in availability of calcium and iron on germination of different legumes had been reported by Giri et al. (1981).

Bishnoi and Khetarpaul (1994c) studied the extractability of minerals in peas. They reported an improvement in mineral extraction upon germination of soaked peas. They observed an increase of 82 to 112 per cent in calcium, 48 to 52 per cent in phosphorus, 58 to 71 per cent in iron when the germination period was prolonged from 24 to 48 h.

Kaur (1986) reported a significant reduction in the extractable calcium content of all ricebean varieties after 12 h soaking whereas an increase in germination period from 40 to 60 h caused on improvement in calcium extractability. She also noticed that autoclaving of soaked and unsoaked seeds resulted in an increase in extractable phosphorus content when compared to cooking of soaked and unsoaked seeds.

Chompreeda and Fields (1984a) reported that extractability of phosphorus from soyabean decreased during autoclaving by 27.1 per cent. This may be because of heating, a complex of phosphorus is formed, which limits the extraction. They also reported an increase in extractbaility of Fe, Mg, Zn and K in autoclaved over non-autoclaved soyabean meal indicating a change in the solubility during heat treatment.

The improvement of HCl-extractability of minerals during fermentation has been reported in corn (Chompreeda and Fields, 1984), soyabean (Grewal, 1992), pearlmillet (Dhankar and Chauhan, 1989; Khetarpaul and Chauhan, 1990a), cereal-legumes blends (Goyal, 1991), rabadi prepared from wheat and barley (Gupta, 1989), blackgram (Chaudhary, 1993) and wadi (Yadav, 1992).

An increase in extractbaility of Ca, P, Fe, Zn, Cu and Mn with an increase in temperature and period of fermentation in various rice-legume blends has been reported by Goyal (1991).

Fermentation brings conversion of bound forms of the minerals to free forms, thereby increasing the amount of extractable minerals (Ramakrishnan et al., 1976; Nolan and Duffin, 1987). The increased bioavailability of minerals may be attributed to the loss of phytates and tannins as a significant and negative correlation has been noticed between minerals' extractability and these antinutrients by previous workers (Khetarpaul and Chauhan, 1990a; Yadav, 1992; Grewal, 1992).

2.2.5 Iron availability (in vitro)

The solubility of minerals in foodstuffs subjected to in vitro gastric or gastro-intestinal digestion is indication of their bioavailability from these foodstuffs (Rao and Prabhavathi, 1978; Lock and Bender, 1980; Miller et al., 1981; Schricker and Miller, 1982; Wein and Schwaltz, 1983; Wein and Schwartz, 1985).

Prabhavathi et al. (1979) studied the effect of simple domestic processing on ionizable iron from cereals and pulses.

They reported that soaking in water alone had no influence on available iron in chickpea. They also observed that boiling rice and dal and cooking whole wheat without fat had no effect on ionizable iron. Annapurani and Murthy (1985) reported that 36 per cent of iron present in bengal gram was available.

Lombardi-Boccia (1991) studied the effect of phytate and extrusion cooling on *in vitro* iron dialysability from 6 Italian legumes, i.e., mottled bean, white bean, fababean, chickpea and lentil. The per cent dialysable iron was 2.3 in mottled bean, 2.4 in white bean, 1.2 in fababean, 2.7 in chickpea and 1.1 in lentil. They reported that after extrusion cooking the flours showed a marked iron contamination and decrease in Fe dialysability, but these changes were significant only for mottled bean. Removal of enzyme phytase induced an increase in iron dialysability more than 100 per cent in all raw legume except mottled bean which showed an increase of only 57 per cent.

Begepalli *et al*. (1982) reported that only 18.5 per cent of total iron in soyabean was ionisable. According to Annapurani and Murthy (1985) only 25 per cent of total iron (11.71 mg/100 g) present in soyabean was available *in vitro*. Chompreeda (1983) found that there was no difference in total iron content in autoclaved or unautoclaved soymeal, but autoclaving at 121°C for 30 min brought 17.2 per cent decrease in ionizable iron. On the contrary, an increase in available iron on cooking has been reported by Annapurani and Murthy (1985).

An increase in iron availability in legume sprouts has been reported by Giri et al. (1981). During germination, translocation of individual mineral elements takes place (Lorenz, 1980). The solubilization may influence the bioavailability of minerals. Singh and Banerjee (1955) reported an increase in soluble iron when germination of different pulses was done for 48 h. Germination after 24 h and above brought an increase in ionisable and soluble iron in bengal gram (Prabhavathi et al., 1979). However, this increase was not observed in dehusked germinated seeds, although they had four times higher iron content than whole grains. Ionizable iron mainly doubled during germination (Rao and Prabhavathi, 1982; Bagepalli et al., 1982; Kakkar, 1992).

Accoring to Rani and Hira (1993) ionisable iron of raw, roasted, sprouted, pressure cooked and dehusked fababean constituted 42, 41, 52, 42 and 41 per cent of total iron, respectively. An increase in ionisable iron observed on sprouting might be due to release of iron from protein bound combinations.

Increase in absolute available iron after germination may be due to increase in phytase activity and decreased phytate content (Chen and Pan, 1977; Reddy et al., 1978), increase in relative biological value of protein (Ranhorta et al., 1971) and decrease in polyphenol content (Satwadhar et al., 1981). Contrary to the above studies, Pawar et al. (1986) reported that cooking and germination did not improve the availability of Ca, Mg, Fe and K through phytate breakdown in mothbean.

Annapurani and Murthy (1985) reported that per cent increase in total iron was 7 and 74 and per cent increase in absolute available iron was 124 and 720 in roasted bengal gram and peas, respectively. According to Kakkar (1992), roasting of chickpea improved the in vitro availability of iron from 4.5 to 6.9 per cent.

An increase of 10 and 3 per cent in total iron and 156 and 180 per cent in absolute available iron in dehulled bengal gram and dehulled blackgram was observed by Annapurani and Murthy (1985). On the other hand, Grewal (1992) reported no changes in in vitro iron availability due to dehulling of soaked seeds followed by autoclaving.

Decortication of various legumes brought a significant increase in per cent ionizable iron (Rao and Prabhavathi, 1982). Further they observed that when seed hulls or pure tannin were added to dehusked grains to restore the tannin level present in whole seed, there was a decrease in ionizable iron to the original value, indicating that tannins are responsible for lower iron bioavailability.

Fermentation significantly improves the iron availability. Grewal (1992) reproted that in vitro availability of iron of soy rabadi which was prepared from autoclaved soyabeans increased from 15.64 per cent in unfermented mixture to 23.71 per cent after 48 h fermentation at 25°C and upto 27.21 per cent after 48 h fermentation at 35°C.

Svanberg and Sandburg (1989) reported that lactic acid fermentation increased the amount of soluble iron 2 to 6 times,

the highest value for fermented flour of germinated grains of black gram. Iron availability (in vitro) varied from 20.6 to 31.4 per cent and 34.4 per cent when various sprout slurries were fermented for different time periods at 30 and 35°C. Fermentation of 48 h sprouts at 30°C for 24 h nearly doubled the iron bioavailability (Chaudhary, 1993).

2.2.6 Ca availability (in vitro)

Chemical determination of total element in food does not indicate the amount of element that is available to meet the physiological requirement of the individual. This is because the absorption and subsequent utilization of element is influenced by many factors (Young and Janghorbave, 1981).

Schwartz et al. (1982) described as in vitro system for measuring exchangeability of intrinsic food minerals. Kim and Zemel (1986) compared the calcium solubility from sea mustard to that of spinach and milk in an in vitro digestive system with normal and reduced gastric acid concentration. Aliquots were subejcted to peptic and pancreatic digestions. The ionic and total soluble calcium measured indicated the potential availability. Therefore, solubility or extractability of minerals in foods subjected to in vitro gastric and intestinal digestion may serve as useful indicator of mineral bioavailability.

Wein and Schwartz (1985) reported that in vitro solubility of Ca in soyabean was 35 per cent after peptic pancreatic digestion. Contradictory to this, calcium solubility

ranged from 55 to 71 per cent in *in vitro* peptic digest of soyabean.

2.3 Development of Products, their Organoleptic and Nutritional Evaluation

Goyal and Mathews (1985) studied the effect of cooking on protein, lysine, tryptophan and sugar content of cereal pulse combination preparations like *khichari*, *khamman dhokala* and *missi roti*. They observed no effect of cooking on total protein of different recipes. Increase in amino acids was observed due to fermentation. Fermentation processing of *khamman dhokala* caused significant losses of sugar (15.2%) which may be due to the utilization of sugar for the formation of lactic acid. Losses of lysine, tryptophan, and sugar was found to be more in *khichari* preparation due to boiling of rice and green gram dal mix. Addition of spices did not bring any significant variation in amino acids and sugar content.

Trypsin and chymotrypsin inhibitory activities were lost by 45 and 54 per cent in *khichadi*, respectively prepared from sorghum (Mulimani and Vadiraj, 1991).

Venkatasubbaiah *et al*. (1984) studied physico-chemical and microbiological changes in *idli* batter during fermentation. The release of free sugars as well as non-protein nitrogen during soaking was much higher in blackgram dal than rice.

Sarasa and Nath (1985) prepared three *idli* like products by replacing either rice or blackgram dal used in conventional *idli* batter. Bhagar, kidney beans, black gram dal and horse gram were used as legume ingredients. After fermentation for

12 h at 30°C, the steam cooked idli like products were examined for acceptability and palatability. Products obtained from bhagar and either blackgram dal or kidney bean were satisfactorily acceptable. However, bhagar combined with horse gram, failed to achieve the expected acceptability.

Mulimani and Vadiraj (1991) observed a decrease of 55 and 75 per cent of trypsin and chymotrypsin inhibitory activities, respectively in idli prepared from sorghum.

Soni and Sandhu (1989) prepared wadi by replacing black gram dal with mungbeans. They observed that fermentation brought an increase in volume and soluble solids whereas reducing sugars decreased significantly. Total nitrogen and total protein did not vary significantly, although non-protein nitrogen increased from 0.20 to 0.69 g per cent. Most of the changes during wadi fermentation caused improvements in digestibility and nutritive value. Mungbean wadi dough fermentation exhibited similar changes as observed in traditional blackgram doughs.

Yadav (1992) prepared wadies from greengram and blackgram dals. She reported that natural fermentation for 12 h at 25°C did not bring about a significant change in crude protein and fat content of wadies. But with an increase in temperature and period of fermentation, there was a significant loss of protein. Ash content was not altered during fermentation. She reported an increase of 85 to 88.2 per cent and 41.0 to 48.3 per cent in starch digestibility and protein digestibility, respectively in wadies.

Khadar (1983) studied the nutritional quality of shoyu a fermented soyabean product, fermented soymilk drink and germinated soyabean. Raw soyabean, germinated soyabean and fermented shoyu contained 42, 43 and 43.5 per cent protein, respectively, whereas fermented soya milk contained 10 per cent protein. Ash content was greater in germinated seeds and calcium increased slightly on germination. After fermentation, phosphorus in shoyu and germinated soyabean was considerably less than that in raw soyabean. TIA was much less in all processed soyabean than in raw soyabean.

In the preparatory treatments during tempeh production, a decrease in phytic acid was observed except for soaking which significantly increased the value. Phytic acid content was halved during tempeh fermentation and further reduced when tempeh was stored for 72 h at 50°C and 30°C. Deep fat frying of tempeh further decreased the phytic acid content (Buckle, 1985).

Taguchi et al. (1986) studied the changes in dietary fibre of natto and tempeh during fermentation. Comparison of quality and quantity of dietary fibre were made between fermented soyabean products natto and tempeh with unfermented controls. Total dietary fibre in natto and tempeh decreases slightly during fermentation. Pectic substances in natto increased upto 14 per cent as compared to the control. The hemicellulose fraction decreased in fermented tempeh.

Reduction in phytic acid and starch was observed in tempeh fermented for 24, 48 and 72 h when compared to their

unfermented controls (Riet et al., 1987). Reduction in oligo-saccharides, phytate and fat content in tempeh prepared from germianted soyabean was also shown by Suparmo (1987). As a result of these reduction, the proportion of protein in tempeh solids increased.

Kaur (1992) observed that chapatis and paranthas prepared by supplementing ricebean flour with wheat flour at 10, 20 and 30 per cent level had slightly lower level of moisture and ether extract than unsupplemented ones. The average amount of crude protein, ash and crude fibres content of chapatis and paranthas at different level of supplementation increased by 18.16 and 18.04, 8.45 and 5.9 and 33.33 and 28.66 per cent, respectively. She also reproted that average Ca, Fe, Zn and Cu contents of supplemented chapatis and paranthas increased significantly indicating that supplemented products were better sources of Ca, Fe, Zn and Cu. Supplementation of chickpea flour with wheat flour has been known to improve crude protein, crude fibre and ash content of chapati (Gandhi and Bourne, 1988; Kaur and Hira, 1988).

Rajagopal et al. (1983) used composite flour for chapati making. They observed that addition of soyflour or ricebean flour to wheat dough improved both quality and quantity of protein in chapati, levels upto 5 per cent were organoleptically acceptable.

Maqbool et al. (1987) studied the proximate and mineral composition, sensory characteristics and biological value of wheat rotis supplemented with soyabean flour at 0, 5, 10, 15

and 20 per cent level. Protein, fat, ash, Ca, P, Fe and phytic acid content of wheat rotis were increased with supplementation. The carbohydrate content of rotis significantly decreased with incorporation of soyabean flour, but crude fibre content remained unchanged. Addition of soyabean flour upto 20 per cent had no adverse effect on the sensory acceptability of the rotis.

Kaur (1992) reported higher protein, ash content and lower fibre content in pakoras prepared from bengal gram flour and leafy vegetables (75:25) as compared to pakoras prepared from ricebean flour and leafy vegetables (75:25). The calcium content of pakora prepared from ricebean flour was significantly higher as compared to pakoras prepared from bengal gram flour.

Pruthi et al. (1984) observed a wide variations in the physico-chemical characteristics of spiced papads. Results indicated wide variation in moisture content, i.e. from 10.7 to 18.2 per cent, total ash from 8.4 to 11.65 per cent and ether extract from 3.1 to 3.6 per cent. Deepa et al. (1992) reported that addition of 30 to 40 per cent of soyflour would not make a significant difference in the physical and sensory characteristic of blackgram papad.

Red kidney and pinto dry beans were processed into ready to eat snack foods by Estevez and Luh (1985). Dry beans were soaked in water overnight or germianted in controlled condition at 22°C for 4 days before processing. Protein digestibility in

vitro was improved as shown by decrease in trypsin and chymotrypsin inhibitor in cooked and fried products.

Almeida et al. (1990) formulated corn based snacks with high nutritive value using chickpea flour and defatted soyabean meal and they observed increase in protein in these products than a commercial corn snack used as control.

Gulati et al. (1989) prepared vadas from a mixture containing 60 or 70 per cent of a single dal, 10 per cent skim milk powder or sesame and 30 per cent soyabean paste. Dals used for preparing vadas were bengal gram, greengram and blackgram. These were evaluated for sensory quality. Vadas prepared from dal and soyabean were generally most acceptable. Bengal gram produced most preferred product.

McWatters (1983) studied the quality characteristics of cake type dough nuts containing peanut, cowpea and soyabean flours. Wheat flour at the level of 10 per cent in cake type doughnuts was replaced with defatted toasted and untoasted peanuts and dry cowpeas. The legume supplemented doughnuts were prepared with and upto 3 per cent soyabean flour. The quality of test doughnuts was assessed in comparison to wheat flour doughnuts. Legume supplemented doughnuts scored favourably in sensory comparison with reference doughnuts.

Wheat flour supplementation with 10, 15 and 20 per cent of each of sorghum millet or defatted soyaflour was used to make baladi bread. Supplementation increased moisture, protein, fat, fibre, ash, sugar, essential amino acid, reduced starch content as reported by Foda et al. (1984). Incorporation of 10

per cent defatted soymeal produced good quality bread with acceptable organoleptic properties and improved nutritional value (Ugarcic et al., 1991; Misra et al., 1991).

Supplementation of chickpea flour with wheat flour has been known to improve the crude protein, crude fibre and ash content of bread (Akbar et al., 1986; Gayle et al., 1986; Estever et al., 1987). Germinated soyabean bread contained 20 per cent protein. TIA was less in germinated soyabean bread than in raw soyabean (Khadar, 1983).

Sweet biscuits were prepared from wheat flour and 5, 10, 15 and 20 per cent of raw and germinated (96 and 144 h) fababean flour (Rahma et al., 1987). Biscuits prepared from 100 per cent wheat flour were used as control. Both germination and the per cent of added fababean flour significantly affect total acceptability of biscuits. Panalist preferred most the biscuits that contained 3 and 6 days germinated bean flour and least those made with ungerminated bean flour. Non-significant differences were observed between 100 per cent wheat flour biscuits and those containing upto 10 per cent fababean flour. Biscuits containing 15 to 20 per cent fababean flour were rejected.

Sharma (1989) prepared laddoo, halwa, dehulled dal, pullao, kadhi, pakora, fried dehulled dal and whole dal using fababean. Overall acceptability of fried dehulled dal was significantly lower than that of laddoo, halwa, dehulled dal, kadhi and pakora. Inspite of some variations observed in different characters all the products were found to be in 'moderatley desirable' to 'desirable' range.

CHAPTER - 3

MATERIALS AND METHODS

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

3.1 Materials
3.2 Physico-chemical properties
3.3 Nutritional analysis of unprocessed ricebean and fababean
3.3.1 Proximate analysis
3.3.1.1 Moisture
3.3.1.2 Crude protein
3.3.1.3 Crude fat
3.3.1.4 Ash
3.3.1.5 True protein
3.3.1.6 Dietary fibre constituents
3.3.2.1 Starch digestibility
3.3.2.2 Protein digestibility
3.3.3 Antinutritional factors
3.3.3.1 Phytic acid
3.3.3.2 Polyphenols
3.3.3.3 Saponins
3.3.3.4 Trypsin inhibitor activity
3.3.4 Mineral composition
3.3.4.1 Acid digestion
3.3.4.2 Calcium
3.3.4.3 Phosphorus

3.1 Materials

Two high yielding varieties of pulses namely ricebean (RB-32) and fababean(VH-82-1) were procured in a single lot from the Department of Plant Breeding, CCS Haryana Agricultural University, Hisar. The seeds of both the beans were cleaned, made free of dust, dirt and foreign materials prior to processing and product development.

3.2 Physico-Chemical Properties

Unprocessed seeds of both the beans were analysed for the following physico-chemical properties:

3.2.1 Density

Seeds (50 g) were weighed accurately and transferred to a measuring cylinder. Then 50 ml distilled water was added to it.

Seed volume was recorded by subtracting 50 ml from the total volume (ml). Density was recorded as g/ml.

3.2.2 Hydration capacity

Seeds weighing 50 g were counted and transferred to a measuring cylinder and to this, water was added. The cylinder was covered with aluminium foil and left overnight at room temperature. Next day seeds were drained, superfluous water removed with filter paper and swollen seeds reweighed. Hydration capacity per seed was determined by using the following formula:

$$\text{Hydration capacity per seed} = \frac{\text{Weight of soaked seeds - Weight of seeds before soaking}}{\text{Number of seeds}}$$

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

$$\text{Swelling capacity} = \frac{\text{Volume after soaking - volume before soaking}}{\text{Number of seeds}}$$

3.2.5 Cooking time

Seeds (100 g) were taken in beakers of crude fibre apparatus. Water was added in a ratio of 1:3 (w/v). Beakers were connected with condensors to avoid evaporation of water

during boiling. Samples were stirred at 2 min interval. After 45 min one seed was withdrawn without interrupting the boiling. Degree of cooking was tested by pressing seeds between the fingers. If seeds were felt uncooked, one seed was again tested after 5 min. This procedure continued until five seeds tested were found cooked. At this time, total cooking time was recorded.

3.3 Chemical Analysis of Unprocessed Ricebean and Fababean

Finely ground samples of raw ricebean and fababean were analysed for the following parameters:

3.3.1 Proximate analysis

3.3.1.1 Moisture: Moisture in the samples was calculated by employing the standard methods of analysis (AOAC, 1990).

3.3.1.2 Crude protein

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 and dissolved in 100 ml 95% ethanol

(iv) NaOH (40%)

(v) Digestion mixture: 10 g K_2SO_4; 0.5 g $CuSO_4$ and 2 g $FeSO_4$ were mixed

Procedure

Took one g sample and digested with 25 ml conc. H_2SO_4 and a pinch of digestion mixture and distilled using 40% NaOH on Kjeldahl apparatus. The ammonia liberated was absorbed in 10 ml boric acid solution containing a few drops of mixed indicator

and titrated against standard N/100 H_2SO_4. The end point was indicated by change of colour. A factor of 6.25 was applied to convert the amount of nitrogen to crude protein.

3.3.1.3 Crude fat

Crude fat was estimated by standard method of analysis (AOAC, 1990) using Soxhlet extraction apparatus.

Procedure

Transferred a weighed amount (2 g) of dry sample to an extraction thimble dried overnight at 105°C. Placed the thimble in a Soxhlet extractor fitted with a condensor and flask containing sufficient petroleum ether (BP 60-80°C). After 6 h extraction, thimble was removed from the extraction apparatus and dried in the hot air oven to a constant weight, cooled in a desiccator to room temperature and weighed. Loss of weight of thimble indicated the amount of fat in the sample.

3.3.1.4 Ash

Ash in the sample was estimated by employing the standard method of analysis (AOAC, 1990).

Procedure

Weighed two g dry sample in a weighed crucible and ignited it until no charred particles remained in the crucible. Then put the crucible in muffle furnace (550°C) for 6 h or till a white ash was obtained. Cooled the crucible in a desiccator and weighed.

3.3.1.5 True protein nitrogen (TPN)

The true protein nitrogen was estimated by the method of Osborne and Voogt (1978).

Reagents

(i) Copper acetate monohydrate (3% w/v)

(ii) Aluminium potassium sulphate 2 H_2O (10% w/v)

(iii) Silicon antifoam (6.6%, w/v)

Procedure

Two g of moisture free sample was transferred into Kjeldahl flask. To this added 50 ml distilled water, a few glass beads and 1-2 drops of silicon (antifoam). The mixture was digested by heating gently for half an hour. While the digest was still hot, 2.0 ml of aluminium potassium sulphate solution (10%) was added, swirled to mix and re-heated to just boiling. Then 50 ml of copper acetate solution was added and mixed thoroughly.

After cooling, the contents were filtered through filter paper Whatman #1. The flask and residue was washed with 50 ml cold distilled water. The filter paper and the residue were returned to the original flask and the nitrogen was determined by Micro-Kjeldahl method (AOAC, 1990). A factor of 6.25 was used to convert TPN to true protein.

3.3.1.6 Dietary fibre constituents

Different dietary fibre constituents were estimated by the method of Van Soest and Wine (1967).

3.3.1.6.1 Neutral detergent fibre (NDF)

Reagents

(i) Neutral detergent solution

Sodium lauryl sulphate 30 g

Disodium ethylene diamine tetra acetate dihydrate (EDTA) 18.61 g

Sodium borate decahydrate	6.81 g
2-ethoxy ethanol	10 ml
Disodium hydrogen phosphate anhydrous	4.36 g
Water	1 litre

EDTA and sodium borate decahydrate were weighed in a beaker. Some water was added and solution heated until the contents dissolved. Sodium lauryl sulphate and 2-ethoxy ethanol were added to it. Disodium hydrogen phosphate was dissolved separately in remaining water by heating in a beaker. Contents of both of the beakers were mixed and pH adjusted to 6.9 to 7.0

(ii) Acetone

Procedure

One g sample (dried and ground to a fine powder) was taken into a beaker of refluxing apparatus. To this, 100 ml NDF solution was added and heated to boiling. In order to avoid foaming, the intensity of heat was reduced as boiling began.

After refluxing for 60 min, it was filtered through a weighed Gooch crucible on filter manifold. The sample was rinsed twice with a minimum of hot water (90° to 100°C) and filtered. The residue was washed twice with acetone. The crucible was dried over night in a hot air oven at 100°C, cooled and weighed. Residue in the crucible was ashed at 525 $\pm$ 25°C for 3 h in a muffle furnace and weighed after cooling. The ash content was recorded as ash insoluble in neutral detergent solution.

$$\text{NDF (\%)} = \frac{\text{(Weight of crucible + fibre contents) - Weight of crucible}}{\text{Weight of sample}} \times 100$$

3.3.1.6.2 Acid detergent fibre (ADF)

Reagents

(i) Acid detergent solution: Twenty g cetyl trimethyl ammonium bromide (CTAB) was dissolved by stirring in IN H_2SO_4 to make one lt.

(ii) Acetone

Procedure

One g dried sample (ground to pass 20-30 mesh screen) was taken in a beaker of refluxing apparatus. To this, 100 ml of ADF solution was added and proceeded further as for NDF 3.3.1.6.1.

$$\text{ADF (\%)} = \frac{\text{(Weight of crucible + fibre content) - weight of crucible}}{\text{Weight of sample}} \times 100$$

3.3.1.6.3 Lignin and cellulose

Reagents

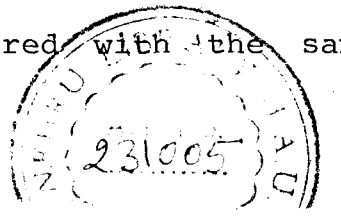
(i) ADF solution (same as in 3.3.1.6.2)

(ii) Acetone

(iii) H_2SO_4 (72% w/v)

Procedure

One g sample was dried and ADF was determined as described in 3.3.1.6.2. Previously weighed crucible containing ADF was placed in a shallow enamel pan and filled with 72% H_2SO_4 and stirred with glass rod to smoothen the paste and break the lumps. The crucibles were refilled with 72% H_2SO_4 for 3-4 times and stirred with the same glass rod at hourly



intervals as acid drained away. Crucible was kept for 3-4 h in the same manner at 20-25°C. After this, the acid was filtered by keeping the crucible on filter manifold and the contents were washed with hot water until free from acid. The crucible was dried at 100°C over night, cooled and weighed to determine lignin. The curcible contents were ashed at 500°C for 3 h in a muffle furnace, cooled and weighed.

$$\text{Cellulose}(\%) = \frac{\text{Weight of crucible with acid detergent fibre} - \text{Weight of crucible with fibre residue after treating with 72\% } H_2SO_4}{\text{Weight of sample taken for ADF estimation}} \times 100$$

$$\text{Lignin}\ (\%) = \frac{\text{Weight of crucible with fibre residue after treating with 72\% } H_2SO_4 - \text{Weight of crucible with ash}}{\text{Weight of sample taken for ADF estimation}} \times 100$$

3.3.1.6.4 Hemicellulose

Hemicellulose was estimated as the difference between NDF and ADF contents.

3.3.1.6.5 Pectin

Total pectin (as calcium pectate) was determined by the method of Ranganna (1977).

Reagents

(i) Acetic acid (1N): Thirty ml acetic acid was diluted with water to make it 500 ml.

(ii) Calcium chloride (1N): Anhydrous calcium chloride (25.7g) was dissolved in distilled water to make it 500 ml.

(iii) Sodium hydroxide (1N): Twenty g sodium hydroxide was dissolved in 500 ml distilled water, titrated and adjusted to make it 1N.

(iv) Silver nitrate (1%): One g silver nitrate was dissolved in distilled water to make it 100 ml.

Procedure

Twenty five g finely powdered sample was taken in a one litre tall beaker and 200 ml distilled water was added to each beaker. It was kept on hot plate for 20 min and the water level was maintained constant. The contents were cooled and volume was made to 250 ml. Then it was filtered through Whatman filter paper#41, and 100 ml distilled water and 10 ml 1N NaOH were added to 100 ml of the above solution. It was kept overnight. Then 50 ml 1N acetic acid was added after 5 min and 50 ml 1N calcium chloride was added with continuous stirring. It was allowed to stand for 60 min and was filtered through previously dried and weighed Whatman filter paper 41. The contents were washed with water until free of chloride (tested with 1% $AgNO_3$) These precipitates were dried at 100°C for 24 h, cooled in a desiccator and weighed. The difference in weight of empty filter paper and that with precipitates gave the quantity of calcium pectate.

3.3.2 *In vitro* digestibility

3.3.2.1 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 0.2M (27.28 g/lt) potassium dihydrogen phosphate was added to 46.8 ml 0.2 M (35.598 g/lt) 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, dinitrosalicyclic acid, 300 g sodium - potassium tartarate and 16 g NaOH in carbon dioxide free water and 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.

Estimation

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 2 h. After the incubation period was over, 3 ml dinitrosalicyclic 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 350 nm. A blank was run simultaneously incubating the sample, the dinitrosalicyclic 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 6.4 mg maltose from a standard maltose solution. 0.187 OD corresponded to 3.2 mg maltose.

3.3.2.2 Protein digestibility (*in vitro*)

In vitro digestibility of protein was carried out by the method of Akeson and Stahmann (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 M 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 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 min 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, 1990). 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:

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

3.4.3 Antinutritional Factors

3.4.3.1 Phytic acid

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

Reagents

(i) 0.5 M HNO_3 : Diluted 15.96 ml 69.5% HNO_3 (AR Grade, Sp. gr. 1.42) to 500 ml with water.

(ii) Ferric ammonium sulphate : Dissolved 215 mg ferric ammonium sulphate in water, added a few drops of HCl and made volume to 500 ml with water.

(iii) Ammonium thiocynate: Dissolved 10 g ammonium thiocyanate in water and made to 100 ml.

(iv) Iso-amyl alcohol

(v) Sodium phytate : Dissolved 30.54 mg sodium phytate (5.5% H_2O, 97% purity and containing 12 Na/mole) in 100 ml 0.5 M HNO_3 which gave a solution containing 20 mg phytic acid in 100 ml or 200 ug phytic acid/ml.

Extraction

Extracted 500 mg sample with 20 ml 0.5 M HNO_3 for 3 h with continuous shaking on a shaker at room temperature. After proper shaking, it was filtered through Whatman filter paper 1. Filtrate was used for estimation of phytic acid.

Procedure

One ml HNO_3 extract was taken in a stoppered test tube and made to final volume of 1.4 ml with water. Added one ml

ferric ammonium sulphate solution, mixed the contents in the tubes thoroughly and placed in a boiling water bath for 20 min. cooled down the tubes to room temperature under running tap water. Added five ml iso-amyl alcohol, mixed the contents vigorously and added 0.1 ml ammonium thiocyanate solution. Shook the tubes well and centrifuged at 3000 rpm for 10 min. Colour intensity in the alcohol was read at 465 nm against iso-amyl alcohol blank exactly after 15 min of addition of ammonium thiocyanate.

For plotting a standard curve, 0.4-1.0 ml standard phytate solution containing 80-200 ug phytic acid was taken and made to 1.4 ml with water. 0.341 O.D. corresponded to 160 ug phytic acid.

3.4.3.2 Polyphenols

Total polyphenols were extracted by the method of Singh and Jambunathan (1981). Defatted sample (500 mg) was refluxed with 50 ml methanol containing 1% HCl for 4 h. The extract was concentrated by evaporating methanol on a boiling water bath and brought its volume to 25 ml with methanol 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 one litre. Twenty ml of this stock solution were further diluted to 100 ml with water to give working standard solution containing 20 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 and filtered through glass wool.

Procedure

The extract, 1.5 ml was diluted with water to 8.5 ml in a graduated test tube. After thorough mixing, added 0.5 ml Folin-Denis reagent and the tubes were well shaken. Exactly after three min, one ml saturated sodium carbonate solution was added and the tubes were thoroughly shaken again. After one h, the absorbance was read at 725 nm using a 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. 0.200 O.D. corresponded to 35 ug tannic acid.

3.3.3.3 Saponins

Saponins were extracted and determined by the modified method of Gestetner et al. (1966).

Reagents

(i) Standard saponin solution: Dissolved 50 mg saponin in acetic acid and made to 100 ml with acetic acid.

(ii) 1 N H_2SO_4 in dioxane : Water (1:3, v/v)

(iii) Acetic acid 10%

(iv) Conc. H_2SO_4

(v) Sodium sulphate

(vi) Alumina (Aluminium oxide, acetic acid)

(vii) Benzene

(viii) Diethyl ether

(ix) Methanol solution (3%) in benzene

Extraction

Five hundred mg sample was taken in an extraction flask, dispersed in 50 ml 1 N H_2SO_4 in dioxane : water (1:3) and hydrolysed under reflux for 8 h. The contents were cooled and diluted with addition of 50 ml water. Sapogenins were extracted with 25 ml and then with three successive portions of 15 ml diethyl ether. The combined ether extracts were washed with water, made moisture-free by adding sodium sulphate and then dried. The dried residue was taken up in minimal amount of benzene and purified on a column of alumina.

Isolation

For preparing column, 5 g freshly activated alumina (110°C for 2 h) was suspended in 100 ml benzene and 0.2 ml 10% acetic acid was added and stirred vigorously for 30 min. Immediately it was poured into a column of 15 mm diameter and washed with 250 ml benzene. Sapogenin extract in benzene was loaded on the column. Various impurities were removed by washing the column with 100 ml benzene and the sapogenins were

then eluted with 100 ml of 3% solution of methanol in benzene. The elute was concentrated nearly to dryness and the residue was dissolved in 10 ml acetic acid.

Estimation

To two ml acetic acid solution of sapogenins one ml glacial acetic acid followed by two ml conc. H_2SO_4 was added. The contents of tubes were mixed thoroughly and were cooled to room temperature. The absorbance was read at 530 nm against a blank (containing 3 ml glacial acetic acid and 2 ml conc. H_2SO_4).

For plotting a standard curve 0.5 ml to 3.0 ml standard solution containing 0.5 to 3 mg sponin was taken and made to 3.0 ml with glacial acetic acid. 0.126 O.D. corresponded to 1.5 mg saponin.

3.3.3.4 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 distilled water and pH adjusted to 7.6.

(ii) 0.05M phosphate buffer (pH 7.0): Fifty ml 0.1 M phosphate buffer was diluted to 100 ml with water and the 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 and shaking on a steam bath for about 10 min. The solution was cooled and made to 100 ml with phosphate buffer and stored in a refrigerator.

(iv) Trypsin solution (5 mg/ml): Dissolved 125 mg trypsin (Sigma, USA) in 25 ml phosphate buffer (0.1 M, pH 7.6).

(v) 0.001 N HCl: Added 8.88 ml HCl to water and made the volume to one litre with distilled water. Pipetted 10 ml of this 0.1 N HCl and made to one litre with water.

(vi) Trichloroacetic acid (TCA) 5%.

Extract

One g sample was taken in a 150 ml conical flask and 25 ml 0.05 M phosphate buffer (pH 7.0) was added to it. The contents were shaken at room temperature for 3 h and centrifuged at 10,000 rpm for 20 min. The following sets of incubation mixtures were prepared.

	Test	Control	Blank
Phosphate buffer (0.1 M, pH 7.6)	1.0 ml	1.1 ml	1.0 ml
Trypsin solution (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
Incubated at 37°C for 20 min			
TCA (5%)	6.0 ml	6.0 ml	-

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

Reagents

(i) Sodium carbonate : 2% in 0.1 N NaOH

(ii) $CuSO_4.5H_2O$: 5% in 1% sodium citrate

(iii) Alkaline $CuSO_4$: 50 parts of solution (i) and one part of solution, (ii) were mixed just before use.

(iv) 1 N Folin- Ciocalteau phenol reagent

(v) Working casein standard solution (1 mg/ml): Diluted 5 ml 2% casein solution to 100 ml with phosphate buffer (0.1 M, pH 7.6).

Estimation

To 0.5 ml supernatant, 5 ml alkaline $CuSO_4$ solution was added. It was mixed thoroughly and allowed to stand for 10 min at room temperature. Then 0. 5 ml 1N Folin-Ciocalteau phenol reagent was added and again immediately mixed. After 30 min the colour intensity was read at 520 against a blank.

For preparing standard curve 0.1 ml to 0.5 ml of working standard casein solution was taken. 0.120 O.D. corresponded to 150 ug.

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 min at pH 7.6. One unit of

inhibitory activity is that which reduces the activity of trypsin by one unit under the assay conditions.

3.3.4 Mineral composition

3.3.4.1 Acid digestion

To one g ground sample in a 150 ml conical flask, 25-30 ml diacid mixture (HNO_3 : $HClO_4$ :: 5:1 v/v) was added and kept overnight. The contents were digested by heating until clear white precipitates settled down at the bottom. The crystals were dissolved by adding double distilled water. The contents were filtered through Whatman Filter Paper #42. the filtrate was made to 50 ml volume with double distilled water and used for determination of total Ca, P and Fe.

3.3.4.2 Calcium

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

Reagents

(i) Standard $CaCO_3$ solution (N/100) : Dissolved 0.5 g $CaCO_3$ in 6 N HCl (52.8 ml HCl made to 100 ml) 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 one litre.

(iii) NaOH solution (10%).

(iv) Hydroxylamine hydrochloride solution (5%)

(v) Triethanolamine

(vi) Calcon indicator: Dissolved 0.4 g calcon indicator in 100 ml methanol.

(vii) Polyvinyl alcohol: One per cent solution in water (cool water).

Procedure

Pipetted a suitable volume of aliquot (10 ml) in a china dish and added about 10 ml water. Added 10% NaOH drop by drop to adjust pH to neutrality. Placed the china dish containing solution on magnetic stirrer for continuous stirring. Added ten drops of 5% hydroxylamine hydrochloride solution. Then added ten drops of triethanolamine followed by 2.5 ml of 1% polyvinyl alcohol. Added 2 ml of 10% NaOH and then 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.

Calculations

$$\text{Ca meq/lt} = \frac{\text{ml of EDTA used x N EDTA x 1000}}{\text{Aliquot taken}}$$

$$\text{mg Ca/100 g} = \frac{\text{Ca (meq/lt x 20 x 50)}}{1000} \times 100$$

Where 50 was the volume of digested material made from one g sample and 20 was the volume of aliquot and water taken in china dish.

3.3.4.3 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 and dry anhydrous monopotassium dihydrogen orthophosphate in a few ml of water and 10 ml 10 N 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 of 4 ml with water. Added 4 ml Reagent C and mixed well. Incubated the contents at 37°C in a water bath for 90 minutes. Removed and allowed to cool to room temeprature and read absorbance at 820 nm against a suitable blank. Standard curve was plotted using one to eight ug P. 0.354 O.D. corresponded to 4 ug P.

3.3.4.4 Iron

Iron in acid digested samples were determined by atomic absorption spectrophotometer AA 120.

3.3.4.5 HCl-extractability

Minerals including calcium, phosphorus and iron, were extracted in 0.03 N HCl (Peterson et al., 1943).

Added 50 ml 0.03 N HCl to one g sample. 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 ashless filter paper (Whatman #42). The filtrate was oven dried, digested in the diacid mixture and proceeded for the determination of each of the minerals as in 3.3.4.2 for Ca, 3.3.4.3 for P and 3.3.4.4 for Fe.

3.3.5 In vitro availability of Iron

Ionizable iron in the samples was extracted according to the procedure of Rao and Prabhavathi (1978).

Two g sample was mixed with 20 ml Pepsin-HCl (0.5% pepsin in 0.1 N HCl) in a conical flask. The pH of the mixture was adjusted to 1.35 with HCl and incubated at 37°C for 90 min in an environmental shaker. After incubation, pH of the contents was adjusted to 7.5 with NaOH and again incubated at 37°C in an environmental shaker for 90 min. Contents of the flask were centrifuged at 9000 rpm for 30 min and the supernatant was filtered through Whatman # 44. The filtrate was used for the determination of ionizable iron.

Ionizable iron

Free form of iron in the filtrate which reacts with α'-α'-dipyridyl was determined as described by AOAC (1990).

Reagents

(i) α'α'-dipyridyl solution: Dissolved 0.1 g dipyridyl in water and made the volume to 100 ml.

(ii) Hydroxylamine hydrochloride solution (10%).

(iii) Acetate buffer solution: Dissolved 8.3 g anhydrous sodium acetate (dried at 100°C) in water, added 12 ml acetic acid and made the volume to 100 ml with water.

(iv) HCl

(v) Iron standard solution (0.01 mg iron/ml): Dissolved 3.512 g $Fe(NH_4)_2 6H_2O$ in water, added two drops of

HCl and made to 500 ml with water. Ten ml of the solution were further diluted with water and made to 500 ml. This solution contained 0.01 mg iron per ml.

Procedure

Ten ml filtrate was taken in 25 ml volumetric flask and one ml 10% hydroxylamine hydrochloride solution was added. Then five ml acetate buffer solution was added, the contents were mixed and then one ml dipyridyl solution was added. The volume was made to 25 ml with water and the contents were mixed well. The colour intensity was read at 510 nm.

For plotting a standard curve, 10 to 50 ml of iron standard were taken in 100 ml volumetric flask, added 2.0 ml of HCl to each and made the volume to 100 ml with water. Blank was also prepared in similar manner. Ten ml of each of these solutions were taken in 25 ml volumetric flask and proceeded as mentioned above. 0.250 O.D. corresponded to 30 ug iron.

3.3.6 Calcium availability (*In vitro*)

Available calcium was extracted by the method of Kim and Zemel (1986).

Two gram finely ground sample was taken in a conical flask and 3 ml distilled water was added to rehydrate it. To this 20 ml pepsin solution (0.1% pepsin in 0.1 N HCl) was added. The pH was adjusted to 1.5 with dilute hydrochloric acid. The contents were incubated at 37°C in a shaker-cum-water bath for 1 h. After 1 h the pH of the contents was raised to 6.8 with sodium bicarbonate solution. Then 2.5 ml of a

suspension containing 0.5% pancreatin and 5% bile was added and the contents were again incubated at 37°C for 1 h. Then the contents were taken out and total volume was made to 50 ml with distilled water. Contents were then immediately centrifuged at 500 x g for 45 min at 5°C. Supernatant was collected and re-centrifuged at 25,000 x g for 45 min at 5°C. Supernatant was collected, oven dried, digested in the diacid mixture and proceeded of the estimation of calcium by the method of Vogel (1962) as given under 3.3.4.2.

3.3.7 Available carbohydrates

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

Added 25 ml ethanol (80%) to 0.5 g sample in a round bottomed flask. The flask was connected to a condenser and kept on a heating mental for 30 min with occasional stirring. The extract was cooled, centrifuged at 8000 rpm for 15 min and the supernatant collected. The above procedure was repeated twice, each time extracting the residue in 25 ml 80% ethanol. The combined extract in the beaker was evaporated to dryness on a boiling water bath. The residue was dissolved in distilled water and made to 50 ml.

3.3.7.1 Total soluble sugars

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

Reagents

(i) Standard sugar solution: Dissolved 25 mg glucose in water and made to 100 ml. This solution contained 250 ug glucose per ml. For obtaining a standard curve, 0.2 ml to 1.0 ml of this solution was added.

(ii) Anthrone reagent (0.2% anthrone in 70% H_2SO_4): This reagent was prepared fresh daily and allowed to stand for 30-40 min before use.

Estimation

Freshly prepared 10 ml anthrone reagent was pipetted in a test tube (150 x 55 mm), chilled and kept in ice cold water. one ml of the sugar extract (as in 3.3. 7) 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. After cooling for 3-5 min, the contents were thoroughly mixed while still immersed in ice cold water. The contents in the tube were heated vigorously in a boiling water bath for 10 min and then immediately cooled in cold water. The absorbance was then read at 625 nm against a blank. 0.192 O.D. in the standard curve corresponded to 150 ug glucose.

3.3.7.2 Reducing sugars

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

Reagents

(i) Copper reagent A: Dissolved 25 g anhydrous sodium carboante, 25 g potassium sodium tartarate, 20 g

sodium bicarbonate and 200 g anhydrous sodium sulphate in about 800 ml distilled water and diluted to one litre.

(ii) Copper reagent B: Dissolved 15 g $CuSO_4$ in 100 ml distilled water containing two drops of HCl.

(iii) Arsenomolybdate reagent: Dissolved 25 g ammonium molybdate in 450 ml distilled water by warming. Added 21 ml conc. H_2SO_4 with stirring. Three g sodium hydrogen arsenate dissolved in 25 ml distilled water was added with stirring. The solution was kept in an incubator at 37°C for 24 h before use. This reagent in a glass stoppered brown bottle was stored in refrigerator.

(iv) Copper reagent A and B were mixed in the ratio of 25:1 (v/v) before use.

(v) Standard sugar solution: Dissolved 25 mg glucose and made to 100 ml with water. This contained 250 ug glucose/ml.

Estimation

One ml test extract obtained in 3.3.7 was taken in a blood sugar tube graduated at 25 ml. One ml mixed copper reagent (iv) was added and then heated for 20 min 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 appeared quickly which was read at 520 nm against a blank. The amount of reducing sugar was then determined by

referring to the glucose standard curve. 0.142 O.D. corresponded to 150 ug glucose.

3.3.7.3 Non-reducing sugars

The amount of non-reducing sugars was calculated as the difference between total soluble sugars and reducing sugars.

3.3.7.4 Starch

Starch from the sugar-free pellet obtained after centrifugation in 3.3.7 was estimated by the method of Clegg (1956).

Extraction

Added 5 ml water to the aforesaid residue of test material and while stirring added 6.5 ml of 52% perchloric acid. Stirred the contents continuously for five min and then occasionally for next 15 min. Added 20 ml water and centrifuged. Collected the supernatant in a 100 ml volumetric flask. Added 5 ml water to the residue and repeated the extraction with 52% perchloric acid stirring occasionally for next 30 min. Washed the contents of the tube into a volumetric flask containing the test extract and made it to 100 ml with distilled water. It was then filtered discarding first 5 ml of filtrate. A suitable aliquot (1.0 ml) of the extract was used for glucose estimation using anthrone reagent by the method of Yemm and Wills (1954) as described under 3.3.7.1. Starch was calcualted using the following formula:

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

3.3.8 Ascorbic acid

Ascorbic acid in fresh blended samples was determined by titration method of AOAC (1990).

Reagents

(i) Metaphosphoric acetic acid solution: Fifteen g of glacial metaphosphoric pellets were dissolved in 40 ml glacial acetic acid and 200 ml water and diluted to 500 ml. It was filtered rapidly through filter paper into a glass-stoppered bottle.

(ii) Ascorbic acid standard solution (1 mg ascorbic acid/ml): Fifty mg ascorbic acid reference standard (that had been stored in a desiccator away from direct sunlight) was weighed and transferred to 50 ml volumetric flask. It was diluted to volume immediately before use with metaphosphoric acetic acid solution.

(iii)Indophenol standard solution: Fifty mg of 2, 6 dichloroindophenol sodium salt (that had been dried in desiccator) was dissolved in 50 ml water, to which 42 mg sodium bicarbonate had been added. When the dye dissolved, it was diluted to 200 ml with water and was filtered through filter paper (Whatman # 1) into amber glass stoppered bottles. This was kept stoppered, away from direct sunlight in refrigerator.

Extraction

To five g sample 50 ml of metaphosphoric acetic acid solution was added. The sample was made to a fine pulp in

pestle and mortar until the suspension appeared. One and a half tea spoon full of activated charcoal was added, mixed well and filtered rapidly through Whatman Filter Paper #1.

Estimation

Three, two ml aliquots of ascorbic acid standard solution were taken in each of three 50 ml conical flasks containing five ml metaphosphoric acetic acid solution. These standard samples were titrated rapidly with indophenol solution from a microburette until light, but distinct, rose pink colour persisted at least for five seconds. Similarly, blank containing seven ml metaphosphoric acetic acid solution and distilled water equal to the reading of standard was titrated. For the sample, five ml metaphosphoric acetic solution was added to each of the two ml of sample aliquots and titrated with indophenol as for blank and standard. Ascorbic acid content in the food sample (mg/100 g) was calculated as follows:

$$\frac{Y-B}{X-B} \times \frac{V}{W} \times 100$$

Where

Y = Volume of dye solution used against sample aliquot

B = Volume of dye solution used against blank

X = Volume of dye solution used against standard

V = Volume of aliquot made.

W = Weight of the sample

3.4 Development of the Products from Ricebean and Fababean

Various domestic processing and cooking methods viz., soaking, dehulling, sprouting, fermentation, frying, baking,

etc., were employed for the development of products from ricebean and fababean. The products prepared from these pulses are as follows:

3.4.1 Boiled products

3.4.1.1 Dal

Four types of dals were prepared from greengram, ricebean and fababean. Greengram dal was used as control for organoleptic evaluation.

	Types of Dal			
	Control	Ricebean	Fababean	
Ingredients (g)	-	-	-	
Greengram whole	100	-	-	
Ricebean whole	-	100	-	
Fababean whole	-	-	100	
Fababean dehulled	-	-	-	100
Water used (ml)	350	400	400	350
Onions chopped	20	20	20	20
Hydrogenated oil	5	5	5	5
Salt	3	3	3	3
Red chilli powder	1	1	1	1
Turmeric powder	2	2	2	2

Method

1. Added dal, salt, turmeric powder and water in a pressure cooker.

2. Pressure cooked dals for 15 min, 20 min, 20 min and 10 min in case of greengram dal, ricebean, fababean whole and fababean dehulled dals, respectively.
3. Chopped the onions and fried the onions in ghee till light brown.
4. Added chilli powder to it
5. Added boiled dal to the above mxiture and cooked for another 3 min.

3.4.1.2 Khichari

Split dals were used for the preparation of khichari. Khichari prepared from greengram dal served as control for organoleptic evaluation. In all the types of khichari rice and dal were mixed in 2:1 (w/w) proportion.

	Types of Khichari		
Ingredients (g)	Control	Ricebean	Fababean
Greengram	25		
Ricebean	-	25	
Fababean	-	-	25
Rice	50	50	50
Hydrogenated oil	05	05	05
Salt	02	02	02
Turmeric powder	01	01	01
Cumin seeds	01	01	01
Red chilli powder	01	01	01
Water (ml)	400	400	400

Method

1. Heated the oil in a pressure cooker.
2. Added cumin seeds and fried till dark brown and added the salt and spices.
3. Added dal, rice and water to the above mixture.
4. Pressure cooked for 8-10 min.

3.4.1.3 Kadhi

Various types of kadhi were prepared by mixing chickpea flour and ricebean/fababean flour in different ratios. Type 1 kadhi prepared from chickpea flour served as the control for organoleptic evaluation. Dehulled dal flour was used in case of chickpea and fababean whereas whole dal flour in case of ricebean.

Standardization was done by incorporating ricebean or fababean flour with chickpea flour in different ratios, i.e., 50:50, 60:40, 70:30 (w/w).

	Control	Kadhi prepared from ricebean flour			Kadhi prepared from fababean flour		
Ingredients (g)	I	II	III	IV	V	VI	VII
Chickpea flour	50	25	20	15	25	20	15
Ricebean flour	-	25	30	35	-	-	-
Fababean flour	-	-	-	-	25	30	35
Butter milk (ml)	1000	1000	1000	1000	1000	1000	1000
Onion (chopped)	20	20	20	20	20	20	20
Salt	03	03	03	03	03	03	03
Red chilli powder	02	02	02	02	02	02	02
Turmeric powder	02	02	02	02	02	02	02
Hydrogenated oil	05	05	05	05	05	05	05

Method

1. Fried the chopped onions till golden brown.
2. Added the salt and spieces and added the mixture of chickpea, ricebean or fababean flour and butter milk.
3. Stirred the mixture well and cooked it on slow fire till the required consistency was obtained.

3.4.2 Fermented products

Three types of fermented products viz., dosa, idli and wadi were prepared. In all the products, dehulled dal was used for the preparation. Products prepared from blackgram dal served as control for organoleptic evaluation.

3.4.2.1 Dosa

Dosas were prepared by using dehulled cotyledons of blackgram dal, ricebean dal and fababean. Different types of dosas were standardized by incorporating blackgram dal with ricebean or fababean dal in different ratios viz., 50:50, 40:60 30:70 and 0:100. Overall the ratio of rice and dal used was 3:1 (w/w).

Ingredients (g)	Types of Dosa								
	Control	Dosa from ricebean				Dosa from fababean			
	I	II	III	IV	V	VI	VII	VIII	IX
Rice	300	300	300	300	300	300	300	300	300
Dehulled blackgram dal	100	50	40	30	-	50	40	30	-
Dehulled ricebean dal	-	50	60	70	100	-	-	-	-
Dehulled fababean dal	-	-	-	-	-	50	60	70	100
Salt	5	5	5	5	5	5	5	5	5

Method

1. Soaked rice and dal separately for overnight at room temperature.
2. Soaked water was discarded and ground the rice and dal separately in an electric blender.
3. Mixed the ground slurries of dal and rice, added salt and kept the mixture in an BOD incubator at 35°C for 12 h for fermentation.
4. Heated the tawa.
5. Poured one laddle full of fermented mixture on tawa and spreaded.
6. Roasted till done.

3.4.2.2 Idli

Standardization of the products was done by incorporating dehulled blackgram dal with dehulled ricebean or fababean dal in different proportions i.e., 50:50, 40:60, 30:70, 0:100. Rice and dal were mixed in 2:1 (w/w) ratio. Idli prepared from dehulled blackgram dal and rice served as the control for organoleptic evaluation.

	Control	Idli prepared from ricebean				Idli prepared from fababean			
Ingredients(g)	I	II	III	IV	V	VI	VII	VIII	IX
Rice	200	200	200	200	200	200	200	200	200
Dehulled blackgram dal	100	50	40	30	-	50	40	30	-
Dehulled ricebean dal	-	50	60	70	100	-	-	-	-
Dehulled fababean	-	-	-	-	-	50	60	70	100
Salt	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5

Method

1. Soaked rice and dal separately in water overnight at room temeprature.
2. Soaked water was discarded and ground the dal to a fine paste and rice little coarsely.
3. Mixed the ground slurries of rice and dal together, added salt and allowed to ferment at 35°C in an BOD incubator for 12 h.

3.4.2.3 Wadi

Three types of wadies were prepared from dehulled dals of blackgram, ricebean and fababean.

	Types of wadi		
Ingredients (g)	Control	Ricebean	Fababean
Dehulled blackgram dal	100	-	-
Dehulled ricebean dal	-	100	-
Dehulled fababean dal	-	-	100
Salt	2	2	2
Black pepper powder	0.65	0.65	0.65

Method

1. 100 g dal was soaked in 200 ml of water at room temperature overnight.
2. Soaked water was discarded and soaked dal were coarsely ground in an electric grinder.
3. The ground dal slurry was kept as such for fermentation in BOD incubator at 35°C for 12 h.
4. At the end of fermentation period, spices, i.e., salt and black pepper powder were added in the above mixture.

5. Small portions from the fermented slurry was taken and shaped into the form of wadi on polythene sheets.

6. Wadies were dried at 60°C for 36 h to a constant weight in the hot air over.

For organoleptic evaluation these wadies were deep fried and potato wadi curry was prepared. For chemical analysis dried wadies were ground in electric grinder and stored in air tight plastic container for further analysis.

3.4.3 Sprouted products

The steps involved in sprouting were:

Soaking: Greengram, ricebean and fababean (100 g) were soaked separately in water (200 ml) for 12 h at room temeprature. The unimbibed water was discarded and soaked seeds were used for germination.

Sprouting: Sprouting of soaked seeds were carried out on germiantion sheets at 35°C in an incubator for 24 h in case of greengram and ricebean and for 48 h in case of fababean as this pulse required a longer time for sprouting. At the end of sprouting period, ungerminated seeds were separated and seeds with uniform hypocotyl length were used for further product development. Fababean was dehulled after sprouting for further use. The sprouted dals were steamed for 10 min and then used in preparation of following products. The products prepared from sprouted greengram were used as control for organoleptic evaluation.

3.4.3.1 Sprouted dal chat

Ingredients (g)	Types of sprouted dal chat		
	Control	Ricebean	Fababean
Sprouted greengram	100	-	-
Sprouted ricebean	-	100	-
Sprouted fababean	-	-	100
Potatoes (boiled)	50	50	50
Salt	2	2	2
Red chilli powder	1	1	1
Mango powder	1.5	1.5	1.5

Method

1. Boiled potatoes were cut into small pieces.
2. The steamed sprouted dal and potatoes were slightly cooked on slow fire for 5 min.
3. Added salt, red chilli powder and mango powder.

3.4.3.2 Tikki

Ingredients (g)	Types of Tikki		
	Control	Ricebean	Fababean
Sprouted greengram	100	-	-
Sprouted ricebean	-	100	-
Sprouted fababean	-	-	100
Potatoes	200	200	200
Sago	25	25	25
Salt	3	3	3
Red chilli powder	2	2	2
Hydrogenated oils	15	15	15

Method

1. Boiled the potatoes, peeled and mashed them.
2. Ground the sprouted dal coarsely.

3. Soaked sago in warm water for 5 min and then strained.

4. Mixed all the above ingredients together.

5. Took small portion from this mixture and shaped it in form of tikki.

6. Heated the tawa and smeared oil on it.

7. Put the tikki on tawa and roasted till brown from both the sides.

3.4.3.3 Cutlet

Ingredients (g)	Types of cutlet		
	Control	Ricebean	Fababean
Sprouted greengram	50	-	-
Sprouted ricebean	-	50	-
Sprouted fababean	-	-	50
Boiled rice	50	50	50
Potato	100	100	100
Onions (chopped)	20	20	20
Salt	3	3	3
Red chilli powder	2	2	2
Hydrogenated oil	25	25	25

Method

1. The potatoes were boiled, peeled, mashed and mixed with the rest of all the ingredients properly.

2. The mixtures was made into the shape of cutlets.

3. Heated the oil in the skillet and deep fried till light brown colour.

3.4.3.4 Kofta

Ingredients (g)	Types of Kofta		
	Control	Ricebean	Fababean
Sprouted greengram	100	-	-
Sprouted ricebean	-	100	-
Sprouted fababean	-	-	100
Chickpea flour	100	100	100
Salt	4	4	4
Hydrogenated oil	20	20	20

Method

1. Mixed chickpea flour, sprouted dal and salt.
2. Made it into a thick batter by using small amount of water.
3. Took small portion of the butter and made it in form of kofta.
4. Fried the koftas till done.

For gravy

1. Fried chopped onions till golden brown, added chopped tomatoes, turmeric, red chilli powder and salt to it.
2. Added water and brought it to a boil.
3. Koftas were put in the gravy and cooked for another 5 min.

For organoleptic evaluation, kofta alongwith gravy were served while for chemical analysis, koftas without gravy were taken.

3.4.3.5 Kachori

Ingredients (g)	Types of Kachori		
	Control	Ricebean	Fababean
Sprouted green gram	50	-	-
Sprouted ricebean	-	50	-
Sprouted fababean	-	-	50
Refined wheat flour	100	100	100
Salt	3	3	3
Red chilli powder	2	2	2
Hydrogenated oil	25	25	25

Method

1. Sprouted dal was coarsely ground and roasted on slow fire.
2. All the spices and condiments were mixed in the dal.
3. Added little salt (2 g/100 g) and ghee (10 g/100 g) to the refined wheat flour and made into a thick dough using water.
4. Kneeded well.
5. Divided the dough in balls, stuffed with the dal mixture and rolled out as for poories.
6. Deep fried them till golden brown in colour.

3.4.4 Fried product

3.4.4.1 Shallow fried product

3.4.4.1.1 Nutritious parantha: For the preparation of paranthas wheat flour was supplemented with the flour of whole ricebean or dehulled fababean at different levels, i.e. 50:50, and 40:60 (w/w).

Ingredients (g)	Types of paranths						
	Control	Parantha prepared from ricebean			Parantha prepared from fababean		
	I	II	III	IV	V	VI	VII
Wheat flour	40	20	16	20	20	16	20
Ricebean flour	-	20	24	15	-	-	-
Fababean flour	-	-	-	-	20	24	15
Chickpea flour	-	-	-	05	-	-	05
Spinach (dried/ powder)	02	02	02	02	02	02	02
Salt	01	01	01	01	01	01	01
Hydrogenated oil	10	10	10	10	10	10	10

Method

1. Sieved wheat flour, pulse flour and spinach powder together.
2. Added salt and kneaded into a dough by using water.
3. Took small amount of dough and rolled out in form of chapaties.
4. Greased the hot tawa and cooked the parantha adding hydrogenated oil on both the sides of it.
5. When both the sides turned golden brown parantha was removed from fire.

3.4.4.1.2 Chilla

Seven types of chilla were prepared by incorporating whole ricebean or dehulled fababean flour with chickpea flour in three different ratio (50:50, 60:40, 70:30). For sensory analysis chickpea chilla served as control. Ricebean flour was made out to whole ricebean whereas for fababean flour dehulled fababean was used.

Ingredients (g)	Types of chilla						
	Control	Chilla prepared from ricebean			Chilla prepared from fababean		
	I	II	III	IV	V	VI	VII
Chickpea flour	100	50	40	30	50	40	30
Ricebean flour	-	50	60	70	-	-	-
Fababean flour	-	-	-	-	50	60	70
Onions	20	20	20	20	20	20	20
Salt	02	02	02	02	02	02	02
Red chilli powder	01	01	01	01	01	01	01
Hydrogenated oil	15	15	15	15	15	15	15

Method

1. All the ingredients were mixed well and made into a batter using water.
2. Greased hot tawa and poured little mixture on it.
3. Cooked the chilla by adding little ghee on the sides.
4. When both the sides turned golden brown removed from fire.

3.4.4.2 Deep fried products

3.4.4.2.1 Pakora

Whole ricebean flour and dehulled fababean flour were used in the preparation of pakora.

Ingredients (g)	Types of pakora						
	Control	Pakora prepared from ricebean			Pakora prepared from fababean		
	I	II	III	IV	V	VI	VII
Chickpea flour	100	50	40	30	50	40	30
Ricebean flour	-	50	60	70	-	-	-
Fababean flour	-	-	-	-	50	60	70
Onion (chopped)	100	100	100	100	100	100	100
Salt	04	04	04	04	04	04	04
Red chilli powder	02	02	02	02	02	02	02
Hydrogenated oil	25	25	25	25	25	25	25

Method

1. Added chopped onions, salt and red chilli powder to the dal flour and made batter of it by using water.
2. Heated the oil and fried the pakoras till brown colour.

3.4.4.2.2 Papad

Papad were prepared using dehulled blackgram dal, dehulled ricebean and dehulled fababean dal. Papad prepared from backgram dal served as control for organoleptic evaluation.

Ingredients (g)	Types of papad						
	Control	Papad prepared from ricebean			Papad prepared from fababean		
	I	II	III	IV	V	VI	VII
Dehulled blackgram dal	100	80	70	60	60	50	40
Dehulled ricebean	-	20	30	40	-	-	-
Dehulled fababean	-	-	-	-	40	50	60
Salt	03	03	03	03	03	03	03
Black pepper	02	02	02	02	02	02	02
Onion seeds	03	03	03	03	03	03	03
Hydrogenated oil	05	05	05	05	05	05	05

Method

1. Spices and condiments were added to the mixtures of blackgram dal and ricebean/fababean dal.

2. Mixture was kneaded to make a hard dough using little amount of water.
3. The dough was ground for 20 min.
4. Took small portion of dough and rolled in form of chapati.
5. Then these were sun dried.
6. The dried papad's were deep fried in oil for 30 seconds.

3.4.5 Baked product

3.4.5.1 Cake

Dehulled dal flour was used for the preparation of cake.

Ingredients (g)	Types of cake						
	Control	Cake prepared from ricebean			Cake prepared from fababean		
	I	II	III	IV	V	VI	VII
Refined wheat flour	110	66	55	44	66	55	44
Ricebean flour	-	44	55	66	-	-	-
Fababean flour	-	-	-	-	44	55	66
Egg (nos)	4	4	4	4	4	4	4
Sugar	120	120	120	120	120	120	120
Hydrogenated oil	50	50	50	50	50	50	50
Baking powder (tsp)	3/4	3/4	3/4	3/4	3/4	3/4	3/4

Method

1. Sugar and eggs were creamed together till the mixture become fluffy and more than twice its volume.
2. Baking powder was added to the mixture of pulse and refined wheat flour and sieved.
3. Sieved flour was added to the greased mixture hydrogenated oil was added and mixed well.
4. The mixture was poured in a baking container and baked in an oven at 160°C for 15 min.

3.4.6 Roasted product

3.4.6.1 Roasted dal

Method

1. Fababean seeds were soaked in water for 4 h.
2. Soaked water was discarded and the seeds were sun dried.
3. Dried seeds were roasted in sand in an iron pan at about 250°C for approximately 2 min.
4. Then they were dehulled.

All the products were prepared in triplicate.

3.5 Organoleptic Evaluation

All the products prepared under 3 were tested organoleptically by a panel of ten judges selected from the Department of Foods and Nutrition, CCS Haryana Agricultural University using 9-point hedonic rating scale (Appendix-I).

3.6 Nutritional Analysis of the Products Prepared from ricebean fababean

The most acceptable products were analysed for the following parameters:

3.6.1 Proximate analysis

As per method given in 3.3.1,

3.6.2 *In vitro* digestibilities

As per method given in 3.3.2.

3.6.3 Anti-nutritional factors

As per method given in 3.3.3.

3.6.4 Mineral composition

As per method given in 3.3.4.

3.6.5 *In vitro* iron availability

As per method given in 3.3.5.

3.6.6 *In vitro* calcium availability

As per method given in 3.3.6.

3.7 Statistical Analysis

The obtained data were subjected to statistical analysis for working out the analysis of variance and finding out some correlations among different parameters (Panse and Sukhatme, 1961).

CHAPTER - 4

RESULTS AND DISCUSSION

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

4.1 Physico-chemical properties
4.2 Effect of domestic processing and cooking
4.2.1 Proximate composition
4.2.1.1 Protein, fat and ash
4.2.1.2 Dietary fibre
4.2.2 Carbohydrates
4.2.3 *In vitro* digestibilities
4.2.3.1 Starch digestibility
4.2.3.2 Protein digestibility
4.2.4 Antinutritional factors
4.2.4.1 Phytic acid
4.2.4.2 Polyphenols
4.2.4.3 Saponins
4.2.4.4 Trypsin inhibitor activity
4.2.5 Minerals
4.2.5.1 Total minerals
4.2.5.2 HCl extractable minerals
4.2.6 *In vitro* availability of calcium and iron
4.3 Sensory evaluation of products prepared from ricebean
4.4 Sensory evaluation of products prepared from fababean

4.5 Nutritive value of products
4.5.1 Proximate composition
4.5.1.1 Protein, fat and ash
4.5.1.2 Dietary fibre constituents
4.5.2 *In vitro* digestibilities
4.5.2.1 Starch digestibility
4.5.2.2 Protein digestibility
4.5.3 Antinutritional factors
4.5.3.1 Phytic acid
4.5.3.2 Polyphenols
4.5.3.3 Saponins
4.5.3.4 Trypsin inhibitor activity
4.5.4 Minerals
4.5.4.1 Total minerals
4.5.4.2 HCl-extractable
4.5.5 *In vitro* availability of calcium and iron
4.5.6 Ascorbic acid

4.1 Physico-Chemical Properties

Physico-chemical properties such as density, hydration capacity, hydration index, swelling capacity, swelling index and cooking time of ricebean and fababean are given in table 1.

Density of ricebean was 0.98 g/ml whereas that of fababean was 0.85 g/ml. Hydration capacity per seed was 0.19 and 0.13 g for ricebean and fababean, respectively. Hydration index, swelling capacity as well as swelling index of ricebean were more as compared to those of fababean.

Cooking time is of paramount importance as most of legumes require a long period for cooking. Fababean required longer cooking time (108 min) than ricebean (87 min). As ricebean had more hydration capacity and swelling capacity so

Table 1. Physico-chemical properties of ricebean and fababean (on dry matter basis)

Physico-chemical properties	Ricebean	Fababean	't' value
Density (g/ml)	0.98±0.02	0.85±0.01	4.73*
Hydration capacity (g/seed)	0.19±0.03	0.13±0.04	5.18*
Hydration index	0.86±0.01	0.53±0.07	6.24*
Swelling capacity (ml/seed)	0.32±0.02	0.20±0.03	3.79*
Swelling index	0.72±0.02	0.61±0.02	4.24*
Cooking time (min)	87±0.05	108±0.09	6.92*

Values are mean ± SD of three independent determinations.

*Significant at 5 % level.

it required less cooking time also because swelling capacity per seed is negatively correlated to cooking time. The results of the present study are consistent with those mentioned by previous workers for fababean (Sharma, 1989) and peas (Bishnoi and Kheterparul, 1993a). They also reported a significant negative correlation between the swelling capacity and cooking time of legumes.

4.2 Effect of Domestic Processing and Cooking

4.2.1 Proximate composition

4.2.1.1 Crude protein, true protein, NPN, fat and ash

Crude protein and true protein contents of whole seeds of ricebean were 18.2 and 18.0 g/100 g, respectively (Table 2). Soaking (12 h) and sprouting (24 h) did not significantly alter the contents of crude protein, true protein and NPN of ricebean. Husk of ricebean had significantly ($P<0.05$) lower crude and true protein contents as compared to raw and processed seeds. Similarly, no effect of soaking and sprouting was observed on fat and ash contents of ricebean (Table 2). Fat and ash contents of husk did not differ significantly from those of raw and processed seeds.

Whole seed of fababean contained crude protein and true protein as 25.5 and 24.7 g/100 g, respectively (Table 3). Soaking and sprouting treatments showed no effect on crude protein, true protein and NPN. Dehulled fababean had relatively more amount of crude protein and true protein (Table 3). Non-significant differences were observed in the protein content of

Table 2. Crude protien, true protein, non-protein nitrogen, fat and ash contents of soaked and sprouted ricebean (on dry matter basis)

Treatments	Crude protein (g/100 g)	True protein (g/100 g)	Non-protein nitrogen (mg/100 g)	Fat (g/100 g)	Ash (g/100 g)
Raw legume (Control)	18.2±0.2	18.0±0.2	31.7±3.1	0.83±0.2	5.0±0.2
Husk	10.5±0.4	10.1±0.1	53.3±12.0	1.33±0.2	5.2±0.4
Soaked (12 h)	18.0±0.1	17.7±0.1	35.0± 7.6	0.83±0.1	4.8±0.3
Sprouted (24 h)	18.8±0.2	18.2±0.2	30.0±6.8	0.83±0.2	4.8±0.3
SE(m)	±0.51	±0.23	±11.37	±0.23	±0.46
CD (P<0.05)	1.06	0.48	23.72	0.53	1.06

Values are means ± SD of three independent determinations

Table 3. Crude protein, true protein, non-protein nitrogen, fat and ash contents of soaked, sprouted and dehulled fababean (on dry matter basis)

Treatments	Crude protein (g/100 g)	True protein (g/100 g)	Non-protein nitrogen (mg/100 g)	Fat (g/100 g)	Ash (g/100 g)
Raw legume (Control)	25.5±0.3	24.7±0.1	91.7±8.7	2.7±0.2	5.1±0.2
Husk	13.0±0.6	12.2±0.4	91.6±7.0	3.2±0.2	5.5±0.3
Dehulled	27.1±0.6	26.5±0.5	45.0±6.8	3.0±0.3	4.2±0.2
Soaked (12 h)	25.5±0.3	24.8±0.1	83.3±11.1	2.8±0.2	5.1±0.2
Sprouted (48 h)	25.9±0.6	25.5±0.2	48.3±10.9	2.8±0.2	4.8±0.2
SE(m)	±0.72	±0.60	±13.40	0.43	0.39
CD ($P<0.05$)	1.48	1.24	27.60	0.98	0.89

Values are means ± SD of three independent determinations.

sprouted and dehulled seeds. A significant decrease was observed in NPN content of dehulled seeds as compared to that of raw pulse. Husk had significantly ($P<0.05$) lower amount of crude protein (13.0%) and true protein (12.2%). As husk contains less amount of protein than the cotyledons, its removal might have accounted for higher value for crude protein and true protein in dehulled than the raw fababeans.

Fat and ash contents of whole seed of fababean were 2.7 and 5.1 g/100 g, respectively. Soaking, sprouting and dehulling did not significantly change the fat and ash contents of fababean. The value for crude protein, fat and ash are within the range reported earlier for ricebean (Kaur, 1986; Bhatnagar, 1986; Malhotra et al., 1988) and fababean (Sammour, 1987; Malhotra et al., 1988) and fababean (Sammour, 1987; Sharma and Sehgal, 1991b). Youssef et al. (1987) observed non-significant differences in crude protein, true protein, fat and ash content of whole seed, soaked and sprouted fababean.

4.2.1.2 Dietary fibre

The results pertaining to dietary fibre constituents of raw and processed ricebean and fababean have been presented in tables 4 and 5. Ricebean husk contained significantly ($P<0.05$) higher levels of NDF and ADF as compared to unprocessed control. NDF and ADF contents of whole seed of ricebean was 13.0 and 8.5 g/100 g, respectively. Soaking and sprouting did not significantly affect the various dietary fibre constituents.

Table 4. Effect of soaking and sprouting on dietary fibre constituents of ricebean (g/100 g, on dry matter basis)

Treatments	NDF	ADF	Hemicellulose	Cellulose	Lignin	Pectin
Raw legume (Control)	13.0±0.6	8.5±0.6	4.5±0.6	7.4±0.2	3.0±0.1	1.9±0.02
Husk	53.5±1.5	47.2±0.5	6.2±1.8	4.5±0.2	2.2±0.1	2.6±0.05
Soaked (12 h)	12.4±1.2	8.2±0.3	4.1±1.5	7.3±0.1	3.3±0.1	1.8±0.01
Sprouted (24 h)	12.8±0.6	8.3±0.3	4.5±0.8	7.3±0.2	5.1±0.1	1.8±0.09
SE(m)	±1.49	±0.63	±1.81	±0.27	±0.15	±0.10
CD ($P<0.05$)	3.43	1.45	4.17	0.62	0.34	0.24

Values are means ± SD of three independent determinations.

The NDF and ADF contents of raw whole, soaked and sprouted fababeans were 15.4 and 9.6, 14.6 and 9.5 and 14.5 and 9.5 g/100 g, respectively (Table 5). Fababean husk contained significantly higher levels of NDF and ADF and hence, removal of husk caused a significant reduction ($P<0.05$) in the contents of NDF and ADF in the dehulled fababeans than the raw whole seed. Dehulled fababeans contained significantly ($P<0.05$) lower amounts of cellulose and lignin too when compared to raw unprocessed seed (Table 5). Soaking and sprouting did not have any significant role in altering the levels of NDF and ADF in fababeans.

ADF and NDF contents of legumes are known to mainly exist in the seed coat (Prema Kumari et al., 1984; Singh, 1986) and, therefore, removal of seed coat may be responsible for significant reduction in the ADF and NDF contents of legume grains (Singh et al., 1988). Beal et al. (1984) reported that sprouting resulted in an increased NDF and ADF contents of peas whereas Kakkar (1992) found non-significant differences in NDF and ADF contents of soaked and sprouted chickpeas.

4.2.2 Carbohydrates

Ricebean and fababean were analysed for different carbohydrate constituents and their carbohydrate profile differed significantly (Table 6). Total soluble and non-reducing sugar contents of ricebean and fababean were 5.6 and 5.0; 4.9 and 4.3 g/100 g, respectively. Ricebean contained significantly ($P<0.05$) higher amounts of total soluble and non-

Table 5. Effect of dehulling, soaking and sprouting on dietary fibre constituents of fababean (g/100 g, on dry matter basis)

Treatments	NDF	ADF	Hemicellulose	Cellulose	Lignin	Pectin
Raw legume (Control)	15.4±1.0	9.6±0.7	5.8±1.7	8.2±0.1	3.5±0.3	2.0±0.07
Husk	60.7±1.4	54.2±0.9	6.4±1.9	50.4±0.5	3.2±0.2	2.8±0.01
Dehulled	7.8±1.0	2.1±0.1	5.7±1.1	1.9±0.2	0.1±0.01	1.8±0.01
Soaked (12 h)	14.6±0.4	9.5±0.2	5.1±0.2	8.2±0.2	3.3±0.2	1.9±0.09
Sprouted (48 h)	14.5±0.5	9.5±0.2	5.0±0.4	8.1±0.3	3.0±0.3	2.0±0.02
SE(m)	±1.41	±0.99	±1.97	±0.60	±0.39	±0.09
CD ($P<0.05$)	3.21	2.26	4.49	1.37	0.89	0.20

Values are means ± SD of three independent determinations.

Table 6. Total soluble sugar, reducing sugars, non-reducing sugars and starch content of raw ricebean and fababean (on dry matter basis)

Carbohydrate constituents	Ricebean	Fababean	't' value
Total soluble sugar (g/100 g)	5.6±0.2	4.9±0.2	5.79*
Reducing sugars (mg/100 g)	547.3±7.7	608.7±5.6	4.10*
Non-reducing sugars (g/100 g)	5.0±0.2	4.3±0.2	6.56*
Starch (g/100 g)	50.7±1.5	53.2±0.7	3.40*

Values are means ± SD of three independent determinations.

*Significant at 5 % level.

reducing sugars and less amount of reducing sugars and starch when compared to fababean. Similar findings have been reported for ricebean (Kaur, 1986), pigeonpea (Duhan, 1992) and peas (Bishnoi and Khetarpaul, 1993b).

4.2.3 In vitro digestibility

4.2.3.1 Starch digestibility (in vitro)

Starch digestibility (in vitro) of whole seed of ricebean was 30.8 mg maltose released/g meal (Table 7). On soaking the seeds for 12 h, starch digestibility increased to the extent of 38 per cent over the control value. Sprouting for 24 h further brought an increase in starch digestibility, i.e., from 30.8 to 61.3 mg maltose released/g meal. The starch digestibility of husk was significantly ($P<0.05$) less than the raw or processed legume (Table 7).

In case of fababean, the starch digestibility (in vitro) was 42.1 mg maltose released/g meal (Table 8). soaking and sprouting significantly ($P<0.05$) improved the starch digestibility by 37 and 90 per cent, respectively over the control values. The increase after soaking has also been observed by Kaur (1986) in ricebean and Sharma and Sehgal (1991a) in fababean. The increase digestibility during soaking may be attributed to the loss of antinutrients (Table 9 and 10) which inhibit the activity of α-amylase and phophorlases (Deshpande and Cheryan, 1983). Increased starch digestibility after germination is expected because of the predigestion of starch molecules by amylolytic enzymes. Amylase and phosphorylases may become active during germination, and hence, catalyse during

Table 7. Effect of soaking and sprouting on *in vitro* protein digestibility and starch digestibility of ricebean (on dry matter basis)

Treatments	Protein digestibility (%)	Starch digestibility (mg maltose released/ g meal)
Raw legume (Control)	58.4±0.9	30.8±0.4
Husk	18.7±1.1	6.3±0.4
Soaked (12 h)	70.1±1.3 (20)	42.4±1.2 (38)
Sprouted (24 h)	76.6±1.4 (31)	61.3±1.3 (100)
SE(m)	±1.71	±1.35
CD (P<0.05)	3.57	2.82

Values are means ± SD of three independent determinations.

Figures in parentheses indicate per cent increase over control values.

Table 8. Effect of dehulling, soaking and sprouting on *in vitro* protein digestibility and starch digestibility of fababean (on dry matter basis)

Treatments	Protein digestibility (%)	Starch digestibility (mg maltose released/ g meal)
Raw legume (Control)	53.3±0.7	42.1±0.3
Husk	12.9±0.4	6.3±0.3
Dehulled	58.0±0.9 (9)	47.7±0.4 (13)
Soaked (12 h)	65.3±0.8 (23)	57.8±0.4 (37)
Sprouted (48 h)	72.0±0.8 (35)	80.1±0.5 (90)
SE(m)	±1.04	±0.56
CD ($P<0.05$)	2.14	1.15

Values are means ± SD of three independent determinations.

Figures in parentheses indicate per cent increase over control values.

germination. The resulting enhanced concentration of oligosaccharides in the sprouts may attribute to better starch digestibility (Jaya and Venkataraman, 1980; Nnanna and Philips, 1990).

Dehulling of fababean seeds significantly ($P<0.05$) increased the starch digestibility; 13 per cent enhancement in starch digestibility over the control value was observed in dehulled fababean. Dehulling may improve the starch digestibility possibly due to reduction in level of antinutritional factors like polyphenols and phytic acid as found in this study also (Table 10). These antinutrients are known to inhibit α-amylase activity (Deshpande and Cheryan, 1983).

4.2.3.2 Protein digestibility (in vitro)

Protein digestibility was found to be 58.4 per cent in whole ricebean seeds (Table 7). A significant ($P<0.05$) enhancement in protein digestibility occurred when the ricebean seeds were soaked in water for 12 h. Germination for 24 h further increased the protein digestibility, i.e., by 31 per cent over the control value. The protein digestibility of husk was only 18.7 per cent.

Upon dehulling, soaking and germination, the protein digestibility of fababean improved from 53.3 to 58.0, 65.3 to 72.0 per cent, respectively (Table 8). The protein digestibility of husk was only 12.9 per cent.

Improvement in protein digestibility as a result of dehulling and soaking may be attributed to loss or leaching out of phytate, polyphenols, saponins, trypsin inhibitor as observed in this study (Table 9 and 10) and noticed by previous

workers (Kataria et al., 1989b; Kaur and Kapoor, 1990b). Soaking of legumes may also initiate activation of certain enzymes resulting in mobilization of proteins, carbohydrates and fats (Khokhar, 1984).

Increased protein digestibility upon germination may be because of decline in antinutritional factors like tannins and phytate (Kaur and Kapoor, 1990b; Sharma and Sehgal, 1991a), modification and degradation of storage proteins (Kataria et al., 1989b), due to action of hydrolytic enzymes (Hamza, 1983). Sprouting causes immobilization of proteins with the help of proteases leading to formation of polypeptides, oligopeptides and free amino acids (Youssef et al., 1986) and hence, leading to improvement in protein digestibility.

4.2.4 Antinutritional factors

4.2.4.1 Phytic acid

Phytic acid is known to be the major storage form of phosphorus in legumes. Whole seed of ricebean contained 2018.2 mg/100 g of phytic acid (Table 9). Soaking and sprouting contributed significantly ($P<0.05$) towards lowering down of phytic acid content in ricebean (Table 9). Soaking for 12 h brought 26 per cent reduction in the level of phytic acid and sprouting further decreased its level to 30 per cent over the control value. Husk of ricebean contained significantly ($P<0.05$) higher amount of phytic acid than control.

The phytic acid content of whole seed of fababean was 1012.7 mg/100 g. Processing methods viz., soaking, sprouting and dehulling of whole seed contributed significantly ($P<0.05$)

Table 9. Effect of soaking and sprouting on the contents of phytic acid, polyphenols, saponins and trypsin inhibitor activity of ricebean (on dry matter basis)

Treatments	Phytic acid (mg/100 g)	Polyphenols (mg/100 g)	Saponins (mg/100 g)	Trypsin inhibitor activity (T IU/g)[a]
Raw legume (Control)	2018.2±5.9	1698.9±6.1	2168.6±8.4	55.2±1.9
Husk	2150.9±14.7	2193.3±4.3	2327.3±5.1	21.9±1.4
Soaked (12 h)	1494.8±2.0 (26)	1168.1±7.4 (31)	1964.3±6.9 (9)	45.8±2.1 (17)
Sprouted (24 h)	1404.0±3.4 (30)	870.6±3.7 (49)	1827.4±9.1 (16)	15.6±1.4 (72)
SE(m)	±11.56	±7.91	±10.63	±2.43
CD (P<0.05)	24.11	16.50	22.17	5.07

Values are mean ± SD of three independent determinations.

[a] 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 minutes at pH 7.6.

Figures in parentheses indicate per cent decrease over control values.

towards reduction in phytic acid content of fababean (Table 10). Phytic acid content was reduced from 1012.7 to 855.8 and 438.7 mg/100 g, after soaking and sprouting, respectively. As the period of sprouting was longer in case of fababean than that of ricebean so more loss of phytic acid, i.e., 57 per cent over the control values occurred upon sprouting. Husk of fababean contained relatively higher concentration of phytic acid as compared to whole grain and, therefore, removal of husk accounted for significantly lower phytic acid content in dehulled grains (Table 10).

The loss of phytic acid in the soaked ricebean and fababean seeds may be because of leaching out 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 soaked legumes have been reported earlier in ricebean (Kaur and Kapoor, 1990a), fababean (Sharma and Sehgal, 1992b) and peas (Bishnoi et al., 1994).

Loss of phytic acid during germination may be due to hydrolytic activity of phytase reported to be present in various plant foods (Lolas and Markakis, 1975; Michael-Eskein and Weibe, 1983). Germination has been reported earlier by different workers to have a diminishing effect on the phytic acid content of various legumes including cowpeas, soybean and limabean (Ologhobo and Fetuga, 1984; Grewal, 1992). Chickpea and blackgram (Duhan et al., 1989; Kakkar, 1992), ricebean

Table 10. Effect of dehulling, soaking and sprouting on the contents of phytic acid polyphenols, saponins and trypsin inhibitor activity of fababean (on dry matter basis)

Treatments	Phytic acid (mg/100 g)	Polyphenols (mg/100 g)	Saponins (mg/100 g)	Trypsin inhibtor activity (TIU/g)[a]
Raw legume (Control)	1012.7±3.4	750.8±6.2	1313.5±9.0	905.2±5.2
Husk	1074.4±5.9	1303.7±5.0	1347.2±8.6	527.1±5.3
Dehulled	879.8±1.7 (13)	312.1±3.6 (58)	1132.9±8.9 (14)	830.2±3.7 (8)
Soaked (12 h)	855.8±1.8 (16)	505.7±1.9 (33)	1150.8±5.8 (12)	851.1±10.1 (6)
Sprouted (48 h)	438.7±1.6 (57)	256.4±1.5 (66)	708.3±6.3 (46)	278.1±2.7 (69)
SE(m)	±4.71	±5.78	±9.29	±8.46
CD (P<0.05)	9.70	11.91	19.14	17.43

Values are means ± SD of three independent determinations.

[a] 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 minutes at pH 7.6

Figures in parentheses indicate per cent decrease over control values.

(Kaur and Kapoor, 1990a), fababean (Sharma and Sehgal, 1992b) and peas (Bishnoi et al., 1994).

4.2.4.2 Polyphenols

The raw unprocessed whole seeds of ricebean contained 1698.9 mg/100 g of polyphenols. Soaked and sprouted ricebean seeds had significantly lower amount of polyphenols than the raw whole seeds (Table 9). Polyphenols were reduced to the extent of 31 and 49 per cent over the control values in soaked and sprouted ricebean seeds, respectively. Husk had significantly ($P<0.05$) higher amount (2193.3 mg/100 g) of polyphenols.

Fababean also contained considerable amount of polyphenols i.e., 750.8 mg/100 g, less than that of ricebean (Table 10). Polyphenols were noticed to be concentrated mainly in the husk of fababean and removal of testa significantly ($P<0.05$) reduced the polyphenol content of dehulled grain (312.1 mg/100 g). Soaking (12 h) of fababean resulted in a significant reduction in polyphenolic content. Sprouts had significantly lower level of polyphenols; sprouts contained about one-third of the amount of polyphenols present in the whole raw seeds.

As polyphenols are present in the periphery of the seed, hence there is 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 polyphenols so dehulling results in loss of polyphenols. Before germination, soaking is also done and some loss of polyphenol during soaking is also expected becuase of

its leaching into the soaking water. Further decrease in polyphenols 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 mothbean (Khokhar and Chauhan, 1986a), ricebean (Kaur and Kapoor, 1990a), fababean (Sharma and Sehgal, 1992a) and peas (Bishnoi et al., 1994).

4.2.4.3 Saponins

Saponin content of ricebean was 2168.6 mg/100 g whereas that of husk alone was 2327.3 mg/100 g (Table 9). After soaking and sprouting of ricebean seeds, saponins reduced significantly ($P<0.05$). After 12 h soaking, ricebean contained saponins which was less by 9 per cent over the control value. Further significant ($P<0.05$) loss in the content of saponins was brought about by sprouting of ricebean.

Whole seed and husk of fababean contained 1313.5 and 1347.2 mg/100 g of saponin. Dehulling, soaking and sprouting caused a significant ($P<0.05$) reduction in saponin content of fababean seeds; the maximum loss being observed in sprouted followed by dehulled and soaked seeds in descending order (Table 10).

The losses observed during soaking may be attributed to the leaching out fo these organic compounds into soaking water. The reduction in saponin level during germination may be due to enzymatic degradation (Khokhar and Chauhan, 1986a; Kataria et al., 1989b). Soaking and germination have been reported to

decrease saponin in various legumes grains (Jood et al., 1986; Kataria et al., 1989b; Kaur and Kapoor, 1990a; Sharma and Sehgal, 1992b; Bishnoi and Khetarpaul, 1994a).

4.2.4.4 Trypsin inhibitor activity

Trypsin inhibitors present in considerable amount in legumes, are knwon to affect the digestibility of protein. Ricebean seeds had less TIA (55.2 TIU/g). Soaking (12 h) reduced the TIA by 17 per cent over the control value. Maximum loss in TIA was noticed in sprouted ricebean seeds. Husk had significantly ($P<0.05$) lower TIA than the unprocessed raw ricebean.

The whole seeds of fababean contained significantly ($P<0.05$) higher amount of TIA i.e., 905.2 TIU/g than ricebean. Soaking and dehulling of fababean reduced the TIA by 6 and 8 per cent, respectively. Sprouting brought maximum decline in TIA. After 48 h sprouting, TIA was reduced to less than one-third of its amount as found in the raw whole seeds. Husk contained significantly low level of TIA than the raw unprocessed seeds. Dehulled fababean had considerably lower amount of TIA than the raw and soaked seeds.

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 inhibitor are low molecular weight protein and hence, they are likely to pass out from the seed to the soaking medium easily. Earlier workers (Deshpande and Cheryan, 1985; Sharma and Sehgal, 1992a;

Bishnoi and Khetarpaul, 1994a) also reported that soaking of dry legumes in water reduced the trypsin inhibitor activity.

A decrease in trypsin inhibitor activity during germination may perhaps be due to the mobilization and breakdown of chemical constituents including trypsin inhibitor. Similar findings have been reported in various legumes including chickpea (Bansal, 1988), ricebean (Verma and Mehta, 1988), fababean (Sharma and Sehgal, 1992a) and blackgram (Chaudhary, 1993).

4.2.5 Minerals

4.2.5.1 Total minerals

Total calcium, iron and phosphorus contents of ricebean were 311.7, 6.6 and 257.1 mg/100 g, respectively (Table 11). Upon soaking, total calcium and iron contents were reduced significantly ($P<0.05$). Sprouted ricebean had significantly less amount of total Ca and Fe than raw whole seeds whereas non-significant differences existed in the total calcium, iron and phosphorus contents of soaked and sprouted seeds. Hence, reduction in total Ca and Fe content in sprouted ricebean was due to soaking and not because of germination.

Whole seed of fababean contained 201.2, 5.2 and 245.8 mg/100 g of Ca, Fe and P, respectively. Upon soaking, total calcium and iron contents were significantly reduced to 182.7 and 4.5 mg/100 g, respectively. Sprouted fababean seeds had lower amount of total Ca and Fe as compared to those in raw seeds. Non-significant differences were noticed in the total Ca, Fe and P content of soaked and sprouted samples. As husk of

Table 11. Effect of soaking and sprouting on total calcium, iron and phosphorus contents of ricebean (mg/100 g, on dry matter basis)

Treatments	Calcium	Iron	Phosphorus
Raw legume (Control)	311.7±1.2	6.6±0.06	257.1±0.9
Husk	319.8±2.8	7.0±0.01	260.3±0.8
Soaked (12 h)	303.0±1.1	6.4±0.03	255.0±0.6
Sprouted (24 h)	299.2±2.3	6.4±0.04	255.8±0.9
SE(m)	±3.53	±0.06	±1.17
CD ($P<0.05$)	7.36	0.14	2.44

Values are means ± SD of three independent determinations.

fababean contained significantly higher levels of these minerals (Table 12) so dehulling of fababean brought, significant ($P<0.05$) reduction in total calcium and iron contents.

The loss in mineral contents upon soaking may be attributed to leaching out of these minerals into the soaking water (Kumar et al., 1978). Actually germination itself did not contribute to loss of minerals. Reduction in the total mineral content in the sprouted seeds may be due to leaching out of these minerals in soaking medium which was done for 12 h prior to sprouting. Minerals present in the hulls might have been lost during dehulling, hence, a contributing factors towards less total mineral content in dehulled fababean seeds.

4.2.5.2 HCl-extractable

The HCl-extractability of calcium, iron and phosphorus was 70.2, 78.0 and 33.4 per cent, respectively in unprocessed ricebean seeds (Table 13). Soaking the seeds for 12 h enhanced the HCl-extractability of Ca, Fe and P by 4, 8 and 13 per cent, respectively over the control values. Significant improvements in HCl-extractability of all minerals were observed after sprouting the seeds for 24 h. In ricebean seeds, maximum enhancement was noticed in HCl-extractability of phosphorus followed by iron and calcium. The HCl-extractability of minerals present in husk was significantly ($P<0.05$) lower than that of the raw whole seeds.

Table 12. Effect of dehulling, soaking and sprouting on total calcium, iron and phosphorus contents of fababean (mg/100 g, on dry matter basis)

Treatments	Calcium	Iron	Phosophorus
Raw legume (Control)	201.2±2.4	5.2±0.04	245.8±1.0
Husk	216.7±2.3	5.8±0.06	251.6±1.5
Dehulled	179.3±1.2	4.6±0.01	244.7±0.9
Soaked (12 h)	182.7±1.1	4.5±0.03	244.3±1.1
Sprouted (48 h)	186.2±1.1	4.5±0.02	244.3±0.8
SE(m)	±2.48	±0.06	±1.55
CD ($P<0.05$)	5.11	0.14	3.19

Values are means ± SD of three independent determinations.

Table 13. Effect of soaking and sprouting on HCl-extractability of calcium, iron and phosphorus contents of ricebean (%, on dry matter basis)

Treatments	Calcium	Iron	Phosphorus
Raw legume (Control)	70.2±0.3	78.0±1.1	33.4±0.3
Husk	34.5±0.3	69.9±1.0	16.8±0.6
Soaked (12 h)	72.7±0.4 (4)	84.0±0.7 (8)	37.7±0.2 (13)
Sprouted (24 h)	76.1±0.3 (8)	88.3±0.7 (10)	38.8±0.2 (16)
SE(m)	±0.44	±1.29	±0.51
CD (P<0.05)	0.92	3.00	1.06

Values are means ± SD of three independent determinations.

Figures in parentheses indicate per cent over control values.

Unprocessed fababean seeds had the highest HCl extractability of iron (71.2%) followed by that of calcium (55.2%) and phosphorus (35.1%). Processing methods viz., soaking, dehulling and germination improved the extractability of Ca, Fe and P to varying extents (Table 14). Sprouting was found to be the best among different processing methods for enhancing the extractability of Ca, Fe and P. Husk had significantly ($P<0.05$) lower extractability of Ca, Fe and P than the unprocessed and processed fababean seeds.

As the divalent cations are generally present in association with phytic acid in processed legumes and, therefore, may be responsible for lower extractability of these divalent cations in ricebean and fababean. Decrease in the level of phytic acid during soaking, dehulling and sprouting (Tables 9 and 10) may partly account for improved extractability of these minerals. A significant negative correlation between the antinutrients, viz., phytic acid, polyphenols, saponin and trypsin inhibitor and extractability of minerals further strengthens our findings (Tables1 89 to 94). Present findings are in line with those reported by previous workers (Kaur, 1986; Grewal, 1992; Chaudhary, 1993; Bishnoi and Khetarpaul, 1994c).

4.2.6 *In vitro* availability of calcium and iron

The availability (*in vitro*) of Ca and Fe was increased from 59.8 and 37.9 to 62.1 and 39.3 per cent, respectively in soaked ricebean seeds (Table 15). Sprouting for 24 h further improved the availability of those minerals from ricebean

Table 14. Effect of dehulling, soaking and sprouting on HCl-extractability of calcium, iron and phosphorus contents of fababean (%, on dry matter basis)

Treatments	Calcium	Iron	Phosphorus
Raw legume (Control)	55.2±0.6	71.2±0.8	35.1±0.2
Husk	32.5±0.5	56.9±1.0	14.0±0.7
Dehulled	58.0±0.9 (5)	77.8±1.1 (9)	39.2±0.2 (12)
Soaked (12 h)	59.3±0.6 (7)	74.4±1.0 (5)	38.6±0.2 (10)
Sprouted (48 h)	64.9±0.5 (18)	78.0±1.0 (10)	39.6±0.2 (13)
SE(m)	±0.91	±1.30	±0.52
CD (P<0.05)	1.87	2.96	1.07

Values are means ± SD of three independent determinations

Figures in parentheses indicate per cent increase over control values

Table 15. Effect of soaking and sprouting on *in vitro* calcium and iron availability of ricebean (%, on dry matter basis)

Treatments	Calcium	Iron
Raw legume (Control)	59.8±0.3	37.9±0.2
Husk	25.9±0.2	18.8±0.6
Soaked (12 h)	62.1±0.3 (4)	39.3±0.4 (4)
Sprouted (24 h)	67.5±0.3 (13)	41.5±0.3 (10)
SE(m)	±0.38	±0.58
CD ($P<0.05$)	0.79	1.34

Values are means ± SD of three independent determinations

Figures in parentheses indicate per cent increase over control values

Calcium and iron availability from husk were almost half of that in the whole ricebean seeds.

The availability of calcium and iron from whole fababean was 45.1 and 34.1 per cent, respectively (Table 16). All the processing methods including soaking, dehulling and sprouting caused a significant improvement in the availability of Ca and Fe. The highest enhancement in the availability of Ca was brought about by sprouting (48 h) followed by soaking (12 h) and dehulling in descending order. The same trend was followed in the availability of iron too. As compared to unprocessed fababean seeds, husk had significantly ($P<0.05$) lower Ca and Fe availability.

An increased availability of iron has been reported in various legumes sprouts (Prabavathi et al., 1979; Giri et al., 1981; Grewal, 1992). Sprouting brings about a considerable translocation of different minerals in the grains (Lorenz, 1980). Increased mineral availability during germination may also be due to increased phytase activity resulting in decreased phytate content in sprouts (Michael Eskin and Wiebe, 1983). Furthermore, during sprouting, phytic acid, saponins, polyphenols and other factors known to hinder the availability of these divalent cations, are catabolised leading to lower level of these antinutritional factors in legume sprouts (Bagepalli et al., 1982; Beal et al., 1984; Grewal, 1992; Kakkar, 1992; Chaudhary, 1993). Hulls an rich in polyphenols and saponins and therefore removal of husk might have resulted in improved availability of minerals in dehulled legumes.

Table 16. Effect of dehulling, soaking and sprouting on *in vitro* calcium and iron availability of fababean (%, on dry matter basis)

Treatments	Calcium	Iron
Raw legume (Control)	45.1±0.6	34.1±0.2
Husk	23.1±0.4	17.4±0.2
Dehulled	48.6±0.3 (8)	38.0±0.2 (11)
Soaked (12 h)	49.7±0.3 (10)	36.4±0.3 (7)
Sprouted (48 h)	55.7±0.4 (24)	41.4±0.2 (21)
SE(m)	±0.57	±0.41
CD ($P<0.05$)	1.17	0.93

Values are means ± SD of three independent determinations

Figures in parentheses indicate per cent increase over the control values

4.3 Sensory Evaluation of Products Prepared from Ricebean

Different ricebean products were organoleptically evaluated in terms of their colour, appearance, aroma, texture, taste and overall acceptability. The overall acceptability of dal, tikki, cutlets, kofta, kachori and wadi prepared from ricebean showed non-significant ($P<0.05$) differences when compared with their respective controls (Table 17). Khichari and sprouted chat prepared from ricebean were acceptable but significantly($P<0.05$) differed from their control.

In terms of colour and texture, ricebean dal was significantly ($P<0.05$) different from the control, i.e., greengram dal whereas appearance, aroma and taste did not differ significantly. Similarly, aroma and texture in case of khichari, appearance in case of sprouted chat, aroma, texture and taste in case of tikki, texture in case of cutlets, aroma in case of kofta, and taste and texture in case of wadi significantly differed from their respective controls.

Four types of nutritious parantha were prepared by taking different proportions of ricebean flour and wheat flour. Parantha prepared from wheat flour (Type 1) served as the control. It was observed that all the types of paranthas prepared from ricebean had significantly ($P<0.05$) lower values regarding colour, appearance, aroma, texture and taste (Table 18) than those of control. Although all types of paranthas were found to be in the category of 'slightly desirable' to 'moderately desirable' but parantha containing 60 per cent ricebean flour

Table 17. Sensory evaluation of boiled, sprouted and fermented ricebean product

Products	Colour	Appearance	Aroma	Texture	Taste	Overall acceptability
Dal						
Control	8.6±0.09	8.7±0.08	8.3±0.08	8.3±0.08	8.7±0.08	8.5±0.05
Test sample	8.3±0.08	8.1±0.08	8.1±0.08	8.1±0.05	8.0±0.05	8.1±0.05
't' value	3.02*	2.34NS	2.45NS	3.5*	1.10NS	2.70NS
Khichari						
Control	8.7±0.05	8.5±0.05	8.2±0.05	8.6±0.09	8.6±0.04	8.1±0.12
Test sample	8.2±0.05	7.9±0.08	8.1±0.05	8.2±0.05	8.3±0.05	7.5±0.12
't' value	1.06NS	2.50NS	3.53*	4.47*	2.36NS	4.81*
Sprouted chat						
Control	8.2±0.05	8.4±0.08	7.8±0.05	7.4±0.16	7.7±0.08	7.9±0.06
Test sample	7.9±0.08	8.1±0.08	7.2±0.08	7.2±0.12	7.3±0.09	7.2±0.12
't' value	2.50NS	3.67*	2.50NS	1.15NS	2.74NS	2.95*
Tikki						
Control	7.4±0.08	7.5±0.08	7.9±0.10	7.1±0.08	7.6±0.05	7.5±0.08
Test sample	7.0±0.05	7.3±0.08	7.6±0.08	6.8±0.04	7.3±0.05	7.2±0.04
't' value	2.57NS	2.60NS	2.87*	3.87*	6.14*	2.58NS

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Products	Colour	Appearance	Aroma	Texture	Taste	Overall acceptability
Cutlets						
Control	8.6±0.08	7.4±0.06	8.2±0.06	7.6±0.08	7.7±0.13	7.4±0.12
Test sample	8.2±0.05	7.1±0.05	7.6±0.08	7.3±0.04	7.4±0.04	7.2±0.05
't' value	2.50NS	2.22NS	2.02NS	3.87*	2.41NS	1.63NS
Kofta						
Control	7.3±0.05	7.2±0.22	7.5±0.09	7.8±0.12	7.4±0.08	7.4±0.12
Test sample	7.1±0.05	6.9±0.08	7.2±0.06	7.4±0.05	7.2±0.08	7.2±0.12
't' value	2.24NS	2.50NS	3.90*	2.49NS	2.45NS	1.60NS
Kachori						
Control	7.5±0.12	7.3±0.05	7.1±0.05	7.0±0.10	6.8±0.08	7.3±0.08
Test value	7.2±0.06	7.2±0.05	6.9±0.08	6.7±0.04	6.7±0.08	6.9±0.06
't' value	1.70NS	2.61NS	2.50NS	2.67NS	1.40NS	2.35NS
Wadi						
Control	7.6±0.15	7.4±0.07	7.8±0.18	7.6±0.07	7.3±0.08	7.5±0.12
Test sample	7.4±0.10	7.1±0.12	7.5±0.13	7.0±0.05	7.1±0.12	7.2±0.13
't' value	2.10NS	2.61NS	2.70NS	3.06*	2.81*	2.69NS

Values are means ± SD of three independent determinations.

*Significant at 5% level.

NS = Non significant at 5% level.

Table 18. Sensory evaluation of nutritious parantha, chilla, pakora and papad prepared from ricebean

Products	Colour	Appearance	Aroma	Texture	Taste	Overall acceptability
Nutritious parantha						
I 100WF : 0RB(Control)	7.0±0.03	6.8±0.03	8.0±0;06	7.2±0.02	8.1±0.03	7.2±0.03
II 50WF : 50RB	6.8±0.06	6.6±0.04	7.5±0.03	7.0±0.06	7.8±0.06	6.5±0.04
III 40WF : 60RB	6.8±0.03	6.8±0.03	7.6±0.03	7.1±0.03	7.8±0.11	6.9±0.07
IV 50WF : 35RB:15CP	6.8±0.09	6.6±0.06	7.5±0.06	7.0±0.03	7.4±0.03	6.4±0.09
SE(m)	±0.08	±0.06	±0.06	±0.05	±0.10	±0.09
CD (P<0.05)	0.18	0.14	0.14	0.11	0.23	0.21
Chilla						
I 100CP : ORB(Control)	7.9±0.06	8.0±0.06	7.4±0.06	7.1±0.03	7.5±0.03	7.5±0.06
II 50CP : 50 RB	7.4±0.09	6.9±0.03	6.9±0.06	6.8±0.03	7.0±0.04	6.8+0.05
III 40CP : 60RB	7.4±0.06	7.0±0.06	7.0±0.05	6.8±0.04	7.1±0.01	6.6±0.07
IV 30CP : 70RB	7.6±0.03	7.1±0.06	7.0±0.03	6.9±0.03	7.1±0.03	7.0±0.03
SE(m)	±0.09	±0.07	±0.07	±0.03	±0.04	±0.06
CD (P<0.05)	0.21	0.16	0.16	0.11	0.07	0.14

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Products	Colour	Appearance	Aroma	Texture	Taste	Overall acceptability
Pakora						
I 100CP : ORB (Control)	7.7±0.03	8.0±0.06	7.5±0.03	7.2±0.06	7.0±0.03	7.4±0.03
II 50CP : 50RB	7.4±0.06	7.5±0.06	6.9±0.07	6.7±0.12	6.6±0.06	6.6±0.05
III 40CP : 60RB	7.4±0.03	7.5±0.06	7.0±0.06	6.7±0.07	6.6±0.09	6.8±0.01
IV 30CP : 70RB	7.5±0.07	7.6±0.08	7.0±0,03	6.8±0.03	6.7±0.08	6.8±0.03
SE(m)	±0.07	±0.08	±0.07	±0.11	±0.08	±0.05
CD (P<0.05)	0.16	0.18	0.16	0.25	0.18	0.11
Papad						
I 100BG : ORB(Control)	7.8±0.09	7.4±0.06	7.6±0.03	7.5±0.03	7.5±0.06	7.5±0.02
II 80BG : 20RB	7.1±0.05	6.8±0.06	6.9±0.06	7.0±0.04	7.0±0.06	6.8±0.03
III 70BG : 30RB	7.1±0.06	7.0±0.08	7.0±0.07	7.1±0.05	7.1±0.07	7.0±0.06
IV 60BG : 40RB	6.8±0.03	6.5±0.09	6.6±0.09	6.9±0.03	6.5±0.06	6.5±0.06
SE(m)	±0.09	±0.08	±0.09	±0.06	±0.08	±0.06
CD (P<0.05)	0.21	0.18	0.21	0.14	0.18	0.14

Values are means ± SD of three independent determinations.

WF - Wheat flour; RB - Ricebean; CP - Chickpea, BG - Black gram

(Type III) was more closer to the control which was selected for further chemical analysis.

Similarly chilla was prepared by supplementing the ricebean flour at different levels i.e. 50, 60 and 70 per cent with chickpea flour. Type I chilla which contained 100 per cent chickpea flour served as control. Overall acceptability of different type of chillas differed significantly among themselves and were in the category of 'moderately desirable' to 'desirable.' Chilla containing 70 per cent ricebean flour (Type IV) had significantly ($P<0.05$) higher acceptability than other chillas prepared from ricebean.

Four types of pakoras were prepared by incorporating the ricebean flour with chickpea flour in different proportions viz., 50:50 (Type II), 60:40 (Type III) and 70:30 (Type IV). Non-significant differences were observed for colour, appearance, aroma, texture and taste in type II, III and IV pakoras whereas all these types significantly ($P<0.05$) differed from Type I pakora (Table 18). Pakora containing 70 per cent ricebean flour had the highest value for overall acceptability and was, therefore, selected for further analysis.

Different types of papads were prepared by mixing the ricebean flour and blackgram flour. The overall acceptability of papads incorporating 20, 30 and 40 per cent ricebean flour ranged from 'slightly desirable' to 'moderately desirable'. Papad contianing 30 per cent ricebean flour had overall acceptability nearer to that of the control i.e. blackgram dal papad and hence, used in further analysis. Kadhi was prepared from

chickpea and ricebean flou. Kadhi prepared from chickpea flour only served as control. It was observed that kadhi containing chickpea had higher overall acceptability score (Table 19). Among all the types of kadhi prepared from ricebean, type IV kadhi in which 70 per cent ricebean flour was used showed the highest acceptability.

Cake was prepared by adding ricebean flour to refined wheat flour at different levels, i.e., 40, 50, and 60 per cent. The cake prepared from refined flour (Type I) served as control. Cakes incorporating ricebean flour upto 60 per cent level were acceptable to the human palate. Colour, appearance, aroma, taste and texture of cake incorporating ricebean flour at the levels of 40, 50, and 60 per cent significantly ($P<0.05$) differed from the control. Among the cakes prepared from ricebean, type III in which 50 per cent ricebean flour was added showed the highest acceptability score.

Five types of idli and dosa were prepared by mixing ricebean dal and blackgram dal in different ratios, i.e., 50:50 60:40, 70:30 and 100:0. All the types of idli and dosa prepared were found to be 'moderately desirable' (Table 19) although they significantly ($P<0.05$) differed from the control. The idli prepared by using 30 per cent blackgram dal and 70 per cent ricebean dal was found to be the most acceptable. Dosa containing 100 per cent ricebean dal got the highest overall acceptability score.

Different ricebean products getting the highest overall acceptability scores were selected for further chemical analysis (Table 23).

Table 19. Sensory evaluation of kadhi, cake, idli and dosa prepared from ricebean

Products	Colour	Appearance	Aroma	Texture	Taste	Overall acceptability
Kadhi						
I 100CP : 0RB (Control)	8.1±0.09	7.9±0.03	8.2±0.06	8.5±0.03	8.1±0.03	7.8±0.02
II 50CP : 50RB	7.5±0.08	7.1±0.06	7.9±0.07	7.7±0.06	7.6±0.03	7.2±0.03
III 40CP : 60RB	7.5±0.06	7.1±0.03	7.9±0.06	7.7±0.06	7.7±0.04	7.5±0 03
IV 30CP : 70RB	7.6±0.04	7.2±0.03	8.0±0.04	7.9±0.04	7.8±0.03	7.6±0.04
SE(M)	±0.10	±0.06	±0.08	±0.07	±0.05	±0.05
CD (P<0.05)	0.23	0.14	0.18	0.16	0.11	0.11
Cake						
I 100RW : ORB(Control)	8.0±0.06	8.1±0.06	7.8±0.06	8.1±0.07	7.5±0.06	8.0±0.03
II 60RW : 40RB	7.7±0.03	7.9±0.06	7.3±0.08	7.5±0.09	7.2±0.06	7.3±0.06
III 50RW : 50RB	7.8±0.03	8.0±0.03	7.5±0.06	7-6±0.06	7.2±0.06	7.6±0.08
IV 40RW : 60RB	7.3±0.06	7.7±0.09	7.3±0.12	7.0±0.12	7.0±0.03	6.7±0.05
SE(m)	±0.07	±0.09	±0.12	±0.12	±0.09	±0.09
CD (P<0.05)	0.16	0.21	0.28	0.28	0.16	0.21

-Contd -

Products	Colour	Appearance	Aroma	Texture	Taste	Overall acceptability
Idli						
I 100BG : ORB(Control)	8.1±0.08	8.0±0.07	8.3±0.02	8.2±0.02	8.1±0.03	8.1±0.08
II 50BG : 50RB	6.7±0.08	7.0±0.08	7.6±0.05	7.6±0.08	7.7±0.03	7.3±0.09
III 40BG : 60RB	6.8±0.03	7.2±0.09	7.7±0.12	7.6±0.07	7.7±0.08	7.4±0.08
IV 30BG : 70RB	7.2±0.08	7.3±0.10	7.8±0.10	7.9±0.03	7.9±0.09	7.7±0.03
V OBG : 100RB	7.0±0.04	7.1±0.03	7.5±0.03	7.3±0.02	7.8±0.10	7.4±0.12
SE(m)	±0.08	±0.10	±0.12	±0.08	±0.11	±0.12
CD (P<0.05)	0.18	0.23	0.27	0.18	0.25	0.27
Dosa						
I 100BG : ORB(Control)	8.0±0.05	8.1±0.07	8.2±0.04	8.4±0.02	8.2±0.03	8.3±0.10
II 50BG : 50RB	7.7±0.03	7.5±0.08	7.6±0.02	8.0±0.03	7.7±0.03	7.6±0.08
III 40BG : 60RB	7.4±0.08	7.6±0.10	7.7±0.02	8.0±0.03	7.8±0.03	7.5±0.08
IV 30BG : 70RB	7.5±0.02	7.7±0.03	7.8±0.03	7.9±0.06	7.8±0.02	7.8±0.08
V OBG : 100RB	7.6±0.03	7.4±0.04	7.8±0.08	8.1±0.06	8.0±0.05	8.0±0.03
SE(m)	±0.08	±0.10	±0.09	±0.06	±0.05	±0.03
CD (P<0-05)	0.18	0.23	0.20	0.14	0.12	0.25

Values are means ± SD of three independent determinations

CP - Chickpea; RB - Ricebean; RW - Refined wheat flour; BG - Black gram

4.4 Sensory Evaluation of Products Prepared from Fababean

The overall acceptability of dal, khichari, sprouted chat, tikki and cutlets prepared from fababean significantly differed from their respective controls whereas kachori, kofta, wadi and roasted dal were almost similar in term of organoleptic characteristic to their respective controls (Table 20). Except for aroma, other characteristics such as colour, appearance, texture, taste of dal differed significantly ($P<0.05$) from those of the control. Khichari incorporating fababean showed non-significant difference for aroma and taste as compared to its control. In case of sprouted chat, taste was significantly different from that of the control whereas other characteristic showed non-significant differences. The characteristic like appearance, aroma, taste and texture showed non-significant difference from their control in kofta, kachori and roasted dal. The aroma, taste and texture of wadis prepared from fababean and blackgram dal differed significantly whereas non-significant differences existed in terms of colour, appearance of the two types (Table 20).

Nutritious parantha was prepared by adding fababean flour and spinach to wheat flour. Type II and III paranthas were prepared by incorporating fababean flour at 50 and 60 per cent level whereas type IV was prepared by mixing wheat flour, fababean flour and chickpea flour in the ratio of 50:35:15. Overall acceptability was the highest for control followed by type III, II and IV parantha (Table 21).

Table 20. Sensory evaluation of boiled, sprouted, fermented and roasted fababean products

Products	Colour	Appearance	Aroma	Texture	Taste	Overall acceptability
Dal						
Control	8.7±0.05	8-5±0.08	8.2±0.05	8.7±0.06	8.6±0.09	8.6±0.05
Test sample	8.2±0.01	7.9±0.08	8.1±0.06	8.1±0.08	8.2±0.02	8.0±0.12
't' value	4.6*	7.68*	1.56NS	8.23*	4.16*	3.89*
Khichari						
Control	8.1±0.12	8.2±0.05	8.4±0.08	7.8±0.04	7.4±0.16	7.7±0.08
Test sample	7.6±0.13	8.0±0.07	8.3±0.16	7.4±0.09	7.1±0.03	7.5±0.04
't' value	3.81*	2.99*	0.47NS	5.65*	2.67NS	2.91*
Sprouted chat						
Control	7.9±0.06	7.3±0.12	7.5±0.08	7.8±0.11	7.1±0.05	7.6±0.05
Test sample	7.8±0.13	7.1±0.12	7.3±0.09	7.6±0.10	6.8±0.08	7.3±0.09
't' value	1.65NS	1.67NS	2.51NS	1.97NS	4.03*	3.58*
Tikki						
Control	8.1±0.08	8.6±0.08	7.4±0.04	8.2±0.06	7.6±0.05	7.8±0.06
Test sample	7.9±0.08	8.1±0.12	7.1±0.05	7.9±0.08	7.3±0.03	7.0±0.05
't' value	2.35NS	4.45*	4.75*	3.98*	4.20*	2.69*

- contd -

Products	Colour	Appearance	Aroma	Texture	Taste	Overall acceptability
Cutlets						
Control	7.4±0.12	7.3±0.05	7.2±0.16	8.3±0.08	7.4±0.16	7.4±0.08
Test sample	7.3±0.06	7.1±0.05	7.1±0.08	8.1±0.08	7.3±0.05	7.1±0.07
't' value	1.07NS	2.81*	0.77NS	2.45NS	0.55NS	3.81*
Kofta						
Control	7.4±0.12	7.3±0.12	7.1±0.08	6.8±0.12	7.2±0.08	7.3±0.06
Test sample	7.2±0.12	7.1±0.03	6.9±0.03	6.7±0.14	6.7±0.04	6.9±0.08
't' value	1.60NS	2.46NS	1.99NS	0.99NS	1.70NS	2.40NS
Kachori						
Control	8.5±0.04	8.3±0.08	8.2±0.04	8.6±0.08	7.6±0.08	8.2±0.09
Test sample	8.2±0.12	8.2±0.11	8.2±0.08	8.1±0.08	7.5±0.12	7.4±0.09
't' value	3.93*	0.52NS	0.77NS	2.12NS	1.26NS	2.26NS
Wadi						
Control	7.6±0.18	7.4±0.07	7.8±0.18	7.6±0.07	7.3±0.08	7.5±0.12
Test sample	7.3±0.21	7.2±0.12	7.3±0.20	7.1±0.07	7.1±0.05	7.2±0.08
't' value	2.33NS	2.51NS	2.90*	2.82*	2.70NS	2.61NS
Roasted dal						
Control	7.5±0.06	7.3±0.05	7.1±0.08	6.9±0.1	6.8±0.08	7.3+0.08
Test sample	7.3±0.08	7.2±0.06	7.1±0.04	6.7±0.08	6.6±0.08	7.0±0.14
't' value	2.98*	0.90NS	1.00NS	2.61NS	2.60NS	2.60NS

Values are mean ± SD of three independent determinations.

*Significant at 5% level.

NS - Non significant at 5% level .

Chilla and pakora were prepared by incorporating the fababean flour in chickpea flour at 50, 60 and 70 per cent levels. The chilla and pakora prepared from chickpea flour only served as control. The colour, appearance, aroma, texture and taste of chilla and pakoras had significantly lower values than those of the controls (Table 21). Chilla and pakora having 70 per cent fababean flour were more closer to the controls and, therefore, were selected for further nutritional analysis.

Five types of papads were prepared by incorporating the fababean flour into blackgram dal flour at different levels that is 0, 40, 50, 60 and 70 per cent. Blackgram dal papad (Control) showed the highest overall acceptability followed by papads incorporating 60 per cent fababean flour (Type IV). The overall acceptability scores of papads containing fababean flour at 40, 50 and 70 per cent levels did not differ significantly (Table 21).

Kadhi was prepared by supplementing the fababean flour to chickpea flour at 50, 60 and 70 per cent levels. The score for colour, appearance, aroma, texture and taste of various types of kadhi ranged from 'moderatley desirable' to 'desirable'. Type IV kadhi being more closer to control in terms of overall acceptability was selected for further analysis (Table 22).

Five types of cakes were prepared by adding the fababean flour to refined wheat flour at different levels. Cakes prepared by incorporating fababean flour at the levels of 40, 50, 60 and 70 per cent were in the category of 'moderately desirable'. The cake containing 60 per cent fababean and 40 per

Table 21. Sensory evaluation of nutritious parantha, chilla, pakora and papad prepared from fababean

Products	Colour	Appearance	Aroma	Texture	Taste	Overall acceptability
Nutritious parantha						
I 100WF : 0FB(Control)	7.1±0.06	6.9±0.06	8.0±0.03	7.3±0.03	8.1±0.03	7.2±0.04
II 50WF : 50FB	6.5±0.03	6.7±0.07	7.8±0.04	7.0±0.22	7.9±0.03	6.4±0.03
III 40WF : 60FB	6.7±0.03	6.7±0.07	7.9±0.03	7.1±0.03	8.0±0.04	6.7±0.02
IV 50WF : 35FB:15CP	6.5±0.02	6.7±0.03	7.6±0.04	7.0±0.04	7.8±0.03	6.$±0.02
SE(m)	±0.05	±0.09	±0.05	±0.05	±0.05	±0.04
CD (P<0.05)	0.11	0.21	0.11	0.11	0.11	0.09
Chilla						
I 100CP : 0FB (Control)	8.0±0.03	7.8±0.06	8.0±0.03	7.5±0.06	7.0±0.03	7.5±0.06
II 50CP : 50FB	7.5±0.03	7.2±0.09	7.6±0.09	7.2±0.02	6.7±0.06	6.9±0.06
III 40CP : 60FB	7.7±0.04	7.5±0.06	7.7±0.07	7.3±0.02	6.9±0.04	7.2±0.02
IV 30CP : 70FB	7.6±0.05	7.4±0.05	7.6±0.06	7.2±0.03	6.7±0.03	7.3±0.02
SE(m)	±0.05	±0.09	±0.09	±0.05	±0.06	±0.06
CD (P<0.05)	0.11	0.21	0.21	0.11	0.14	0.14

- Contd -

Products	Colour	Appearance	Aroma	Texture	Taste	Overall acceptability
Pakora						
I 100CP : 0FB (Control)	7.8±0.06	7.9±0.04	7.5±0.06	7.2±0.06	7.0±0.03	7.0±0.03
II 50CP : 50FB	7.5±0.06	7.6±0.03	7.1±0.09	6.9±0.03	6.8±0.03	6.6±0.05
III 40CP : 60FB	7.6±0.03	7.6±0.03	7.2±0.06	7.0±0.03	6.9±0.03	6.6±0.02
IV 30CP : 70FB	7.4±0.06	7.4±0.03	7.1±0.03	6.9±0.03	6.7±0.02	6.8±0.03
SE(m)	±0.07	±0.05	±0.09	±0.05	±0.04	±0.05
CD (P<0.05)	0.16	0.11	0.21	0.14	0.09	0.11
Papad						
I 100BG : 0FB(Control)	7.8±0.09	7.4±0.06	7.6±0.04	7.5±0.04	7.5±0.03	7.6±0.08
II 60BG : 40FB	7.2±0.03	7.0±0.03	7.0±0.04	7.1±0.08	7.0±0.03	7.1±0.03
III 50BG : 50FB	7.3±0.04	7.1±0.04	7.1±0.06	7.1±0.09	7.1±0.05	7.1±0.08
IV 40BG : 60FB	7.0±0.06	7.1±0.05	7.3±0.09	7.2±0.10	7.3±0.07	7.3±0.10
V 30BG : 70FB	7.2±0.03	7.1±0.06	7.1±0.03	7.0±0.03	7.6±0.08	7.0±0.12
SE(m)	±0.09	±0.06	±0.09	±0.10	±0.08	±0.12
CD (P<0.05)	0.20	0.14	0.20	0.23	0.18	0.27

Values are means ± SD of three independent determinations.

WF - Wheat flour, FB - Fababean, CP - Chickpea, BG - Black gram

Table 22. Sensory evaluation of kadhi, cake, idli and dosa prepared from fababean

Products	Colour	Appearance	Aroma	Texture	Taste	Overall acceptability
Kadhi						
I 100CP : OFB(Control)	8.1±0.03	7.9±0.06	8.2±0.03	8.4±0.06	8.1±0.06	7.8±0.04
II 50CP : 50FB	7.7±0.03	7.4±0.05	7.8±0.03	7.6±0.03	7.5±0.03	7.4±0.03
III 40CP : 60FB	7.7±0.06	7.6±0.03	7.8±0.04	7.7±0.09	7.4±0.04	7.5±0.03
IV 30CP : 70FB	7.9±0.06	7.4±0.03	7.9±0.06	8.1±0.09	7.7±0.04	7.6±0.04
SE(m)	±0.06	±0.07	±0.06	±0.10	±0.06	±0.05
CD (P<0.05)	0.10	0.16	0.14	0.23	0.14	0.11
Cake						
I 100RW : 0FB (Control)	8.0±0;05	8.1±0.07	7.7±0.05	7.5±0.06	8.5±0.07	8.1±0.03
II 60RW : 40FB	7.4±0.03	7.8±0.08	7.3±0.08	7.2±0.09	8.0±0.05	7.3±0.06
III50RW : 50FB	7.6±0.03	7.8±0.06	7.4±0.05	7.3±0.06	7.8±0.01	7.4±0.07
IV 40RW : 60FB	7.3±0.06	7.9±0.08	7.5±0.08	7.3±0.08	7.8±0.08	7.8±0.08
V 30RW : 70FB	7.2±0.07	7.8±0.09	7.2±0.10	7.2±0.11	7.5±0.09	7.2±0.05
SE(m)	±0.09	±0.09	±0.10	±0.11	±0.09	±0.08
CD (P<0.05)	0.17	0.20	0.23	0.25	0.20	0.18

-contd-

Products	Colour	Appearance	Aroma	Texture	Taste	Overall acceptability
Idli						
I 100BG : 0FB (Control)	8.2±0.07	8.0±0.06	8.3±0.03	8.1±0.07	8.3±0.07	8.2±0.04
II 50BG : 50FB	8.0±0.05	7.7±0.06	7.6±0.05	8.0±0.08	7.7±0.08	7.7±0.04
III 40BG : 60FB	7.8±0.05	7.8±0.08	7.7±0.06	7.9±0.05	7.8±0.08	7.8±0.08
IV 30BG : 70FB	7.9±0.03	7.8±0.07	7.8±0.05	8.0±0.06	7.9±0.09	7.9±0.09
V 0BG : 100FB	7.6±0.08	7.6±0.10	7.6±0.03	7.9±0.03	7.6±0.10	7.6±0.03
SE(m)	±0.08	±0.10	±0.06	±0.09	±0.10	±0.09
CD (P<0.05)	0.18	0.23	0.14	0.20	0.23	0.20
Dosa						
I 100BG : 0FB (Control)	8.0±0.05	8.1±0.06	8.2±0.03	8.1±0.02	8.4±0.07	8.3±0.05
II 50BG : 50FB	7.6±0.05	7.6±0.07	7.9±0.03	7.5±0.05	8.0±0.04	7.7±0.02
III 40BG : 60FB	7.6±0.07	7.7±0.03	7.8±0.06	7.6±0.07	7.9±0.03	7.7±0.02
IV 30BG : 70FB	7.7±0.06	7.8±0.02	7.8±0.04	7.6±0.08	8.0±0.02	7.7±0.08
V 0BG : 100FB	7.7±0.05	8.0±0.08	7.9±0.05	7.8±0.10	8.1±0.08	8.1±0.12
SE(m)	±0.07	±0.08	±0.07	±0.10	±0.08	±0.12
CD (P<0.05)	0.16	0.18	0.16	0.22	0.18	0.27

Values are means ± SD of three independent determinations.

CP - Chickpea flour; FB - Fababean flour; RW - Refined wheat flour; BG - Black gram

cent refined wheat flour was taken for chemical analysis as it showed the highest score for overall acceptability.

Idli and dosa were prepared by mixing fababean dal and blackgram dal at four different levels i.e. 50, 60, 70 and 100 per cent. Type IV idli containing 70 per cent fababean dal which was 'moderately desirable' showed the score closer to the control and was taken for chemical analysis. Type V dosa, containing 100 per cent fababean flour was in the 'desirable' range and was selected for further analysis (Table 23).

4.5 Nutritive Value of Products Made from Ricebean and Fababean

4.5.1 Proximate composition

4.5.1.1 Crude protein, true protein, fat and ash

The moisture content of whole seed of ricebean and fababean was 6.3 and 6.8 per cent, respectively. Boiled ricebean and fababean products like dal, khichari and kadhi had 72.4 to 87.2 and 73.2 to 86.8 per cent moisture, respectively (Table 24). The moisture content of idli, dosa and wadi prepared from ricebean was 56.7, 36.9 and 6.9 per cent, respectively, whereas those prepared from fababean was 55.4, 41.3 and 77.7 per cent, respectively. The moisture content of sprouted ricebean and fababean products varied from 38.4 to 66.1 and 37.7 to 69.5 per cent, respectively. In case of fried ricebean and fababean products, the moisture content ranged from 8.4 to 52.6 and 9.1 to 51.8 per cent, respectively (Table 24).

Among the boiled legume products dal and khichari were pressure cooked whereas kadhi was ordinarily cooked. The crude

Table 23. Final selection of products prepared from ricebean and fababean based on organoleptic evaluation

S.No.	Products	Ricebean	Fababean
1.	Nutritious parantha	40 wheat flour : 60 ricebean flour	40 wheat flour: 60 fababean flour
2.	Chilla	30 chickpea flour : 70 ricebean flour	30 chickpea flour : 70 fababean flour
3.	Pakora	30 chickpea flour : 70 ricebean flour	30 blackgram flour : 70 fababean flour
4.	Papad	70 blackgram flour : 30 ricebean flour	40 blackgram flour : 60 fababean flour
5.	Kadhi	30 chickpea flour : 70 ricebean flour	30 chickpea flour : 70 fababean flour
6.	Cake	50 refined wheat flour: 50 ricebean flour	40 refined wheat flour: 60 fababean flour
7.	Idli	30 blackgram dal : 70 ricebean dal	30 blackgram dal : 70 fababean dal
8.	Dosa	0 blackgram dal : 100 ricebean dal	0 blackgram dal : 100 fababean dal

Table 24. Moisture content of ricebean and fababean products (%, on fresh matter basis)

Products	Ricebean product	Fababean product
Raw Legume (Control)	6.3±1.1	6.8±1.2
Boiled products		
Dal	72.4±1.3	73.2±0.2
Khichari	78.3±1.5	75.0±0.9
Kadhi	87.2±0.2	86.8±0.1
Fermented products		
Dosa	36.9±0.6	41.3±3.8
Idli	56.7±0.5	55.4±0.7
Wadi	6.9±1.0	7.7±1.6
Sprouted products		
Sprouted chat	56.7±0.3	57.2±0.5
Tikki	62.8±0.3	64.2±0.4
Cutlet	66.1±1.2	69.5±0.2
Kofta	42.5±0.5	43.1±0.8
Kachori	38.4±0.2	37.7±0.8
Fried products		
Nutritious parantha	32.8±1.2	33.5±1.7
Chilla	51.5±2.9	51.3±0.4
Pakora	52.6±1.2	51.8±0.8
Papad	8.4±0.5	9.1±0.8
Baked product		
Cake	30.4±0.3	31.1±0.8
Roasted product		
Roasted dal	—	6.5±1.0

Values are means ± SD of three independent determinations

protein and true protein content of boiled ricebean products ranged from 11.5 to 18.6 and 11.1 and 18.3 per cent, respectively (Table 25). Among the boiled legume products, khichari had the lowest crude protein content due to addition of cereal i.e. rice to dal in khichari. The NPN of boiled products varied from 40.3 to 52.0 mg/100 g. It was noticed that pressure cooking as well as ordinary cooking did not affect the crude protien, true protein and NPN contents of boiled ricebean products as non-significant differences existed between the raw mixture and cooked products for the above mentioned parameters.

Fat and ash content of different boiled products varied from 6.2 to 9.7 and 3.7 to 7.7 per cent, respectively. Kadhi contained more of fat and ash than dal and khichari. Cooking did not change the fat and ash content of boiled products as differences between the raw mixture and cooked products were not significant. The crude protein, fat and ash contents of cake were 13.3, 20.2 and 2.8 per cent, respectively. Baking treatment also did not affect the above mentioned nutrients (Table 25).

Similar trends were noticed in case of boiled fababean products (Table 26). Crude and true protein contents varied form 14.9 to 27.3 and 14.3 to 27.0 per cent, respectively. The fat of cooked products viz., dal, khichari and kadhi was 7.2, 7.0 and 10.3 per cent, respectively whereas ash contents of these products ranged from 3.0 to 7.0 per cent. Non-significant differences were observed between raw mixtures and cooked boiled fababean products.

Table 25. Crude protein, true protein, non-protein nitrogen, fat and ash contents of boiled and baked ricebean products (on dry matter basis)

Products	Crude protein (g/100 g)	True protein (g/100 g)	Non-protein nitrogen (mg/100 g)	Fat (g/100 g)	Ash (g/100 g)
Boiled products					
Dal					
Raw mixture	18.2±0.8	17.9±0.7	31.6±2.8	6.2±0.2	4.8±0.2
Cooked product	17.5±0.1	17.1±0.1	42.3±10.3	6.3±0.2	4.7±0.2
't' value	1.77NS	0.98NS	0.58NS	0.71NS	0.71NS
Khichari					
Raw mixture	11.6±0.8	11.3±0.7	33.5±6.8	6.3±0.2	3.8±0.2
Cooked product	11.5±0.6	11.1±0.4	40.3±7.8	6.2±0.2	3.7±0.2
't' value	0.34NS	0.96NS	0.35NS	0.71NS	0.71NS
Kadhi					
Raw mixture	18.7±0.2	18.3±0.2	46.0±5.8	8.3±0.2	7.7±0.2
Cooked product	18.6±0.2	18.3±0.1	52.0±6.0	9.7±0.2	7.7±0.1
't' value	1.03NS	1.95NS	1.41NS	2.50NS	0.00NS
Baked product					
Cake					
Raw mixture	13.4±0.2	13.2±0.3	23.2±7.3	20.2±0.2	2.8±0.2
Baked product	13.3±0.2	13.0±0.2	30.8±4.6	20.2±0.2	2.8±0.6
't' value	0.27NS	0.63NS	0.52NS	0.00NS	0.10NS

Values are means ± SD of three independent determinations.

NS - Non significant at 5% level.

Table 26. Crude protein, true protein, non-protein nitrogen, fat and ash contents of boiled fababean products (on dry matter basis)

Products	Crude protein (g/100 g)	True protein (g/100 g)	Non-protein nitrogen (mg/100 g)	Fat (g/100 g)	Ash (g/100 g)
Dal					
Raw mixture	27.4±0.3	27.1±0.1	32.3±9.1	17.2±0.2	4.2±0.2
Cooked product	27.3±1.2	27.0±0.2	35.6±8.1	7.2±0.2	4.3±0.3
't' value	0.19NS	0.26NS	0.86NS	0.01NS	0.50NS
Khichari					
Raw mixture	15.0±0.3	14.4±0.2	60.6±6.3	6.8±0.2	3.2±0.2
Cooked product	14.9±0.2	14.3±0.3	64.2±5.6	7.0±0.4	3.0±0.0
't' value	0.56NS	0.65NS	0.75NS	0.50NS	1.00NS
Kadhi					
Raw mixture	25.7±0.3	25.4±0.2	30.8±3.5	9.8±0.6	6.5±0.4
Cooked product	25.7±0.3	25.3±0.3	41.7±6.3	10.3±0.6	7.0±0.0
't' value	0.00NS	1.16NS	0.89NS	0.80NS	1.73NS

Values are means ± SD of three independent determinations

NS - Non significant at 5%level

Cooking did not change the crude protein, fat and ash content of the boiled products. On the contrary, Kosson and Bakowski (1986) reported that cooking, slightly decreased the crude protein and ether extract in chickpea grain as compared to raw grain. According to Savage and Des (1989) cooked peas had slightly lower crude protein contents, whereas Sotelo et al. (1987) observed no differences in cooked and raw chickpea grains with respect to protein and fat content.

Fermented products like idli, dosa and wadi were prepared from the ricebean and fababean. Samples were derived at different stages involved in the preparation of these products i.e. soaked, fermented slurry and final product and were analysed for different nutrients as to see any change in the nutrient composition of the products. The crude protein content in different fermented ricebean products including idli, dosa and wadi ranged from 10.2 to 18.5 g/100 g with the highest value in wadi followed by idli and dosa (Table 27). Non protein nitrogen content varied from 19.0 to 42.9 mg/100 g in different fermented products.

The raw mixture of rice bean idli had crude protein, fat ash contents as 11.8, 0.7 and 3.7 per cent, respectively (Table 27). After soaking, fermentation and steaming, no significant changes occurred in the crude protein, fat and ash contents. Finally, the raw mixture and final product had the similar composition for the above mentioned nutrients. The crude protein, fat and ash contents ranged from 14.2 to 14.3, 2.7 to

Table 27 . Crude protein, true protein, non-protein nitrogen, fat and ash contents of fermented ricebean products (on dry matter basis)

Products	Crude protein (g/100 g)	True protein (g/100 g)	Non-protein nitrogen (mg/100 g)	Fat (g/100 g)	Ash (g/100 g)
Idli					
Raw mixture	11.8±0.1	11.2±0.1	62.2±11.2	0.7±0.2	3.7±0.2
Soaked mixture	11.7±0.1	11.2±0.1	60.1±6.5	0.8±0.2	3.5±0.3
Fermented slurry	11.7±0.1	11.1±0.1	63.2±7.5	0.8±0.2	3.7±0.3
Final product	11.8±0.1	11.4±0.1	42.9±7.8	0.8±0.2	3.7±0.3
SE(m)	±0.16	±0.09	±12.32	±0.23	±0.41
CD (P<0.05)	0.33	0.19	25.69	NS	NS
Dosa					
Raw mixture	10.4±0.2	10.2±0.2	26.7±6.1	1.0±0.1	3.7±0.2
Soaked mixture	10.2±0.1	10.0±0.1	20.0±10.3	1.0±0.3	3.8±0.2
Fermented slurry	10.5±0.2	10.3±0.2	18.3±9.2	1.2±0.2	3.8±0.2
Final product	10.2±0.1	10.0±0.1	23.3±7.1	1.2±0.2	3.8±0.2
SE(m)	±0.17	±0.21	±12.20	±0.26	±0.31
CD (P<0.05)	0.35	0.44	25.45	NS	NS
Wadi					
Raw mixture	18.5±0.2	18.2±0.1	31.7±7.9	0.7±0.2	4.3±0.2
Soaked mixture	18.5±0.1	18.3±0.2	28.2±8.7	0.8±0.2	4.3±0.3
Fermented slurry	18.3±0.1	18.1±0.1	20.0±8.9	0.8±0.2	4.5±0.3
Final product	18.3±0.1	18.1±0.1	19.0±7.6	0.8±0.2	4.5±0.3
SE(m)	±0.21	±0.18	± 9.23	±0.23	±0.39
CD (P<0.05)	0.43	0.37	19.25	NS	NS

Values are means ± SD of three independent determinations

NS - Non significant

2.8 and 3.7 to 3.8 per cent, respectively in the samples derived from various stages involved in the preparation of fababean idli (Table 28).

Similar trend was witnessed in case of dosa and wadi made from ricebean and fababean (Tables 27 and 28). Soaking, fermentation and shallow frying or drying involved in the preparation of dosa and wadi did not change the composition of proximate nutrients.

According to Goyal (1991) fermentation either decreased or did not alter the crude protein of cereal legume blends. Total nitrogen and crude protein did not changed although non protein nitrogen increased during fermentation of mung bean wadi (Soni and Sadhu, 1990). Ash and fat content of wadi (Yadav, 1992) and soy-rabadi an indigenous fermented product (Grewal, 1992) did not change. Aliya and Geervani (1981) observed a decrease in crude protein of bengal gram and green gram whereas Eka (1980) showed an increase in protein and fat during fermentation. Since no addition or deletion of mineral source is involved hence no change in ash content during fermentation is exerted (Chaudhary, 1993).

Ricebean and fababean sprouts were steamed for 10 min before their use in different sprouted products like sprouted chat, tikki, cutlets, kofta and kachori. Crude and true protein content of different sprouted ricebean products ranged from 10.9 to 19.4 and 10.4 to 19.1 per cent, respectively (Table 29). Fat content of sprouted chat was less than other sprouted products as fat was not added during its preparation (Table 29).

Table 28 . Crude protein, true protein, non-protein ntirogen, fat and ash contents of fermented fababean products (on dry matter basis)

Products	Crude protein (g/100 g)	True protein (g/100 g)	Non-protein nitrogen (mg/100 g)	Fat (g/100 g)	Ash (g/100 g)
Idli					
Raw mixture	14.3±0.1	14.1±0.2	23.7±12.2	2.7±0.2	3.7±0.2
Soaked mixture	14.3±0.1	14.1±0.1	20.0±7.3	2.7±0.2	3.8±0.2
Fermented slurry	14.2±0.2	14.0±0.1	23.3±12.1	2.8±0.2	3.8±0.2
Final product	14.3±0.1	14.0±0.1	31.7±11.9	2.7±0.2	3.8±0.2
SE(m)	±0.21	±0.21	±15.90	±0.24	±0.24
CD (P<0.05)	0.44	0.44	33.17	NS	NS
Dosa					
Raw mixture	12.9±0.1	12.7±0.1	21.3±6.0	2.8±0.2	3.7±0.2
Soaked mixture	12.7±0.1	12.5±0.1	20.0±8.1	2.8±0.2	3.8±0.2
Fermented slurry	12.7±0.1	12.5±0.1	21.7±9.4	2.8±0.2	3.8±0.2
Final product	12.8±0.1	12.5±0.1	26.7±6.1	3.0±0.3	3.8±0.2
SE(m)	±0.16	±0.16	±10.70	±0.29	±0.24
CD (P<0.05)	0.33	0.33	22.32	NS	NS
Wadi					
Raw mxiture	28.0±0.2	27.8±0.2	21.9±5.5	2.7±0.2	3.8±0.2
Soaked mixture	27.9±0.1	27.6±0.1	36.6±12.0	2.7±0.2	4.0±0.3
Fermented slurry	28.0±0.1	27.7±0.1	36.7±9.5	2.8±0.2	4.0±0.3
Final product	28.0±0.2	27.8±0.1	18.3±8.3	2.8±0.3	4.0±0.3
SE(m)	±0.20	±0.22	±12.90	±0.34	±0.37
CD (P<0.05)	0.42	0.46	26.91	NS	NS

Values are means ± SD of three independent determinations

NS - Non significant

Table 29. Crude protein, true protein, non-protein nitrogen, fat and ash cotnents of sprouted ricebean products (on dry matter basis)

Products	Crude protein (g/100 g)	True protein (g/100 g)	Non-protein nitrogen (mg/100 g)	Fat (g/100 g)	Ash (g/100 g)
Sprouted chat					
Raw mixture	18.1±0.4	17.7±0.4	40.2±6.3	1.0±0.4	4.8±0.2
Cooked product	18.5±0.5	18.1±0.5	41.3±2.8	1.0±0.4	5.0±0.4
't' value	1.27NS	1.27NS	0.28NS	0.00NS	0.50NS
Tikki					
Raw mixture	10.6±0.7	10.3±0.6	31.8±3.1	11.3±0.2	5.6±0.2
Cooked product	10.9±0.9	10.4±0.9	52.8±7.8	11.5±0.4	5.5±0.4
't' value	0.60NS	0.98NS	0.77NS	0.50NS	0.50NS
Cutlet					
Raw mixture	12.9±0.2	12.7±0.2	20.9±2.1	20.5±0.4	5.0±0.4
Cooked product	13.0±0.3	12.7±0.3	31.6±2.9	20.3±0.5	5.2±0.2
't' value	0.11NS	0.07NS	2.01NS	0.38NS	0.50NS
Kofta					
Raw mixture	19.4±0.3	19.1±0.3	28.6±2.6	12.8±0.5	5.0±0.4
Cooked product	19.4±0.2	19.1±0.2	32.5±4.8	12.8±0.2	5.2±0.2
't' value	0.16NS	0.16NS	0.72NS	0.10NS	0.50NS
Kachori					
Raw mixture	13.3±0.2	12.8±0.2	51.3±5.7	21.0±0.3	5.8±0.2
Cooked product	13.3±0.2	12.7±0.2	62.3±8.2	20.8±0.3	6.0±0.4
't' value	0.25NS	0.95NS	1.40NS	0.00NS	0.05NS

Values are means ± SD of three independent determinations

NS - Non significant at 5% level

Fat content of other sprouted products in which frying was involved ranged from 11.5 to 20.8 per cent. Depending upon the ingredients used, the ash content of different sprouted ricebean products ranged from 5.0 to 6.0 per cent with the highest being in kachori and the lowest in sprouted chat.

Among the sprouted fababean products, the highest crude and true protein content was in sprouted chat as it contained more of the legume than in other products, and the lowest in tikki (Table 30). Fat content was the highest in deep fried fababean sprouted products like kachori (21.0%), cutlets (20.2%), kofta (14.3%) followed by shallow fried recipe i.e. tikki (11.8%). Ash content varied from 3.2 to 5.5 per cent in various sprouted fababean recipes.

The combination of different domestic processing and cooking methods, viz., sprouting, steaming, slight cooking, shallow frying or deep frying involved in the preparation of various sprouted ricebean and fababean products did not show any effect on the contents of crude and true protein, fat and ash.

Fried products made from ricebean and fababean involved both the shallow and deep frying. Shallow fried products included nutritious parantha and chilla and deep fried products included pakora and papad. Crude protein, true protein, fat and ash content of nutritious parantha was 15.4, 15.2, 8.7 and 6.2 per cent, respectively whereas that of chilla was 18.9, 18.3, 9.7 and 5.8 per cent, respectively. Non-significant differences for crude protein, true protein, NPN, fat and ash contents were

Table 30. Crude protein, true protein, non-protein nitrogen, fat and ash contents of sprouted fababean products (on dry matter basis)

Products	Crude protein (g/100 g)	True protein (g/100 g)	Non-protein nitrogen (mg/100 g)	Fat (g/100 g)	Ash (g/100 g)
Sprouted chat					
Raw mxiture	28.0±0.3	27.7+0.3	41.9±4.6	2.7±0.2	4.0±0.4
Cooked product	27.8±0.3	27.5±0.1	32.6±5.3	2.7+0.2	3.8+0.2
't' value	1.13NS	0.62NS	1.48NS	0.00NS	0.50NS
Tikki					
Raw mixture	14.9±0.2	14.6±0.3	30.7±3.8	11.7±0.2	3.7±0.2
Cooked product	14.9±0.2	14.6±0.1	31.4±4.3	11.8±0.2	4.2±0.2
't' value	0.00NS	0.13NS	0.33NS	0.71NS	2.12NS
Cutlet					
Raw mixture	18.1±0.2	17.7±0.2	42.5±7.2	19.8±0.2	5.3±0.2
Cooked product	17.9±0.3	17.3±0.8	61.2±10.2	20.2±0.6	5.5±0.0
't' value	1.40NS	1.03NS	1.70NS	0.71NS	1.00NS
Kofta					
Raw mixture	23.7±0.2	23.2±0.1	50.7+5.6	14.3±0.2	3.3±0.4
Cooked product	23.8±0.2	23.2±0.2	62.3±7.8	14.3±0.2	3.8±0.2
't' value	0.48NS	0.84NS	0.58NS	0.05NS	1.34NS
Kachori					
Raw mixture	16.7±0.1	16.4±0.1	31.2±6.8	20.8±0.6	3.0±0.4
Cooked product	16.5±0.2	16.1±0.1	40.2±7.8	21.0±0.7	3.2±0.6
't' value	1.29NS	1.48NS	0.38NS	0.25NS	0.31NS

Values are means ± SD of three independent determinations.

NS - Non significant at 5% level

observed between the raw mixtures and shallow fried products (Table 31).

Pakora prepared from ricebean contained 18.7 and 18.1 per cent crude and true protein content whereas the crude and true protein contents in case of papad were 20.7 and 20.4 per cent, respectively. Among all the fried products, pakora contained the maximum amount of fat (22.0%) followed by chilla (9.7%), nutritious parantha (8.7%) and papad (5.8%). Although papad was deep fried but it was fried for less period as compared to other products and, therefore, contained less fat (Table 31). Pakora contained the highest amount of fat whereas parantha had the lowest amount due to difference in the amount of fat used in frying. Different fried products contained good amount of minerals too as the ash content ranged from 5.3 to 6.2 per cent.

Different shallow as well as deep fried products made from fababean had more of crude and true protein than ricebean as fababean contained more amount of crude protein than that of ricebean. Fat and ash content of nutritious parantha, chilla, pakora and papad was 8.0 and 6.5, 13.0 and 6.2, 20.8 and 5.8, 12.3 and 4.2, respectively (Table 32). Shallow or deep fat frying did not bring any change in the crude protein, true protein, fat and ash contents of various fababean products.

Supplementation of ricebean flour with wheat flour improved the crude protein and ash content in chapaties and paranthas (Kaur, 1992). Similarly, supplementation of chickpea

Table 31. Crude protein, true protein, non-protein nitrogen, fat and ash contents of fried ricebean products (on dry matter basis)

Products	Crude protein (g/100 g)	True protein (g/100 g)	Non-protein nitrogen (mg/100 g)	Fat (g/100 g)	Ash (g/100 g)
Shallow fried					
Nutritious parantha					
Raw mixture	15.5±0.2	15.3±0.1	25.2±3.8	8.8±0.2	6.3±0.2
Cooked product	15.4±0.1	15.2±0.1	26.3±2.5	8.7±0.2	6.2±0.2
't' value	0.52NS	1.50NS	0.47NS	0.25NS	0.71NS
Chilla					
Raw mixture	18.8±0.2	18.4±0.2	40.3±5.6	9.7±0.4	5.8±0.2
Cooked product	18.9±0.2	18.3±0.2	56.3±10.2	9.7±0.5	5.8±0.6
't' value	1.10NS	0.34NS	1.50NS	0.38NS	0.00NS
Deep fried					
Pakora					
Raw mixture	18.9±0.3	18.5±0.3	40.9±7.2	21.5±0.4	5.5±0.4
Cooked product	18.7±0.4	18.1±0.3	58.6±8.3	22.0±1.4	5.8±0.2
't' value	0.87NS	0.60NS	2.01NS	0.48NS	1.07NS
Papad					
Raw mixture	20.8±0.4	20.6±0.3	22.7±5.2	5.7±0.2	5.2±0.3
Cooked product	20.7±0.3	20.4±0.3	33.1±4.2	5.8±0.2	5.3±0.2
't' value	0.17NS	0.49NS	0.57NS	0.71NS	0.00NS

Values are means ± SD of three independent determinations

NS - Non significant at 5% level

Table 32. Crude protein, true protein, non-protein nitrogen, fat and ash contents of fried fababean products (on dry matter basis)

Products	Crude protein (g/100 g)	True protein (g/100 g)	Non-protein nitrogen (mg/100 g)	Fat (g/100 g)	Ash (g/100 g)
Shallow fried					
Nutritious parantha					
Raw mixture	21.6±0.3	21.4±0.4	23.9±5.2	7.8±0.2	6.3±0.2
Cooked product	21.5±0.3	21.3±0.3	25.6±4.8	8.0±0.4	6.5±0.4
't' value	0.46NS	0.34NS	0.21NS	0.50NS	0.50NS
Chilla					
Raw mixture	23.9±0.2	23.5±0.1	38.3±11.9	12.8±0.2	6.0±0.0
Cooked product	23.8±0.2	23.6±0.1	25.0±9.5	13.0±0.4	6.2±0.2
't' value	1.29NS	0.24NS	1.24NS	0.50NS	1.00NS
Deep fried					
Pakora					
Raw mixture	25.6±0.2	25.2±0.2	41.2±2.8	21.2±0.8	5.8±0.6
Cooked product	25.3±0.3	25.0±0.3	33.7±5.6	20.8±0.6	5.8±0.2
't' value	1.55NS	0.44NS	0.32NS	0.45NS	0.00NS
Papad					
Raw mixture	28.8±0.7	28.4±0.6	42.9±4.5	12.3±0.2	4.2±0.2
Cooked product	28.6±0.8	28.3±0.5	35.2±6.0	12.3±0.2	4.2±0.2
't' value	0.29NS	0.12NS	0.44NS	0.05NS	0.00NS

Values are means ± SD of three independent determinations

NS - Non significant at 5% level

flour with wheat flour has been known to improve the crude protein and ash content of chapati (Gandhi and Bourne, 1988; Kaur and Hira, 1988).

Fababean cake contained 20.5 per cent crude protein, 20.5 per cent fat and 2.8 per cent ash content (Table 33). Roasted dal had 27.5, 27.0, 3.1 and 4.6 per cent of crude protein, true protein, fat and ash content, respectively. Baking and roasting of fababean did not show any effect on the crude protein, fat and ash content whereas according to Hamilton and Thompson (1992), flame roasting of corn resulted in higher nitrogen content and did not change the ash content.

4.5.1.2 Dietary fibre constituents

NDF, ADF and hemicellulose contents of various boiled ricebean products like dal, khichari and kadhi varied from 10.4 to 14.5, 5.1 to 8.2 and 4.4 to 5.7 per cent, respectively. Cellulose content was the highest in kadhi (8.9%) followed by cooked dal (7.0%) and khichari (5.0%) (Table 34). Lignin and pectin contents in dal, khichari and kadhi were 0.26 and 1.04; 0.23 and 0.96; 0.25 and 1.03 per cent, respectively. Ordinary cooking as well as pressure cooking had no effect on the dietary fibre constituents.

The NDF content of raw mixtures of dal, khichari and kadhi prepared from fababean was 7.6, 6.2 and 9.9 per cent, respectively whereas in these cooked products it was 8.2, 6.8 and 10.7 per cent, respectively (Table 35). Among the boiled fababean products, kadhi contained the maximum ADF (4.4%) followed by khichari (3.1%) and dal (1.9%). Hemicellulose

Table 33. Crude protein, true protein, non-protein nitrogen, fat and ash contents of baked and roasted fababean products (on dry matter basis)

Products	Crude protein (g/100 g)	True protein (g/100 g)	Non-protein nitrogen (mg/100 g)	Fat (g/100 g)	Ash (g/100 g)
Cake					
Raw mixture	20.5±0.5	20.3±0.4	20.6±2.8	20.3±0.5	2.8±0.2
Baked product	20.5±0.3	20.3±0.3	21.2±3.1	20.5±0.4	2.8±0.2
't' value	0.08NS	0.03NS	0.18NS	0.38NS	0.00NS
Roasted dal					
Raw dal	27.4±1.0	27.0±0.3	40.9±5.6	3.0±0.4	4.2±0.2
Roasted dal	27.5±0.4	27.0±0.4	52.8±4.8	3.1±0.2	4.6±0.3
't' value	0.17NS	0.23NS	0.92NS	0.50NS	2.02NS

Values are means ± SD of three independent determinations

NS - Non significant at 5% level

Table 34. Dietary fibre constituents of boiled and baked ricebean products (g/100 g, on dry matter basis)

Products	NDF	ADF	Hemicellulose	Cellulose	Lignin	Pectin
Boiled products						
Dal						
Raw mixture	15.0±0.5	8.7±0.6	4.8±1.4	7.5±0.3	0.30±0.02	1.23±0.02
Cooked product	14.5±0.6	8.2±0.8	5.7±1.5	7.0±0.2	0.26±0.02	1.04±0.02
't' value	0.90NS	0.62NS	0.61NS	1.82NS	1.40NS	2.07NS
Khichari						
Raw mixture	13.5±0.8	6.3±0.5	5.3±0.8	5.1±0.2	0.24±0.03	0.98±0.01
Cooked product	13.9±0.6	6.0±0.4	5.4±0.1	5.0±0.2	0.23±0.02	0.96±0.01
't' value	0.55NS	0.56NS	0.26NS	1.83NS	0.45NS	2.21NS
Kadhi						
Raw mixture	9.3±0.9	5.8±0.4	3.6±0.4	9.5±0.5	0.29±0.03	1.21±0.01
Cooked product	10.4±0.6	5.1±0.5	4.4±0.7	8.9±0.5	0.25±0.03	1.03±0.02
't' value	1.45NS	1.48NS	1.43NS	1.24NS	1.36NS	1.43NS
Baked product						
Cake						
Raw mixture	8.7±0.5	5.4±0.4	3.3±0.2	4.6±0.3	0.43±0.01	0.90±0.01
Baked product	9.5±0.2	5.0±0.4	4.2±0.6	4.5±0.2	0.52±0.04	0.94±0.03
't' value	2.21NS	1.14NS	2.24NS	1.05NS	2.20NS	1.31NS

Value are means ± SD of three independent determinations

NS - Non significant at 5% level

Table 35. Dietary fibre constituents of boiled fababean products (g/100 g, on dry matter basis)

Products	NDF	ADF	Hemicellulose	Cellulose	Lignin	Pectin
Dal						
Raw mixture	7.6±0.4	2.5±0.6	5.0±1.0	2.0±0.3	0.12±0.02	1.63±0.03
Cooked product	8.2±0.3	1.9±0.1	6.8±0.3	1.9±0.2	0.12±0.02	1.60±0.02
't' value	2.18NS	1.41NS	2.35NS	0.38NS	0.00NS	1.31NS
Khichari						
Raw mixture	6.2±0.2	3.5±0.3	2.8±0.3	3.0±0.2	0.30±0.02	0.95±0.01
Cooked product	6.8±0.3	3.1±0.2	3.8±0.4	2.5±0.1	0.35±0.04	0.99±0.02
't' value	2.57NS	2.21NS	2.60NS	2.45NS	2.41NS	2.34NS
Kadhi						
Raw mixture	9.9±0.3	4.9±0.3	4.9±0.1	5.0±0.3	0.35±0.02	1.09±0.06
Cooked product	10.7±0.3	4.4±0.2	6.4±0.2	4.7±0.2	0.46±0.02	1.22±0.02
't' value	2.72NS	2.69NS	2.75NS	1.43NS	2.58NS	2.71NS

Values are means ± SD of three independent determinations.

NS - Non significant at 5% level

content of dal (6.8%) and kadhi (6.4%) was more than that of khichari (3.8%). Cellulose content ranged from 1.9 to 4.7 per cent in various boiled fababean products being the highest in kadhi and the lowest in dal. Cooking lowered down the cellulose content of fababean products but reduction was not significant. Pectin content of different boiled fababean products varied from 0.99 to 1.60 per cent (Table 35). All the dietary fibre constituents of the raw mixture and cooked products did not differ significantly ($P<0.05$) among themselves.

Ordinary cooking and pressure cooking did not affect any of the dietary fibre constituents in boiled products prepared from ricebean and fababean. Vidal-Valverde and Frias (1991) reported that pressure cooking of soaked cowpeas showed a decrease in NDF, ADF cellulose and lignin provided cooking water is removed. Whereas in lentil, no difference in these values was observed as cooking water was retained. Cooking water was retained in the preparation of dal, khichari or kadhi incorporating ricebean or fababean and hence our findings are in line with those reported by Vidal-Valverde and Frias (1991).

NDF and ADF contents of various fermented ricebean products ranged from 5.7 to 11.8 and 3.0 to 7.6 per cent, respectively (Table 36). Cellulose content of idli, dosa and wadi was 6.3, 6.5 and 1 .3 per cent, respectively. Lignin and pectin contents were maximum in wadi and minimum in idli (Table 36).

Table 36. Dietary fibre constituents of fermented ricebean products (g/100 g, on dry matter basis)

Products	NDF	ADF	Hemicellulose	Cellulose	Lignin	Pectin
Idli						
Raw mixture	11.4±0.6	7.1±0.1	4.3±0.6	6.1±0.1	0.35±0.01	0.70±0.01
Soaked mixture	10.2±0.5	6.8±0.2	3.5±0.5	5.9±0.1	0.40±0.01	0.74±0.01
Fermented slurry	11.2±0.5	7.2±0.2	4.0±0.6	5.6±0.1	0.50±0.02	0.78±0.01
Final product	11.5±0.1	7.4±0.2	4.6±0.2	6.3±0.1	0.58±0.01	0.92±0.01
SE(m)	±0.60	±0.24	±0.73	±0.16	±0.02	±0.02
CD (P<0.05)	1.38	0.55	NS	NS	NS	NS
Dosa						
Raw mixture	11.6±0.2	7.6±0.2	4.0±0.3	6.2±0.2	0.42±0.02	0.73±0.01
Soaked mixture	11.1±0.2	7.1±0.1	4.0±0.2	6.3±0.1	0.47±0.02	0.79±0.01
Fermented slurry	11.7±0.2	7.5±0.2	4.2±0.4	6.1±0.2	0.57±0.02	0.82±0.01
Final product	11.8±0.3	7.6±0.2	4.5±0.4	6.5±0.2	0.62±0.01	0.96±0.01
SE(m)	±0.34	±0.24	±0.48	±0.24	±0.02	±0.02
CD (P<0.05)	0.78	0.55	NS	NS	NS	NS
Wadi						
Raw mixture	5.6±0.4	3.1±0.1	2.3±0.3	1.1±0.1	0.95±0.03	1.30±0.01
Soaked mixture	5.0±0.1	2.8±0.1	2.2±0.1	1.1±0.1	1.01±0.04	1.34±0.01
Fermented slurry	5.7±0.3	3.0±0.1	2.6±0.4	1.3±0.1	1.09±0.06	1.40±0.01
Final product	5.7±0.3	3.0±0.1	2.6±0.4	1.3±0.1	1.07±0.06	1.40±0.02
SE(m)	±0.41	±0.13	±0.41	±0.11	±0.07	±0.02
CD (P<0.05)	0.95	0.30	NS	NS	NS	NS

Values are means ± SD of three independent determinations

NS - Non significant.

Among the fermented fababean products, dosa had the maximum NDF (10.2%) whereas wadi had the minimum level of NDF (9.2%). ADF and hemicellulose content of various fermented fababean products ranged from 5.2 to 6.9 and 2.3 to 4.5 per cent, respectively (Table 37). Pectin content was the highest in wadi (1.62%) and the lowest in dosa (0.93%).

Processing methods like soaking, fermentation in combination with steaming or shallow frying or drying in the preparation of fermented products like idli, dosa and wadi from ricebean or fababean did not affect the various dietary fibre constituents. On the contrary, Taguchi et al. (1986) observed that total dietary fibre in natto and tempeh decreased slightly during fermentation. Pectic substances in natto increased by 14 per cent as compared to control. The hemicellulose fraction decreased in fermented tempeh.

NDF and ADF contents of different sprouted ricebean products varied from 9.7 to 14.4 and 5.4 to 8.6 per cent, respectively; maximum being in kofta and minimum in tikki (Table 38). The lowest value for hemicellulose was in sprouted chat (3.6%) and the highest was in kofta (5.8%) may be due to the addition of chickpea flour. Among the sprouted products, chat contained maixmum amount of cellulose followed by kofta, kachori, tikki and cutlet. The products which contained more amount of ricebean sprouts, had more value for cellulose too. Lignin and pectin contents ranged from 0.30 to 0.54 and 0.80 to 1.68 per cent, respectively among different sprouted products. For all the dietary fibre constituents non-significant

Table 37. Dietary fibre constituents of fermented fababean products (g/100 g, on dry matter basis)

Products	NDF	ADF	Hemicellulose	Cellulose	Lignin	Pectin
Idli						
Raw mixture	9.1±0.3	5.2±0.1	3.8±0.4	5.2±0.1	0.37±0.01	0.71±0.01
Soaked mixture	8.9±0.2	5.0±0.1	3.9±0.2	5.1±0.1	0.42±0.02	0.78±0.01
Fermented slurry	9.4±0.7	5.3±0.1	3.9±0.4	5.0±0.1	0.49±0.02	0.87±0.01
Final product	9.4±0.3	5.2±0.1	4.2±0.2	5.3±0.1	0.54±0.01	0.95±0.00
SE(m)	±0.59	±0.14	±0.42	±0.15	±0.03	±0.01
CD (P<0.05)	1.36	0.32	0.97	NS	NS	NS
Dosa						
Raw mixture	10.0±0.2	5.4±0.3	4.6±0.5	5.4±0.1	0.41±0.01	0.77±0.01
Soaked mixture	9.5±0.2	5.4±0.2	4.1±0.4	5.4±0.1	0.46±0.02	0.82±0.01
Fermented slurry	9.9±0.7	5.7±0.2	4.3±0.9	5.6±0.1	0.54±0.01	0.84±0.01
Final product	10.2±0.3	5.7±0.1	4.5±0.1	5.7±0.1	0.59±0.02	0.93±0.01
SE(m)	±0.59	±0.32	±0.79	±0.14	±0.02	±0.01
CD (P<0.05)	1.36	0.74	1.82	NS	NS	NS
Wadi						
Raw mixture	8.5±0.6	6.0±0.7	2.5±0.7	5.6±0.1	0.13±0.02	1.50±0.01
Soaked mixture	8.4±0.6	6.0±0.4	2.4±0.4	5.7±0.2	0.16±0.02	1.54±0.02
Fermented slurry	9.2±0.6	6.9±0.5	2.3±0.1	5.5±0.2	0.20±0.02	1.63±0.01
Final product	9.2±0.4	6.9±0.5	2.3±0.1	5.5±0.2	0.20±0.02	1.62±0.01
SE(m)	±0.81	±0.73	±0.32	±0.22	±0.03	±0.02
CD (P<0.05)	1.87	1.68	0.74	NS	NS	NS

Values are means ± SD of three independent determinations

NS - Non significant at 5% level

Table 38. Dietary fibre constituents of sprouted ricebean products (g/100 g, on dry matter basis)

Products	NDF	ADF	Hemicellulose	Cellulose	Lignin	Pectin
Sprouted chat						
Raw mixture	12.8±0.5	8.5±0.3	4.2±0.3	7.3±0.2	0.32±0.02	1.70±0.02
Cooked product	11.6±0.2	8.0±0.3	3.6±0.6	7.2±0.3	0.30±0.02	1.68±0.02
't' value	2.90NS	1.77NS	1.41NS	0.28NS	0.79NS	0.92NS
Tikki						
Raw mixture	9.0±0.6	5.9±0.3	3.1±0.5	4.3±0.3	0.29±0.03	0.76±0.02
Cooked product	9.7±0.8	5.4±0.3	4.3±0.5	4.0±0.2	0.32±0.01	0.81±0.02
't' value	1.01NS	1.70NS	2.54NS	1.17NS	1.37NS	1.06NS
Cutlet						
Raw mixture	9.5±0.4	6.4±0.6	3.3±1.0	4.1±0.2	0.38±0.04	0.80±0.02
Cooked product	10.5±0.7	5.8±0.6	4.7±1.7	3.8±0.1	0.43±0.03	0.84±0.02
't' value	1.82NS	1.11NS	1.37NS	1.90NS	1.68NS	1.65NS
Kofta						
Raw mixture	14.0±0.4	9.5±0.6	4.5±0.2	7.5±0.3	0.48±0.04	0.98±0.02
Cooked product	14.4±0.4	8.6±0.3	5.8±0.5	7.0±1.4	0.54±0.03	1.02±0.02
't' value	0.95NS	1.95NS	2.27NS	1.43NS	1.97NS	1.59NS
Kachori						
Raw mixture	10.2±0.4	7.0±0.4	3.3±0.7	5.9±0.3	0.30±0.05	0.76±0.02
Cooked product	11.3±0.4	6.3±0.2	5.0±0.6	5.3±0.2	0.35±0.05	0.80±0.02
't' value	2.25NS	1.83NS	2.55NS	2.07NS	1.04NS	1.65NS

Values are means ± SD of three independent determinations

NS - Non significant at 5% level

differences were observed between the raw mixtures and various final sprouted products. A similar trend was observed in sprouted fababean products (Table 39) indicating that processing methods like sprouting in combination with slight cooking, shallow frying on deep frying showed no effect on the dietary fibre constituents of various ricebean or fababean sprouted products.

NDF, ADF, hemicellulose, cellulose, lignin and pectin contents of nutritious parantha and chilla prepared from ricebean were 11.9, 7.8, 4.1, 4.4, 0.40 and 0.95 per cent and 15.3, 9.6, 5.7, 8.2, 0.41 and 0.97 per cent, respectively (Table 40). NDF and ADF constituents increased from 14.9 to 15.2 and 9.1 to 9.7 per cent when raw mixture of pakoras was given the shape of final product. Hemicellulose and cellulose content was more of chilla than the rest of shallow and deep fried ricebean products. Lignin content of the papad was the highest (0.47%) followed by pakora (0.41%), chilla (0.41%) and parantha (0.40%). Pectin content of various fried products was not affected by frying.

NDF and hemicellulose content was maximum in chilla and minimum in nutritious parantha among different fried fababean product (Table 41). Pectin content of different fried fababean products ranged from 0.74 to 1.02 per cent whereas their raw mixtures contained pectin ranging from 0.72 to 1.15 per cent. In case of shallow fried and deep fried ricebean and fababean products, non-significant differences were observed between the

Table 39. Dietary fibre constituents of sprouted fababean products (g/100 g, on dry matter basis)

Products	NDF	ADF	Hemicellulose	Cellulose	Lignin	Pectin
Sprouted chat						
Raw mixture	7.2±0.2	4.8±0.2	2.4±0.1	4.5±0.3	0.30±0.02	1.81±0.02
Cooked product	6.6±0.4	4.2±0.2	2.4±0.1	4.3±0.5	0.25±0.02	1.73±0.01
't' value	2.19NS	2.75NS	0.73NS	0.50NS	2.06NS	2.72NS
Tikki						
Raw mixture	5.3±0.2	2.8±0.2	2.6±0.4	2.8±0.2	0.24±0.03	0.85±0.03
Cooked product	6.2±0.5	2.3±0.2	4.2±0.3	2.5±0.1	0.36±0.02	0.89±0.02
't' value	2.29NS	2.74NS	2.73NS	2.15NS	2.15NS	1.26NS
Cutlet						
Raw mixture	5.8±0.1	3.0±0.3	2.8±0.1	2.7±0.2	0.25±0.03	0.85±0.02
Cooked product	6.4±0.4	2.7±0.2	3.7±0.5	2.4±0.2	0.34±0.03	0.91±0.01
't' value	2.25NS	1.50NS	2.58NS	2.18NS	2.72NS	2.68NS
Kofta						
Raw mixture	9.5±1.1	4.9±0.3	4.7±1.4	5.2±0.4	0.35±0.03	1.02±0.02
Cooked product	10.0±0.8	4.4±0.1	5.3±0.8	5.0±0.2	0.41±0.04	1.11±0.02
't' value	0.52NS	2.43NS	0.58NS	0.65NS	2.64NS	2.46NS
Kachori						
Raw mixture	6.8±0.1	4.2±0.2	2.7±0.1	4.1±0.3	0.25±0.03	0.81±0.03
Cooked product	7.4±0.4	3.7±0.2	3.8±0.3	3.6±0.2	0.34±0.02	0.87±0.02
't' value	2.27NS	2.57NS	2.27NS	2.03NS	2.28NS	2.12NS

Values are means ± SD of three independent determiantions.

NS - Non significant at 5% level

Table 40. Dietary fibre constituents of fried ricebean product (g/100 g, on dry matter basis)

Products	NDF	ADF	Hemicellulose	Cellulose	Lignin	Pectin
Shallow fried						
Nutritious parantha						
Raw mixture	11.5±0.8	7.3±0.3	4.1±0.9	4.7±0.5	0.30±0.04	0.91±0.01
Cooked product	11.9±0.5	7.8±0.2	4.1±0.2	4.4±0.5	0.40±0.03	0.95±0.01
't' value	0.60NS	1.78NS	0.09NS	0.64NS	2.12NS	2.21NS
Chilla						
Raw mixture	14.7±0.8	9.2±0.2	5.6±0.7	8.5±0.4	0.30±0.02	0.93±0.01
Cooked product	15.3±0.2	9.6±0.3	5.7±0.2	8.2±0.2	0.41±0.04	0.97±0.02
't' value	0.99NS	1.75NS	0.34NS	1.21NS	2.14NS	1.97NS
Deep fried						
Pakora						
Raw mixture	14.9±0.7	9.1±0.4	5.8±0.4	8.5±0.1	0.32±0.04	0.96±0.02
Cooked product	15.2±0.5	9.7±0.6	5.5±0.2	8.4±0.2	0.41±0.02	0.92±0.01
't' value	0.53NS	1.30NS	0.87NS	1.06NS	2.25NS	2.02NS
Papad						
Raw mixture	12.4±0.3	8.4±0.3	4.2±0.3	6.3±0.4	0.41±0.03	0.65±0.02
Cooked product	12.6±0.6	8.6±0.5	3.9±0.8	6.1±0.2	0.47±0.04	0.73±0.01
't' value	0.34NS	0.65NS	0.46NS	0.75NS	1.71NS	1.98NS

Values are means ± SD of three independent determinations

NS - Non significant at 5% level

Table 41. Dietary fibre constituents of fried fababean products (g/100 g, on dry matter basis)

Products	NDF	ADF	Hemicellulose	Cellulose	Lignin	Pectin
Shallow fried						
Nutritious parantha						
Raw mixture	7.7±0.4	4.2±0.3	3.5±0.1	4.0±0.3	0.30±0.02	0.98±0.03
Cooked product	8.2±0.3	3.9±0.2	4.3±0.2	3.7±0.2	0.37±0.03	1.02±0.02
't' value	1.51NS	1.19NS	2.76NS	1.50NS	2.18NS	1.14NS
Chilla						
Raw mixture	9.9±0.2	4.7±0.2	5.1±0.3	4.8±0.5	0.27±0.03	1.06±0.04
Cooked product	10.5±0.7	4.4±0.3	6.2±0.5	4.1±0.2	0.36±0.03	1.00±0.06
't' value	1.40NS	1.73NS	2.47NS	1.87NS	2.52NS	1.67NS
Deep fried						
Pakora						
Raw mixture	9.7±0.4	4.7±0.2	5.0±0.5	4.8±0.4	0.25±0.02	1.15±0.05
Cooked product	10.4±0.6	4.4±0.2	6.0±0.6	4.5±0.3	0.32±0.02	1.01±0.02
't' value	1.37NS	2.01NS	1.81NS	0.96NS	2.48NS	3.50NS
Papad						
Raw mixture	8.6±0.3	3.9±0.2	4.7±0.5	3.2±0.4	0.35±0.03	0.72±0.02
Cooked product	8.9±0.2	3.4±0.1	5.5±0.3	2.9±0.2	0.45±0.04	0.74±0.02
't' value	1.27NS	2.23NS	1.84NS	1.13NS	2.68NS	1.20NS

Values are means ± SD of three independent determinations

NS - Non significant at 5% level

raw mixtures and their final products for NDF, ADF, hemicellulose, lignin and pectin contents (Table 40 and 41). Hence, frying did not change the various dietary fibre constituents of fried ricebean and fababean products.

More the quantity of fababean in a product, more was the amount of NDF, hemicellulose and pectin; roasted dal had 8.7 per cent NDF, 6.5 per cent hemicellulose and 1.61 per cent pectin as compared to 6.1 per cent NDF, 3.7 per cent hemicellulose and 0.96 per cent pectin in cake (Table 42). When the raw mixtures of fababean was baked or roasted the composition of various dietary fibre constituents did not change. Similar findings has been reported by Hamilton and Thompson (1992) in corn where flame roasting resulted in no change in the fibre fraction.

4.5.2 In vitro digestibilities

4.5.2.1 Starch digestibility (in vitro)

The starch digestibility of raw mixtures of dal, khichari and kadhi prepared from ricebean was 30.8, 34.8 and 32.8 mg maltose released/g meal, respectively (Table 43). Pressure cooking as well as ordinary cooking brought a significant ($P<0.05$) improvement in starch digestibility with maximum enhancement observed in khichari followed by dal and kadhi. The increase in the cooked products i.e. in dal, khichari and kadhi was 49, 72 and 30 per cent, respectively, over the control values. The starch digestibility of raw mixtures of cake was 35.9 mg maltose released/g meal which was increased to 48.4 mg maltose/g meal after baking.

Table 42. Dietary fibre constituents of baked and roasted fababean products (g/100 g, on dry matter basis)

Products	NDF	ADF	Hemicellulose	Cellulose	Lignin	Pectin
Cake						
Raw mixture	5.8±0.1	2.5±0.2	3.1±0.2	2.3±0.1	0.34±0.4	0.92±0.02
Baked product	6.1±0.4	2.2±0.1	3.7±0.3	2.0±0.2	0.42±0.4	0.96±0.01
't' value	2.58NS	1.93NS	2.71NS	2.74NS	2.62NS	2.34NS
Roasted dal						
Raw dal	7.8±1.4	2.1±0.1	5.7±1.5	1.9±0.3	0.10±0.02	1.63±0.02
Roasted dal	8.7±1.1	2.0±0.8	6.5±0.5	1.9±0.2	0.19±0.03	1.61±0.05
't' value	0.71NS	0.62NS	0.70NS	0.20NS	2.60NS	0.4#NS

Values are means ± SD of three independent determinations

NS - Non significant at 5% level

Table 43. *In vitro* protein digestibility and starch digestibility of boiled and baked ricebean products (on dry matter basis)

Products	Protein digestibility (%)	Starch digestibility (mg maltose released/g meal)
Boiled products		
Dal		
Raw mixture	58.2±2.2	30.8±0.5
Cooked product	72.4±2.7 (24)	46.0±0.7 (49)
't' value	9.16*	37.7*
Khichari		
Raw mixture	62.8±2.42	34.8±0.7
Cooked product	76.5±3.73 (22)	59.7±1.1 (72)
't' value	6.86*	40.98*
Kadhi		
Raw mixture	59.6±2.3	32.8±0.5
Cooked product	68.2±2.0 (14)	42.5±1.1 (30)
't' value	6.32*	17.0*
Baked product		
Cake		
Raw mxiture	64.1±2.3	35.9±0.6
Baked product	72.9±2.0 (14)	48.4±1.1 (35)
't' value	6.55*	21.76*

Values are means ± SD of three independent determinations

*Significant at 5% level

Figures in parentheses indicate per cent increase over control values

The *in vitro* starch digestibility of raw mixtures of fababean *dal*, *khichari* and *kadhi* varied from 42.4 to 51.9 mg maltose released/g meal (Table 44). Pressure cooked product showed more improvement in starch digestibility than ordinarily cooked products. Maximum improvement in starch digestibility was noticed in *khichari* followed by *dal* and *kadhi*.

Significant ($P<0.05$) variations were observed between the *in vitro* starch digestibility of raw mixtures and final cooked products of *dal*, *khichari* and *kadhi* prepared from ricebean and fababean. Similar increases in starch digestibility on boiling and pressure cooking have been reported by earlier workers in different legumes including amphidiploids (Kataria *et al.*, 1990), ricebean (Kaur and Kapoor, 1990b), pigeonpeas (Duhan, 1992), fababean (Sharma and Sehgal, 1992; Parihar *et al.*, 1993) and peas (Bishnoi and Khetarpaul, 1993b).

Enhanced digestibility of cooked legumes starches by alpha-amylase could be attributed to the swelling and rupturing of starch granules which facilitates more randomized configuration for α-amylase to affect hydrolysis, the disintegration of various bean components during cooking and inactivation of α-amylase inhibitors. Differences in starch digestibility during heat treatment may occur due to differences in the extent of starch gelatinisation.

The starch digestibility of raw mixtures of *idli* prepared from ricebean was 41.1 which was increased significantly ($P<0.05$) to 48.8 mg maltose released/g meal on soaking (Table 45). Fermentation at 35°C for 12 h further brought an

Table 44. *In vitro* protein digestibility and starch digestibility of boiled fababean products (on dry matter basis)

Products	Protein digestibility (%)	Starch digestibility (mg maltose released/g meal)
Dal		
Raw mixture	57.5±1.9	42.4±0.4
Cooked product	63.9±2.5 (11)	59.3±1.0 (40)
't' value	4.52*	34.5*
Khichari		
Raw mxiture	60.1±3.1	45.9±0.88
Cooked product	69.3±4.4 (15)	70.6±0.73 (54)
't' value	3.82*	48.3*
Kadhi		
Raw mixture	55.0±1.1	51.9±0.8
Cooked product	62.7±1.4 (14)	63.7±0.7 (23)
't' value	13.03*	24.38*

Values are means ± SD of three independent determinations

*Significant at 5% level

Figures in parentheses indicate per cent increase over control values

enhancement in starch digestibility i.e. 54 per cent over the control value. The fermented slurry was steamed in idli moulds, the final product had 73 per cent increase in starch digestibility over the control value. Maximum improvement in starch digestibility was observed due to fermentation, followed by soaking and then steaming in the preparation of idli (Table 45).

Similar trend for improvement in starch digestibility was observed at different stages i.e. soaking, fermentation and shallow frying involved in the preparation of ricebean dosa. Raw mixture of dosa had the starch digestibility of 39.5 mg maltose released/g meal. Soaking, fermentation and shallow frying of dosa increased the digestibility of stach by 22, 59 and 72 per cent, respectively over the control values. The starch digestibility of wadi prepared from ricebean increased from 38.4 in the raw mixture to 58.7 mg maltose released/g meal in the final product. Soaking (at 35°C for 12 h) and fermentation (at 35°C for 12 h) significantly improved the starch digestibility by 12 and 53 per cent, respectively over the control values. During drying of wadi, no further improvement occurred indicating that drying did not affect the starch digestibility.

The in vitro starch digestibility of raw mixtures of fermented fababean products ranged from 43.0 to 47.8 mg maltose released/g meal (Table 46). Soaked rice-dal mixtures or only dal for the preparation of idli, dosa and wadi showed an increase of 19, 21 and 14 per cent, respectively, over the control values. Fermentation at 35°C caused further increase in

Table 45. *In vitro* protein digestibility and starch digestibility of fermented ricebean products (on dry matter basis)

Products	Protein digestibility (%)	Starch digestibility (mg maltose released/g meal)
Idli		
Raw mixture	63.4±1.0	41.1±0.2
Soaked mixture	74.0±1.0 (17)	48.8±0.2 (19)
Fermented slurry	81.6±1.3 (29)	63.4±0.5 (54)
Final product	88.8±1.0 (40)	70.9±0.3 (73)
SE(m)	±1.54	±0.50
CD (P<0.05)	3.21	1.04
Dosa		
Raw mixture	63.3±1.2	39.5±0.3
Soaked mixture	74.1±1.5 (17)	48.0±0.4 (21)
Fermented slurry	81.2±1.0 (28)	62.6±0.3 (59)
Final product	87.4±1.6 (38)	67.9±0.3 (72)
SE(m)	±1.93	±0.45
CD (P<0.05)	4.02	0.94
Wadi		
Raw mixture	63.8±0.6	38.4±0.4
Soaked mixture	72.4±0.8 (14)	42.9±0.3 (12)
Fermented slurry	84.4±0.7 (32)	58.9±0.2 (53)
Final product	84.3±0.6 (32)	58.7±0.3 (53)
SE(m)	±1.02	±0.43
CD (P<0.05)	2.13	0.90

Values are means ± SD of three independent determinations
Figures in parentheses indicate the percent increase over control values.

Table 46. In vitro protein digestibility and starch digestibility of fermented fababean products (on dry matter basis)

Products	Protein digestibility (%)	Starch digestibility (mg maltose released/g meal)
Idli		
Raw mixture	59.7±2.0	44.3±0.9
Soaked mixture	65.6±1.9 (10)	52.5±0.6 (19)
Fermented slurry	73.5±1.3 (23)	67.2±0.4 (52)
Final product	79.3±1.5 (33)	75.9±0.6 (71)
SE(m)	±2.41	±0.95
CD (P<0.05)	5.03	1.98
Dosa		
Raw mixture	61.5±1.2	43.0±0.6
Soaked mxiture	66.3±2.2 (7)	51.9±0.3 (21)
Fermented slurry	71.9±2.0 (17)	65.6±0.6 (53)
Final product	79.5±1.7 (29)	70.6±0.3 (64)
SE(m)	±2.56	±0.66
CD (P<0.05)	5.34	1.38
Wadi		
Raw mixture	56.0±0.7	47.8±0.4
Soaked mixture	61.2±0.9 (9)	54.5±0.4 (14)
Fermented slurry	68.5±0.6 (22)	69.8±0.8 (46)
Final product	68.2±0.8 (22)	70.4±1.0 (47)
SE(m)	±1.10	±1.01
CD (P<0.05)	2.29	2.11

Values are means ± SD of three independent determinations

Figures in parentheses indicate per cent increase over control values

starch digestibility of idli, dosa and wadi, maximum improvement occurred in the fermented slurry of dosa (53%) followed by idli (52%) and wadi (46%) when compared to their respective raw mixtures. Steaming of fermented fababean idli batter resulted in an enhancement of 19 per cent whereas shallow frying in case of dosa increased the starch digestibility by 11 per cent after fermentation indicating that steaming was more effective than shallow frying for improving the starch digestibility. In case of wadi, non-significant differences were witnessed between the starch digestibility of fermented slurry and dried product showing that drying was not effective in improving the starch digestibility.

The cumulative effect of different treatments used in preparation of idli, dosa and wadi from ricebean and fababean in increasing the starch digestibility has been observed. The breakdown of starch to oligosaccharides by fermenting microflora (Cronk et al., 1977) or by the enzyme inherent in legume grains may be responsible for improvement in starch digestibility during fermentation. Amylolysis has been reported to be inhibited by phytic acid (Thompson and Yoon, 1984) and hence the reduction in the phytate content of fermented products during fermentation as observed in this study (Tables 60 and 61) may account for improvement in starch digestibility of the fermented products. A significant ($P<0.05$) and negative relationship has been found between antinutrients and starch digestibility in all the fermented products prepared from ricebean (Table 54) and fababean (Table 55).

An increase in starch digestibility (in vitro) during fermentation has been reported in soyabean (Boralkar and Reddy, 1985; Grewal, 1992), cereal-legume blends (Goyal, 1991), tef (Ramachandran and Bolodia, 1984) and blackgram (Chaudhary, 1993). Soni and Sandhu (1990) reported a higher amylase activity in conventional blackgram wadi dough after 3 day fermentation. Similar increases in starch digestibility of greengram and blackgram dal wadies at different time and period of fermentation has been reported by Yadav (1992).

The starch digestibility of different sprouted products varied from 58.2 to 77.8 mg maltose released/g meal with maximum starch digestibility in sprouted chat, followed by cutlets, tikki, kofta and kachori (Table 47). The starch digestibility of the raw mixture of sprouted chat was 31.6 mg maltose released/g meal and after sprouting and slight cooking, the starch digestibility of the final product was more than doubled. An increase to the extent of 31, 37, 18 and 22 per cent over the control value occurred in case of tikki, cutlet, kofta and kachori, respectively. More the amount of sprouted pulse used in the preparation of a product more was the improvement in starch digestibility.

Significant improvement in starch digestibility was observed in all the fababean sprouted products too (Table 48). Starch digestibility of raw mixtures of sprouted chat, tikki, cutlets, kofta and kachori prepared from fababean was 51.9, 64.4, 70.5, 51.7 and 50.3 mg maltose released/g meal. Maximum increase over the control value in starch digestibility was

Table 47. *In vitro* protein digestibility and starch digestibility of sprouted ricebean products (on dry matter basis)

Products	Protein digestibility (%)	Starch digestibility (mg maltose released g/meal)
Sprouted chat		
Raw mixture	58.8±2.0	31.6±0.6
Final product	75.9±2.9 (29)	77.8±0.7 (146)
't' value	10.74*	12.58*
Tikki		
Raw mixture	72.9±3.7	52.8±0.7
Final product	77.2±4.3 (6)	69.0±0.8 (31)
't' value	3.80*	32.63*
Cutlet		
Raw mixture	63.4±2.7	51.4±1.3
Final product	77.7±2.2 (23)	70.3±0.7 (37)
't' value	9.10*	27.3*
Kofta		
Raw mixture	67.0±2.4	49.8±0.8
Final product	74.1±2.4 (11)	58.6±0.6 (18)
't' value	4.69*	18.66*
Kachori		
Raw mixture	69.4±2.7	48.1±0.6
Final product	77.5±3.3 (12)	58.2±0.8 (22)
't' value	4.19*	21.98*

Values are means ± SD of three independent determinations

*Significnat at 5% level

Figures in parentheses indicate per cent increase over control values

Table 48. In vitro protein digestibility and starch digestibility of sprouted fababean products (on dry matter basis)

Products	Protein digestibility (%)	Starch digestibility (mg maltose reseased/g meal)
Sprouted chat		
Raw mixture	59.0±1.9	51.9±1.4
Cooked product	71.7±2.0	85.1±1.5
	(21)	(64)
't' value	8.99*	35.81*
Tikki		
Raw mixture	71.6±1.2	64.4±0.6
Cooked product	78.0±1.7	79.3±0.7
	(9)	(23)
't' value	6.90*	34.2*
Cutlet		
Raw mixture	66.1±3.6	70.5±0.7
Cooked product	74.8±3.6	82.4±0.8
	(13)	(17)
't' value	3.85*	25.93*
Kofta		
Raw mixture	65.7±3.6	51.7±1.9
Cooked product	73.7±2.4	68.0±2.6
	(12)	(32)
't' value	4.15*	13.63*
Kachori		
Raw mixture	57.1±2.8	50.3±1.4
Cooked product	65.2±2.8	62.3±3.0
	(14)	(24)
't' value	4.61*	11.14*

Values are means ± SD of three independent determinations

*Significant at 5% level

Figures in parentheses indicate per cent increase over cotnrol values.

noticed in sprouted chat (64%), followed by kofta (32%), kachori (24%), tikki (23%) and cutlets (17%).

The combination of processing and cooking treatments like sprouting and frying significantly ($P<0.05$) enhanced the starch digestibility of all the sprouted products prepared from ricebean and fababean. During germination the activity of certain enzymes like amylase and phosphorylase present in legume grains is enhanced and hence, causes the predigestion of starch molecule. The resulting enhanced concentration of oligosaccharide in the sprouts may attribute to better starch digestibility (Nnanna and Philips, 1990). Morever, the level of anti-nutrients including phytic acid, polyphenol, saponin and trypsin inhibitor activity is reduced (Tables 62 and 63) in sprouted products which also contributes to improved starch digestibility. A significant and negative correlation between in vitro starch digestibility with antinutrients in sprouted products further strengthened our findings (Tables 54 and 55). Earlier workers (Kataria et al., 1990a; Nnanna and Philips, 1990; Kaur and Kapoor, 1990b; Sharma and Sehgal, 1991a; Bishnoi and Khetarpaul, 1993b) have also reported the beneficial effects of sprouting on starch digestibility.

The starch digestibility of raw mixture of nutritious parantha and chilla prepared from ricebean was 32.7 and 33.1 and was increased to 37.6 and 41.9 mg maltose released/g meal respectively on shallow frying (Table 49). In deep fried product like pakora, the improvement in starch digestibility was 31 per cent whereas in papad, it was only 9 per cent over

Table 49. In vitro protien digestibility and starch digestibility of fried ricebean products (on dry matter basis)

Products	Protein digestibility (%)	Starch digestibility (mg maltose reseased/g meal)
Shallow fried		
Nutritious parantha		
Raw mixture	58.5±2.5	32.7±0.7
Final product	61.8±4.1 (6)	37.6±2.0 (15)
't' value	3.52*	5.21*
Chilla		
Raw mixture	58.3±1.5	33.1±0.6
Final product	64.7±2.7 (11)	41.9±1.0 (27)
't' value	4.07*	16.49*
Deep fried		
Pakora		
Raw mixture	57.4±2.5	34.4±1.0
Final product	67.1±2.0 (17)	45.1±1.3 (31)
't' value	6.87*	14.12*
Papad		
Raw mxiture	60.3±2.4	40.7±0.6
Final product	63.9±1.7 (6)	44.4±0.5 (9)
't' value	5.59*	10.12*

Values are means ± SD of three independent determinations

*Significant at 5% level

Figures in parentheses indicate per cent increase over control values

the control values. Less improvement in starch digestibility of papad than pakora may be due to less time of frying involved in papad frying.

In the fried products prepared from fababean, the starch digestibility of raw mixture ranged 49.2 to 51.9 mg maltose released/g meal (Table 50). Maximum improvement was observed in pakora followed by nutritious parantha, chilla and papad. There were significant ($P<0.05$) differences between the starch digestibility of raw mixtures and final fried products prepared from ricebean and fababean showing that frying did improve the starch digestibility.

Starch digestibility of raw mixtures of cake and roasted dal prepared from fababean was 50.6 and 47.7 mg maltose released/g meal and it improved to the extent of 14 and 37 per cent, respectively over the control values (Table 51). Roasting was found to be more effective than baking in enhancing the starch digestibility of fababean.

During frying, baking and roasting, the heat treatment involved increases the activity of alpha-amylases as a result of which the rate of amylosis is increased which ultimately leads to higher starch digestibility of fried, baked and roasted products. The rate of amylosis in cooked mothbean and horse gram was about 3 times than that observed in uncooked samples (Subhulakshmi et al., 1976). Significant difference in amylosis rates in processed legume seeds, as compared to raw has been reported (Geervani and Theophilus, 1980; El-Faki et al., 1984).

Table 50. *In vitro* protein digestibility and starch digestibility of fried fababean products (on dry matter basis)

Products	Protein digestibility (%)	Starch digestibility (mg maltose released/g meal)
Shallow fried		
Nutritious parantha		
Raw mixture	53.3±1.8	49.2±1.8
Cooked product	57.0±2.2 (7)	55.7±0.6 (13)
't' value	4.49*	7.49*
Chilla		
Raw mixture	60.8±2.0	51.3±0.6
Cooked product	64.2±2.4 (6)	56.4±0.7 (10)
't' value	2.52*	11.91*
Deep fried		
Pakora		
Raw mixture	59.2±1.6	51.9±0.5
Cooked product	64.4±2.5 (8)	61.6±0.7 (19)
't' value	3.91*	26.10*
Papad		
Raw mixture	60.5±1.9	50.3±0.6
Cooked product	64.2±2.0 (6)	55.3±1.1 (10)
't' value	2.89*	7.83*

Values are means ± SD of three independent determinations

*Significant at 5% level

Figures in parentheses indicate per cent increase over control values

Table 51. *In vitro* protein digestibility and starch digestibility of baked and roasted fababean products (on dry matter basis)

Products	Protein digestibility (%)	Starch digestibility (mg maltose released/g meal)
Cake		
Raw mixture	59.0±2.0	50.6±0.7
Baked product	68.4±3.1 (16)	57.5±0.5 (14)
't' value	5.64*	17.33*
Roasted dal		
Raw dal	58.0±1.9	47.7±1.0
Roasted dal	63.0±2.0 (7)	65.1±1.8 (37)
't' value	4.01*	18.59*

Values are means ± SD of three independent determinations.

*Significant at 5% level.

Figures in parentheses indicate per cent increase over control values.

Overall, it was observed that among all the products prepared from ricebean, the maximum improvement in starch digestibility was observed in sprouted products (18 to 146%) followed by fermented (53 to 72%), boiled (30 to 71%), baked (35%) and fried products (9 to 31%) (Table 52). In case of fababean products maximum improvements were in the sprouted products, followed by fermented, boiled, roasted, fried and baked products (Fig. 1).

4.5.2.2 Protein digestibility (in vitro)

The protein digestibility of raw mixtures of dal, khichari and kadhi varied from 58.2 to 62.8 per cent due to variation in the type and amount of ingredients used in their preparation (Table 43). There were significant ($P<0.05$) differences between the protein digestibility of raw mixtures and the cooked products. As the result of cooking, the protein digestibility of these products improved significantly ($P<0.05$). Protein digestibility of dal, khichari and kadhi increased from 58.2 to 72.4, 62.8 to 76.5 and 59.6 to 68.2 per cent, respectively when their raw mixtures were cooked. The protein digestibility was increased by 24 per cent in dal, 22 per cent in khichari and 14 per cent in kadhi over the control values. The increase in the protein digestibility was more due to pressure cooking than ordinary cooking. Baking of cake could cause 14 per cent increase in protein digestibility over the control value (Table 43).

The raw mixture of dal, khichari and kadhi prepared from fababean had 57.5, 60.1 and 55.0 per cent protein digestibility

Table 52. Per cent increase in *in vitro* protein digestibility and starch digestibility over the control values of ricebean products

Products	Protein digesti-bility	Ranks	Starch digesti-bility	Ranks
Boiled products	14-24	III	30-71	III
Fermented products	32-40	I	53-72	II
Sprouted products	6-29	II	18-146	I
Fried products	6-17	IV	9-31	V
Baked product	14	V	35	IV

Table 53. Per cent increase in *in vitro* protein digestibility and starch digestibility over the control values of fababean products

Products	Protein digesti-bility	Ranks	Starch digesti-bility	Ranks
Boiled products	11-15	IV	23-54	III
Fermented products	22-23	I	47-71	I
Sprouted products	9-22	II	17-64	II
Fried products	6-8	VI	10-19	V
Baked product	16	III	14	VI
Roasted product	9	V	36	IV

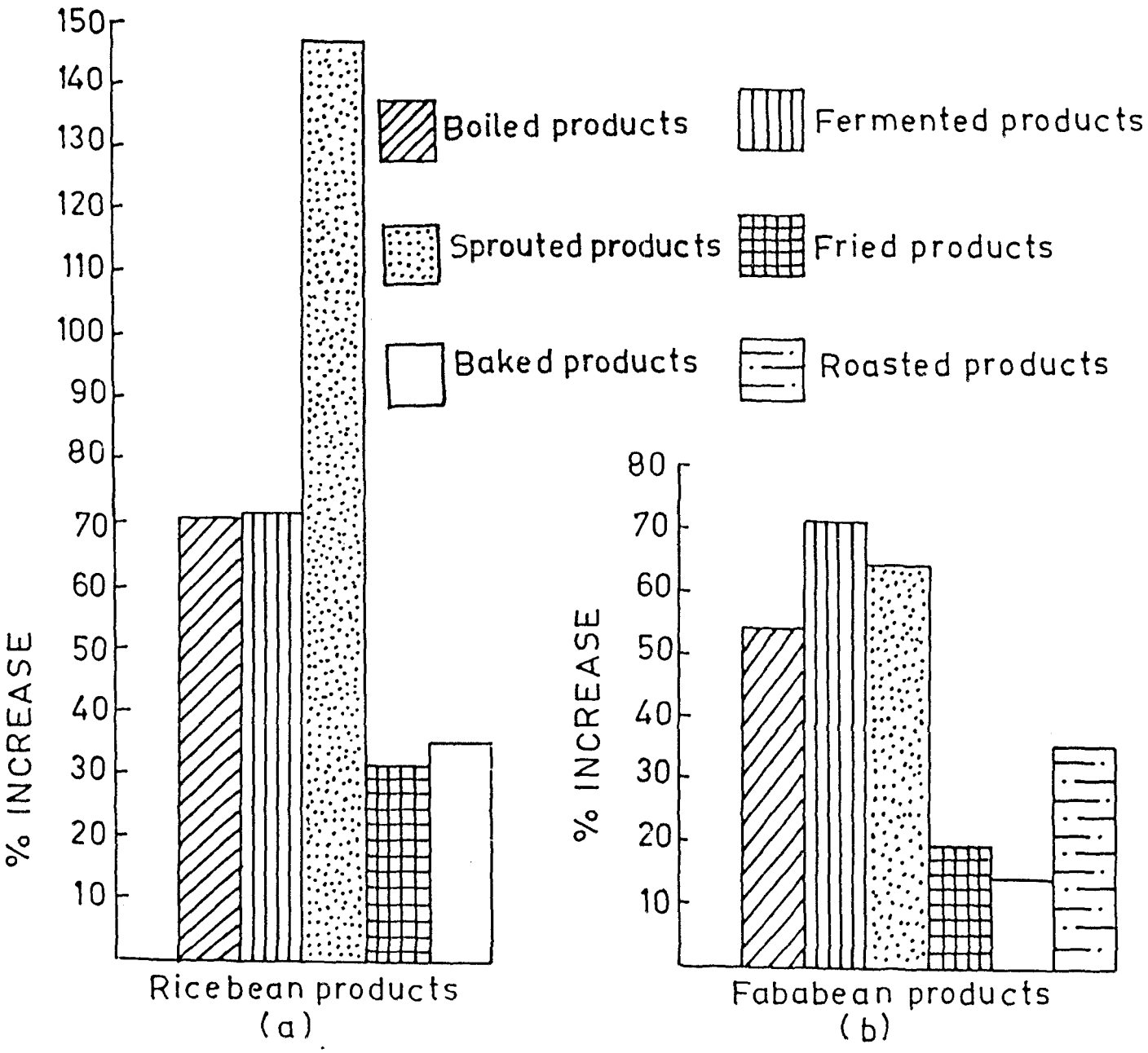

FIG. 1. EFFECT OF BOILING, FERMENTATION, SPROUTING, FRYING, BAKING AND ROASTING ON STARCH DIGESTIBILITY (in vitro) OF RICEBEAN (a) and FABABEAN PRODUCTS (b)

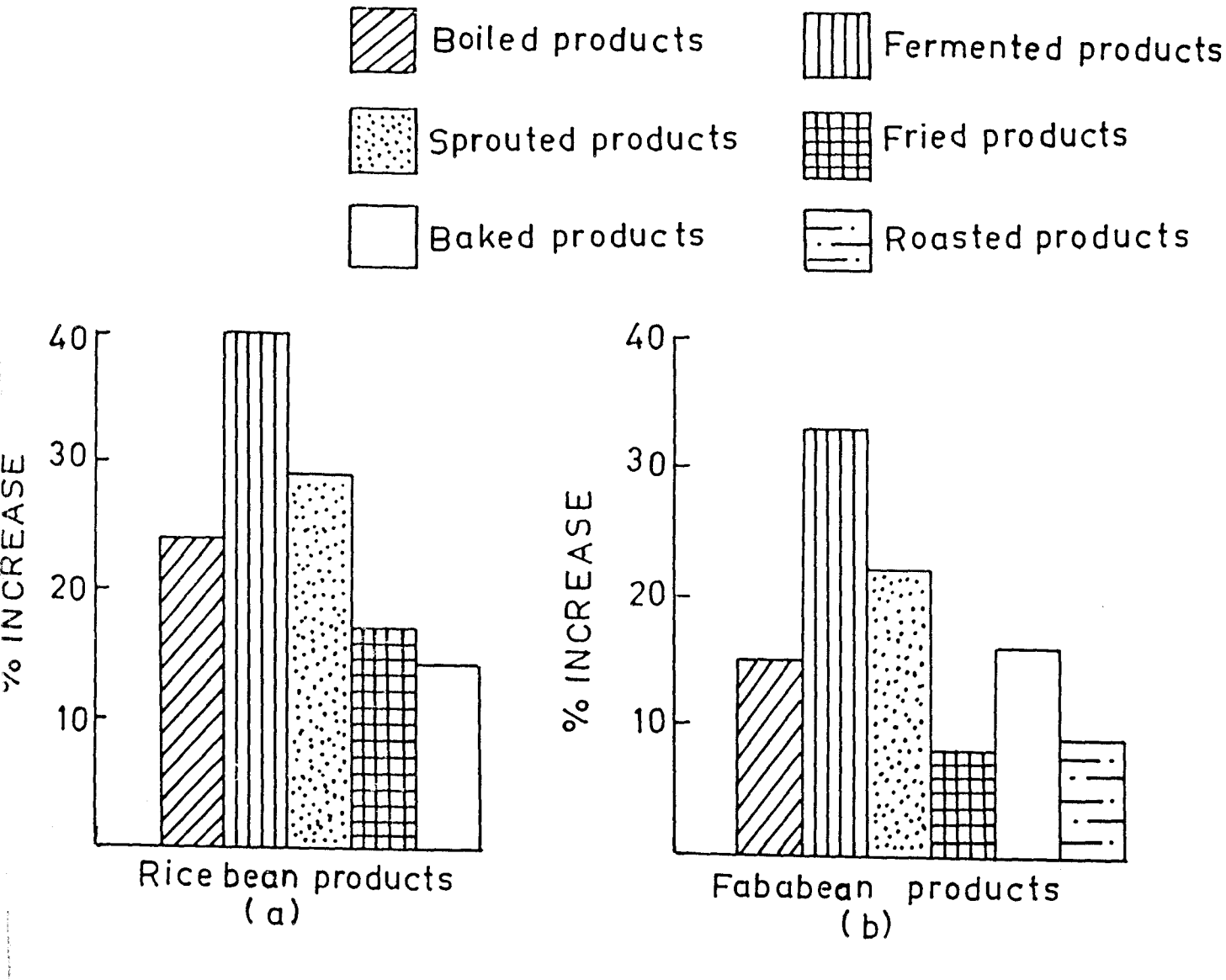

FIG. 2. EFFECT OF BOILING, FERMENTATION, SPROUTING, FRYING, BAKING AND ROASTING ON PROTEIN DIGESTIBILITY (in vitro) OF RICEBEAN (a) AND FABABEAN PRODUCTS (b).

Table 54. Correlation coefficients of antinutritional factors with *in vitro* digestibility of starch of ricebean and its products

	Antinutritional factors			
	Phytic acid	Polyphenols	Saponins	Trypsin inhibitor activity
Raw	-0.7423*	-0.7128	-0.7682*	-0.8236*
Soaked	-0.7864*	-0.8102*	-0.8468*	-0.9021*
Sprouted	-0.8973*	-0.8829*	-0.9128**	-0.9216**
Boiled products	-0.9103*	-0.9031*	-0.9241**	-0.9761*
Fermented products	-0.9281**	-9.9179**	-9.9381**	-0.9461**
Sprouted products	-0.9305**	-0.8578*	-0.8821*	-0.8683*
Fried products	-0.7061*	-0.7124*	-0.8028*	-0.7926*
Baked product	-0.6283*	-0.5823*	-0.4082	-0.7284*

* Significant at 5% level

**Significant at 1% level

Table 55. Correlation coefficients of antinutritional factors with *in vitro* digestibility of starch of fababean and its products

	Antinutritional factors			
	Phytic acid	Polyphenols	Saponins	Trypsin inhibitor activity
Raw	-0.7621*	-0.8120*	-0.8223*	-0.8421*
Soaked (12 h)	-0.7853*	-0.7621*	-0.7980*	-0.7321*
Sprouted (48 h)	-0.8941*	-0.8742*	-0.8550*	-0.9124**
Dehulled	-0.7961*	-0.8259*	-0.8228*	-0.7456*
Boiled products	-0.9203**	-0.8587*	-0.9426**	-0.9524**
Fermented products	-0.9823**	-0.9568**	-0.9673**	-0.9846**
Sprouted products	-0.9628**	-0.9421**	-0.9741**	-0.9563**
Fried products	-0.7061*	-0.6926*	-0.8246*	-0.8410*
Baked product	-0.5042	-0.4894	-0.6124	-0.6283
Roasted product	-0.7867*	-0.8123*	-0.8257*	-0.8461*

* Significant at 5% level

**Significant at 1% level

(in vitro). Significant improvement was observed after cooking involved in the preparation of these products (Table 44) with maximum increase observed in khichari (15%) and the minimum in fababean dal (11%).

The increase in protein digestibility on cooking of ricebean and fababean may be due to inactivation or destruction of trypsin inhibitors (Sharma and Sehgal, 1991a; Parihar et al., 1993; Mehta et al., 1993) and opening up of protein structure through denaturation. Reduction in the content of antinutritional factors like phytates, polyphenols, saponins and trypsin inhibitor activity brought about by soaking, cooking and autoclaving as reported by previous workers (Kataria et al., 1989b; Bishnoi and Khetarpaul, 1994b) and also observed in the present study (Tables 56 and 57) may also be responsible for increasing protein digestibility.

Various processing steps involved in the preparation of fermented products from ricebean and fababean enhanced the protein digestibility to varying extents. The raw mixture of idli, dosa and wadi prepared from ricebean had 63.4, 63.3 and 63.8 per cent protein digestibility, respectivley (Table 45). Soaking of the raw mixture for 12 h at 35 °C improved the protein digestibility to the extent of 14-17 per cent in different fermented products. The improvement may be attributed to leaching out of phytate, polyphenols, saponins and trypsin inhibitors as reported by previous workers (Kataria et al., 1989b; Kaur and Kapoor, 1990a; Bishnoi and Khetarpaul, 1994b). Soaking of legumes may also initiate activation of proteins, carbohydrates and fats (Khokhar, 1984).

Table 56. Correlation coefficients of antinutritional factors with *in vitro* digestibility of protein of ricebean and its products

	Antinutritional factors			
	Phytic acid	Polyphenols	Saponins	Trypsin inhibitor activity
Raw	-0.8163*	-0.8024*	-0.8456*	-0.8321*
Soaked (12 h)	-0.8412*	-0.8521*	-0.8920*	-0.9024*
Sprouted (24 h)	-0.8608*	-0.8812*	-0.9424**	-0.9362**
Boiled products	-0.8514*	-0.8475*	-0.9241**	-0.9073*
Fermented products	-0.9564**	-0.9306**	-0.9781**	-0.9608**
Sprouted products	-0.9673**	-0.9459**	-0.9923**	-0.9754**
Fried products	-0.6869*	-0.5861	-0.6424	-0.6991*
Baked product	-0.6087	-0.5572	-0.7024*	-0.6271

* Significant at 5% level

**Significant at 1% level

Table 57. Correlation coefficients of antinutritional factors with *in vitro* digestibility of protein of fababean and its products

	Antinutritional factors			
	Phytic acid	Polyphenols	Saponins	Trypsin inhibitor activity
Raw	0.8462*	-0.8341*	-0.8671*	-0.9071*
Soaked (12 h)	-0.8617*	-0.8463*	-0.8804*	-0.9123**
Sprouted (48 h)	-0.8872**	-0.877**	-0.9024*	-0.9324**
Boiled products	-0.8908*	-0.8975*	-0.9228**	-0.9543**
Fermented products	-0.9456**	-0.9364**	-0.9656**	-0.9671**
Sprouted products	-0.9542**	-0.9428**	-0.9742**	-0.9924**
Fried products	-0.7924*	-0.7861*	-0.8021*	-0.8128*
Baked product	-0.6829*	-0.6920*	-0.5969*	-0.7021*
Roasted product	-0.7241*	-0.7314*	-0.6874*	-0.7348*

* Significant at 5% level

**Significant at 1% level

Fermentation carried out at 35°C for 12 h further caused an appreciable enhancement in protein digestibility of idli, dosa and wadi. Improved protein digestibility varied from 28 to 32 per cent in different fermented products. Steaming and shallow frying involved in the preparation of final product of idli and dosa further increased the protein digestibility from 81.6 to 88.8 per cent and 81.2 to 87.4 per cent, respectively. But in case of wadi non-significant differences were obtained in the protein digestibility of the fermented slurry and final product showing that drying had no effect on improvement of protein digestibility.

The protein digestibility of raw mixtures of fermented fababean products ranged from 56.0 to 61.5 per cent (Table 46). Significant ($P<0.05$) improvements were observed in soaked mixtures of idli, dosa and wadi with maximum increase observed in idli and minimum in dosa. Soaking (12 h at 35°C) increased the protein digestibility of idli from 65.6 to 73.5 per cent; dosa from 66.3 to 71.9 per cent and wadi from 61.2 to 68.5 per cent. Fermentation carried out at 35°C for 12 h of the soaked mixture of idli, dosa and wadi further brought significant ($P<0.05$) improvement in the protein digestibility. Improvement in protein digestibility was upto 23, 17 and 22 per cent over the control values in the fermented slurry of idli, dosa and wadi, respectively (Table 46). Further cooking of fermented slurry into the final product by steaming and shallow frying brought an enhancement in protein digestibility of idli and dosa whereas no increase was observed in wadi due to frying.

Different processing technique involved in preparation of fermented products from fababean and ricebean whether used in isolation or incombination, significantly ($P<0.05$) enhanced the protein digestibility of all the products. Improvement observed during soaking, steaming and frying may be attributed to the loss or leaching of antinutrients (Jood et al., 1988), inactivaiton or destruction of trypsin inhibitors (Sharma and Sehgal, 1991a; Parihar et al., 1993) and opening up of the protein structure through denaturation.

Improvement in protein digestibility of fermented slurry of products is mainly associated with enhanced proteolytic activity of fermented microflora. High proteinase activity has been reported by various workers in protein fermented foods (Wang et al., 1975; Steinkraus,1983). An increase in the amino nitrogen by fermentation signifies partial breakdown of protein to peptide and amino acid resulting in improved protein digestibiltiy (Kao and Robinson, 1978). Phytic acid known to inhibit the proteolytic enzyme (Tan et al., 1983; Knuckles et al., 1985) is considerably reduced during fermentation (Tables 60 and 61), which may explain partly the increase in protein digestibility during fermentation. Various workers have reported increased protein digestibility in different foods including tempeh and miso (Kao and Robinson, 1978), fermented sorghum meal (Kazanas and Field, 1981; Paul and Fields, 1981), germinated and fermented soybean (Boralkar and Reddy, 1985; Grewal, 1992). Protein digestibility of blackgram and greengram dal wadies increased significantly to 44.7 and 37.4 per cent,

over the control values when fermented at 35°C for 12 h (Yadav, 1992).

A significant and negative relationship has been found between antinutrients with protein digestibility in fermented ricebean and fababean products (Tables 56 and 57).

The protein digestibility in different sprouted products prepared from ricebean and fababean improved as a cumulative effect of various processing methods i.e., soaking, germination, steaming and frying. There was an appreciable improvement in protein digestibility of sprouted ricebean and fababean products. Protein digestibility of the raw mixtures of different sprouted ricebean products ranged from 58.8 to 72.9 per cent with maximum being in the raw mixture of tikki and minimum in that of sprouted chat (Table 47). More the amount of pulse in a product, less was the protein digestibility. Sprouting in combination with other cooking methods brought a significant ($P<0.05$) enhancement in the protein digestibility of all the products. An improvement to the extent of 29, 23, 12, 11 and 6 per cent over the control values occurred in sprouted chat, cutlets, kachori, kofta and tikki, respectively.

The raw mixtures of sprouted chat, tikki, cutlet, kofta and kachori prepared from fababean had 59.0, 71.6, 66.1, 65.7 and 57.1 per cent protein digestibility, respectively. There was a significant ($P<0.05$) variation between the protein digestibility of raw mixture and final cooked product. Preparation of chat from the fababean sprouts witnessed the maximum i.e. 22 per cent improvement over the control value

followed by kachori (14%), cutlets (13%), kofta (12%) and tikki (9%).

An enhancement in protein digestibility upon germination may be because of decline in antinutritional factors like trypsin inhibitors, phytate (Sharma and Sehgal, 1991a; Bishnoi and Khetarpaul, 1994b), modification and degradation of storage proteins (Kataria et al., 1989b), due to action of hydrolytic enzymes (Hamza, 1983). Sprouting causes immobilization of proteins with the help of proteases leading to formation of polypeptides, oligopeptides and free amino acids (Youssef et al., 1986) and hence, leading to improvement in protein digestibility. Furthermore, phytase is also activated during germination which hydrolysis phytic acid leaching to its less content in sprouts. Antinutrients including phytic acid, polyphenols, saponins and TIA have been found to possess negative and significant ($P<0.05$) relationship with protein digestibility in sprouted products (Tables 56 and 57).

Improvement in protein digestibility did occur in the shallow and deep fried products prepared from ricebean and fababean. The protein digestibility of raw mixture of nutritious parantha and chilla was increased from 58.5 to 61.8 and 58.3 to 64.7 per cent, respectively after shallow frying. Deep fried products i.e. pakora and papad had significantly ($P<0.05$) more protein digestibility than their respective raw controls. Increase in the protein digestibility of papad was comparatively less than the rest of fried products (Table 49).

Similarly, the protein digestibility of fried fababean products also significantly ($P<0.05$) increased as a result of shallow and deep frying involved in the preparation of different fried products (Table 50). Significant differences were observed in the raw mixtures and cooked nutritious parantha and chilla. The enhancement in protein digestibility was to the extent of 7 and 6 per cent, respectively in case of nutritious parantha and chilla. Significant improvement did occur in protein digestibility of pakora and fried papad to the extent of 8 and 6 per cent over the control value, respectively.

The cake and roasted dal prepared from fababean had the protein digestibility of 68.4 and 63.0 per cent, respectively whereas their raw mixtures had the protein digestibility of 59.0 and 58.0 per cent, respectively (Table 51). Both baking and roasting treatments improved the protein digestibility significantly ($P<0.05$). The increase in the in vitro protein digestibility was more during baking than roasting.

The improvements in protein digestibility as observed in fried, baked and roasted products may be due to inactivation and desctruction of trypsin inhibitors (Kataria et al., 1989b) and opening up of protein structure through denaturation. Reductions in the levels of antinutrients during heat treatment (Tables 64 to 66) may also be responsible for the increase in protein digestibility (Jood et al., 1987; Kataria et al., 1989b).

Previous workers have also reported the beneficial effect of heating and autoclaving on protein digestibility (*in vitro*) of various legume including peas (Bishnoi and Khetarpaul, 1994b), ricebean (Kaur and Kapoor, 1990b), soyabean (Shrivastav *et al.*, 1990; Grewal, 1992) and fababean (Sharma and Sehgal, 1991a; Parihar *et al.*, 1993).

The oveall view of the enhancement in protein digestibility indicated due to various processing and cooking methods was maximum in fermented products (32-40%) followed by sprouted (6-29%), boiled (14-24%), fried (6-17%) and baked ricebean products (14%) (Table 52, Fig. 2.). In case of fababean products maximum increase was observed in fermented products followed by sprouted, boiled, baked, roasted and fried products (Table 53).

4.5.3 Antinutritional factors

4.5.3.1 Phytic acid

The phytic acid content of raw mixtures of *dal*, *khichari* and *kadhi* prepared from ricebean was 2015.5, 875.1 and 1690.1 mg/100 g, respectively which was decreased to 1738.2, 747.5 and 1472.0 mg/100 g, respectively on cooking (Table 58). Pressure cooking was more effective than ordinary cooking for bringing reduction in the level of phytic acid in ricebean products. In case of cake, baking process could lower the phytic acid level by 14 per cent.

In boiled fababean products, the phytic acid content of the raw mixtures of different products viz., *dal*, *khichari* and *kadhi* varied from 543.9 to 874.2 mg/100 g (Table 59), more the

Table 58. Phytic acid, polyphenols, saponin contents and trypsin inhibitor activity of boiled and baked ricebean products (on dry matter basis)

Products	Phytic acid (mg/100 g)	Polyphenols (mg/100 g)	Saponins (mg/100 g)	Trypsin inhibitor activity (TIU/g)[a]
Boiled products				
Dal				
Raw mixture	2015.5±12.5	1701.3±15.5	2158.7±13.2	55.2±4.3
Cooked product	1738.2±07.3 (14)	1397.3±11.7 (18)	1954.4±12.7 (10)	10.4±2.9 (81)
't' value	14.05*	17.87*	24.98*	19.23*
Khichari				
Raw mixture	875.1±07.9	833.0±01.1	1238.1±09.7	77.1±5.9
Cooked product	747.5±06.1 (15)	659.7±04.8 (21)	1127.0±16.4 (9)	15.6±3.1 (80)
't' value	10.42*	32.12*	13,05*	20.60*
Kadhi				
Raw mixture	1690.1±11.9	1305.2±17.0	2581.3±10.7	341.7±4.6
Cooked product	1472.0±15.5 (13)	1087.9±13.0 (17)	2264.7±12.1 (12)	71.9±3.1 (79)
't' value	12.20*	22.61*	39.41*	107.50*
Baked product				
Cake				
Raw mixture	1233.7±09.3	398.4±04.8	813.5±11.2	35.4±4.7
Roasted product	1063.7±04.7 (14)	352.3±05.1 (12)	629.0±08.2 (23)	9.4±0.1 (73)
't' value	6.87*	14.87*	29.70*	10.38*

Values are means ± SD of three independent determinations
*Significant at 5% level
a-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 minutes at pH 7.6
Figures in parentheses indicate per cent decrease over control values.

Table 59. Phytic acid, polyphenols, saponin contents and trypsin inhibitor activity of boiled fababean products (on dry matter basis)

Products	Phytic acid (mg/100 g)	Polyphenols (mg/100 g)	Saponins (mg/100 g)	Trypsin inhibitor activity (TIU/g)a
Dal				
Raw mixture	874.2±12.5	310.9±6.3	1138.9±17.7	832.3±09.1
Cooked product	745.4±12.4 (15)	252.0±4.3 (19)	1039.4±10.2 (9)	171.9±10.7 (79)
't' value	16.40*	16.64*	6.34*	105.08*
Khichari				
Raw mixture	543.9±04.8	357.8±4.2	912.7±21.4	350.0±08.0
Cooked product	488.6±03.8 (10)	284.5±3.3 (21)	830.7±15.9 (9)	74.0±08.3 (79)
't' value	14.78*	30.74*	9.60*	53.20*
Kadhi				
Raw mixture	742.7±05.4	329.2±6.1	1898.8±20.3	878.1±10.7
Cooked product	663.2±06.2 (11)	281.9±3.9 (14)	1712.3±15.9 (10)	180.2±08.4 (80)
't' value	12.26*	14.56*	16.12*	114.90*

Values are means ± SD of three independent determinations
*Significant at 5% level
a-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 minutes at pH 7.6
Figures in parentheses indicate per cent decrease over control values

amount of fababean used in a product, more was the phytic acid content. Raw mixtures of the dal contained were amount of phytic acid followed by that of kadhi and khichari. Besides fababean dal, addition of rice in the raw mixture of khichari may be responsible for less phytic acid content than dal and kadhi. Pressure cooking and boiling brought a significant ($P<0.05$) decrease in the level of antinutrients. Reduction in the phytic acid content was 15, 10 and 11 per cent in dal, khichari and kadhi, respectively over the control values.

An obvious decrease noticed in phytic acid content of boiled products due to ordinary and pressure cooking and dry heat treatment like baking may be attributed to the formation of insoluble complexes between phytate and other components (Kumar et al., 1978). Similar reductions during cooking and autoclaving has been reported in various legumes like ricebean (Kaur and Kapoor, 1990a), fababean (Sharma and Sehgal, 1992b) and peas (Bishnoi et al., 1994).

Phytic acid content of the fermented products i.e. idli, dosa and wadi was also analysed at different stages of processing and preparation. The unprocessed mixtures of fermented ricebean products contained 1351.6 to 1751.4 mg/100 g of phytic acid with maximum value seen in wadi and minimum in idli (Table 60). As wadi was prepared from ricebean dal only, hence, contained more amount of phytic acid as compared to idli which was prepared from the mixture of rice and dal in 2:1 proportion.

The different treatments involved in the preparation of idli, dosa and wadi caused a significant ($P<0.05$) reduction in the level of phytic acid. A loss of ranging from 17 to 30 per cent occurred over the control value after 12 h soaking of the raw mixtures of various fermented products (Table 60). Fermentation of soaked slurry carried for 12 h at 35°C significantly ($P<0.05$) reduced the phytic acid content from 975.3 to 817.8, 957.0 to 801.7 and 1454.9 to 1239.5 mg/100 g in idli, dosa and wadi, respectively. Steaming and shallow frying of the fermented slurries in idli and dosa further decreased the phytic acid content by 7 and 8 per cent, respectively. Non-significant differences were observed in phytic acid content of the fermented slurry and final product in case of wadi.

Similar trend in reduction of phytic acid content of different fermented fababean products has been observed (Table 61). The phytic acid content of unprocessed mixture of fermented fababean products ranged from 454.2 to 875.5 mg/100 g maximum being in wadi followed by idli and dosa in descending order. Soaking prior to fermentation of idli, dosa and wadi mixtures reduced the level of phytic acid significantly ($P<0.05$). The decrease was upto 14, 8 and 8 per cent in the soaked mixtures of idli, dosa and wadi, respectively. Fermentation of soaked mixtured further diminished the level of phytic acid. The reduction in the level of phytic acid content varied from 22 to 52 per cent over the control values in fermented slurries of fababean idli, dosa and wadi. Steaming of idli reduced the phytic acid content of fermented slurry from

Table 60. Phytic acid, polyphenols, saponin contents and trypsin inhibitor activity of fermented ricebean product (on dry matter basis)

Products	Phytic acid (mg/100 g)	Polyphenols (mg/100 g)	Saponins (mg/100 g)	Trypsin inhibitor activity (TIU/g)[a]
Idli				
Raw mixture	1351.6±3.1	449.2±2.1	1121.0±7.9	88.5±3.0
Soaked mixture	975.3±3.4 (28)	317.0±2.0 (29)	1004.0±5.0 (10)	80.2±1.9 (9)
Fermented slurry	817.8±2.2 (40)	213.8±2.1 (52)	769.8±5.0 (31)	16.7±1.3 (81)
Final product	713.0±3.3 (47)	210.1±1.9 (53)	686.5±5.0 (39)	14.6±1.3 (84)
SE(m)	±4.35	±2.89	±7.96	±2.83
CD (P<0.05)	9.07	6.03	16.60	5.90
Dosa				
Raw mixture	1369.7±3.0	411.2±1.8	1091.3±6.1	80.2±1.9
Soaked mixture	957.0±3.2 (30)	298.7±1.5 (27)	994.0±5.1 (9)	72.9±3.4 (9)
Fermented slurry	801.7±4.9 (42)	207.7±2.3 (50)	763.9±3.7 (30)	16.7±2.1 (79)
Final product	690.9±3.4 (50)	189.9±1.9 (54)	678.6±4.3 (38)	12.5±1.6 (84)
SE(m)	±5.28	±2.70	±6.08	±3.37
CD (P<0.05)	11.01	5.63	12.68	7.03
Wadi				
Raw mixture	1751.4±2.9	492.6±2.8	2007.9±5.9	52.1±2.6
Soaked mixture	1454.9±9.2 (17)	350.6±1.5 (29)	1703.6±5.1 (15)	46.8±2.7 (10)
Fermented slurry	1239.3±5.7 (29)	253.3±2.6 (49)	1355.2±3.6 (33)	18.7±4.2 (64)
Final product	1242.8±6.4 (29)	252.0±2.0 (49)	1355.1±3.6 (33)	17.7±3.8 (66)
SE(m)	±9.32	±3.20	±6.61	±4.90
CD (P<0.05)	19.44	6.67	13.79	10.22

Values are means ± SD of three independent determinations
*Significant at 5% level
a-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 minutes at pH 7.6
Figures in parentheses indicate per cent decrease over control values

Table 61. Phytic acid, polyphenols, saponin contents and trypsin inhibitor activity of fermented fababean products (on dry matter basis)

Products	Phytic acid (mg/100 g)	Polyphenols (mg/100 g)	Saponins (mg/100 g)	Trypsin inhibitor activity (TIU/g)[a]
Idli				
Raw mixture	485.6±3.7	350.9±2.9	1037.7±7.1	385.4±2.6
Soaked mixture	417.9±3.9 (14)	249.4±2.6 (29)	865.1±6.6 (17)	358.8±4.3 (7)
Fermented slurry	370.8±2.3 (24)	175.3±2.0 (50)	658.7±5.0 (37)	59.4±2.7 (85)
Final product	353.4±1.7 (36)	149.6±1.9 (57)	579.4±5.9 (44)	44.8±1.9 (88)
SE(m)	±4.31	±3.41	±8.81	±4.27
CD (P<0.05)	8.99	7.11	18.38	8.91
Dosa				
Raw mixture	454.2±2.4	299.9±3.7	863.1±9.1	286.2±2.5
Soaked mixture	418.6±3.7 (8)	230.2±2.1 (23)	694.4±8.5 (20)	268.5±2.3 (6)
Fermented slurry	354.4±1.4 (22)	146.4±2.4 (51)	553.6±5.1 (36)	42.7±1.9 (85)
Final product	342.7±5.7 (32)	134.5±2.3 (55)	509.6±5.3 (41)	35.4±2.1 (88)
SE(m)	±5.22	±3.83	±10.22	±3.11
CD (P<0.05)	10.89	7.93	21.32	6.49
Wadi				
Raw mixture	875.5±3.2	305.7±2.7	1129.0±12.8	825.6±10.5
Soaked mixture	804.6±3.4 (8)	233.0±3.2 (24)	908.7±5.0 (20)	792.9±3.5 (4)
Fermented slurry	416.8±4.1 (52)	141.8±1.8 (54)	736.3±3.7 (35)	129.1±3.5 (84)
Final product	417.8±4.0 (52)	142.0±1.2 (54)	734.1±3.9 (35)	131.1±4.2 (84)
SE(m)	±5.42	±3.33	±10.46	±7.45
CD(P<0.05)	11.31	6.95	21.82	15.50

Values are means ± SD of three independent determinations
*Significant at 5% level
a-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 minutes at pH 7.6
Figures in parentheses indicate per cent decrease over control values

370.8 to 353.4 mg/100 g and shallow frying from 354.4 to 342.7 mg/100 g in dosa whereas drying of fermented slurry in case of wadi brought no further decrease in phytic acid levels.

A wide range of microflora have been known to possess phytase activity (Daniels and Fisher, 1981; Lopez et al., 1983) which may partly be responsible for decrease in phytic acid content. The inherent phytase activity reported in legumes may also be responsible for decreasing phytase content during fermentation. Optimum temperature for phytase activity from plants and microbial sources has been known to range between 35 to 45°C. They may account for greater reduction in phytic acid content at 35°C.

Decrease in phytic acid content during fermentation has been reported in various fermented food including tempeh (Riet et al., 1987; Suparma, 1987) and rabadi (Duhan et al., 1989; Gupta et al., 1991; Grewal, 1992). Buckle (1985) reported that phytic acid content was halved during tempeh fermentation and deep fat frying further decreased the phytic acid. Wadi prepared from blackgram dal fermented at 35°C for 18 h had near about one half of phytic acid content of that present in unfermented ones (Yadav, 1992).

The phytic acid content of raw mixture of sprouted ricebean products ranged from 784.4 to 1992.7 mg/100 g (Table 62). The combination of various treatments viz., soaking, sprouting, cooking, shallow and deep frying used for preparing sprouted products like chat, tikki, cutlets, kofta and kachori significantly ($P<0.05$) reduced the level of phytic acid by 21

Table 62. Phytic acid, polyphenols, saponin contents and trypsin inhibitor activity of sprouted ricebean products (on dry matter basis)

Products	Phytic acid (mg/100 g)	Polyphenols (mg/100 g)	Saponins (mg/100 g)	Trypsin inhibitor activity (TIU/g)
Sprouted chat				
Raw mixture	1992.7±12.3	901.2±10.8	2156.7±12.7	53.1±5.9
Cooked product	1348.4±4.1 (32)	806.4±08.5 (11)	1672.6±16.4 (22)	16.7±2.9 (69)
't' value	11.39*	7.60*	36.95*	12.22*
Tikki				
Raw mixture	1433.3±15.6	548.6±3.6	1299.6±16.0	70.8±5.9
Cooked product	1091.9±11.1 (24)	442.9±3.2 (19)	1121.0±15.9 (14)	17.7±4.3 (75)
't' value	51.83*	49.07*	17.65*	16.29*
Cutlet				
Raw mixture	1098.2±6.6	506.3±7.3	1555.5±8.9	66.6±4.6
Cooked product	846.5±12.3 (23)	424.6±2.8 (16)	1236.9±11.4 (21)	21.9±3.1 (67)
't' value	49.94*	24.20*	64.81*	17.86*
Kofta				
Raw mixture	1159.5±9.3	571.1±1.9	2990.1±12.7	699.9±8.0
Cooked product	918.1±7.9 (21)	485.9±3.3 (15)	2513.9±10.7 (16)	279.2±5.9 (61)
't' value	44.26*	49.63*	64.14*	94.86*
Kachori				
Raw mixture	784.4±11.3	408.8±4.0	1117.1±12.7	46.9±3.1
Cooked product	621.4±12.4 (21)	341.9±2.9 (16)	882.9±12.5 (21)	14.6±2.9 (69)
't' value	24.36*	49.82*	29.14*	16.81*

Values are means ± SD of three independent determinations
*Significant at 5% level
a-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 minutes at pH 7.6
Figures in parentheses indicate per cent decrease over control values

to 32 per cent, over the control values. The per cent decrease in phytic acid content was maximum in sprouted chat and minimum in kachori and kofta. Raw mixture of tikki contained 1433.3 mg/100 g of phytic acid which was reduced to 1091.9 mg/100 g after germiantion and shallow frying in cooked product. In case of cutlet, kofta and kachori which involved sprouting and deep frying, the decreases in phytic acid ranged from 21-23 per cent over the control values.

Similar trend for reduction in phytic acid content was observed in sprouted fababean products. The phytic acid content of raw mixtures of different sprouted fababean products including sprouted chat, tikki, cutlet, kofta and kachori was 859.7, 540.1, 609.1, 855.2, 391.7 mg/100 g, respectively which was reduced to 440.6, 358.2, 392.4, 677.3 and 299.0 mg/100 g, respectively after different processing and cooking methods used in the preparation of these products (Table 63). The phytic acid content was reduced to the highest level in sprouted chat (49%) followed by cutlet (36%), tikki (24%), kachori (24%) and kofta (21%) when compared with their respective control mixtures.

As a result of sprouting, steaming, slight cooking, shallow and deep fat frying involved the preparation of various sprouted dal products, the phytic acid content of ricebean and fababean products was decreased significantly ($P<0.05$). Loss of phytic acid during germination may be due to hydrolytic activity of phytase present in various plant foods (Mandal et al., 1972; Lolas and Markakis, 1975). Phytic acid is also

Table 63. Phytic acid, polyphenols, saponin contents and trypsin inhibitor activity of sprouted fababean products (on dry matter basis)

Products	Phytic acid (mg/100 g)	Polyphenols (mg/100 g)	Saponins (mg/100 g)	Trypsin inhibitor activity (TIU/g)[a]
Sprouted chat				
Raw mixture	859.7±10.2	250.0±3.7	1113.1±12.3	845.8±7.8
Cooked product	440.6±05.2 (49)	218.2±2.6 (13)	772.6±15.9 (31)	228.1±7.9 (73)
't' value	43.01*	15.70*	34.25*	124.74*
Tikki				
Raw mixture	540.1±7.6	223.4±5.0	877.0±19.0	566.7±5.9
Cooked product	358.2±6.3 (24)	198.0±3.1 (11)	686.5±20.2 (24)	121.9±6.0 (78)
't' value	40.89*	9.55*	11.85*	118.43*
Cutlet				
Raw mixture	609.1±5.4	223.1±5.2	1047.6±15.7	515.6±6.0
Cooked product	392.4±3.7 (36)	175.3±3.7 (21)	802.4±18.2 (23)	119.8±6.7 (77)
't' Value	41.13*	16.70*	14.51*	98.78*
Kofta				
Raw mixture	855.2±8.6	322.3±5.4	2811.5±15.9	946.9±6.0
Cooked product	677.3±3.9 (21)	275.3±8.4 (15)	2315.5±14.7 (17)	383.3±5.9 (59)
't' value	41.95*	10.48*	50.61*	150.04*
Kachori				
Raw mixture	391.7±10.4	203.0±4.1	688.5±18.7	313.5±6.7
Cooked product	299.0±4.6 (24)	183.2±5.7 (19)	551.6±13.2 (20)	91.7±4.6 (71)
't' value	18.09*	6.32*	13.38*	60.98*

Values are means ± SD of three independent determinations
*Significant at 5% level
a-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 minutes at pH 7.6
Figures in parentheses indicate per cent decrease over control values

utilized as a soruce of phosphorus during sprouting. Deductions in phytic acid content during germination has been reported earlier in various legumes including cowpea, limabean and soyabean (Ologhobo and Fetuga, 1982; Grewal, 1992), ricebean (Kaur and Kapoor, 1990a), fababean (Sharma and Sehgal, 1992b) and peas (Bishnoi et al., 1994).

The raw mixtures of nutritious parantha and chilla prepared from ricebean had considerable amount of phytic acid i.e. 1606.6 and 1714.2 mg/100 g which was reduced significantly ($P<0.05$) to 1552.5 and 1630.4 mg/100 g, respectively after shallow frying (Table 64). The phytic acid content of raw mixtures of pakora and papad was 1741.7 and 1455.1 mg/100 g. Deep fat frying brought down the level of phytic acid by only 5 per cent over the control value in both the products.

In the unprocessed mixtures of fried fababean products, the phytic acid content ranged from 725.6 to 852.0 mg/100 g and the loss varied from 687.9 to 822.4 mg/100 g after frying of these products (Table 65). The decrease was maximum in pakora (7%) and in the rest of the fried products, the phytic acid level was lowered down by 3-4 per cent only.

Unprocessed mixtures of cake and roasted dal had 602.8 and 879.0 mg/100 g phytic acid, respectively. After baking and roasting, significant ($P<0.05$) reduction in phytic acid content was noticed (Table 66). Roasting proved to be more beneficial than baking for lowering down the phytic acid level.

Significant decreases were observed during frying, baking and roasting due to heat treatment in different products.

Table 64. Phytic acid, polyphenols, saponin contents and trypsin inhibitor activity of fried ricebean products (on dry matter basis)

Products	Phytic acid (mg/100 g)	Polyphenols (mg/100 g)	Saponins (mg/100 g)	Trypsin inhibitor activity (TIU/g)[a]
Shallow fried				
Nutritious parantha				
Raw mixture	1606.8±6.9	988.7±18.9	1488.1±9.7	68.7±5.1
Cooked product	1552.5±10.5 (3)	930.4±13.1 (6)	1267.8±11.4 (15)	49.0±4.2 (29)
't' value	9.59*	5.67*	32.87*	6.63*
Chilla				
Raw mixture	1714.2±9.6	1251.2±11.3	2511.9±9.7	344.8±4.3
Cooked product	1630.4±8.3 (5)	1186.8±09.4 (5)	2216.3±8.1 (12)	227.1±5.9 (34)
't' value	14.64*	9.81*	52.02*	36.10*
Deep fried				
Pakora				
Raw mixture	1741.7±14.5	1245.4±14.8	2513.4±12.7	343.7±5.1
Cooked product	1646.7±13.1 (5)	1124.4±14.9 (10)	2132.9±12.7 (15)	173.9±4.3 (49)
't' value	10.84*	12.83*	47.41*	56.92*
Papad				
Raw mixture	1455.1±5.8	504.3±3.7	1403.7±11.2	577.1±5.9
Cooked product	1381.2±9.8 (5)	472.2±3.3 (6)	1293.6±13.1 (8)	457.3±4.3 (21)
't' value	16.13*	27.83*	14.88*	36.73*

Values are means ± SD of three independent determinations.
*Significant at 5% level.
a-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 minutes at pH 7.6

Figures in parentheses indicate per cent decrease over control values.

Table 65. Phytic acid, polyphenols, saponin and trypsin inhibitor activity of fried fababean products (on dry matter basis)

Products	Phytic acid (mg/100 g)	Polyphenols (mg/100 g)	Saponins (mg/100 g)	Trypsin inhibitor activity (TIU/g)[a]
Shallow fried				
Nutritious parantha				
Raw mixture	852.0±4.4	340.1±6.3	996.0±20.3	540.6±6.0
Cooked product	822.4±3.6 (4)	324.9±1.8 (5)	914.8±12.7 (8)	347.9±2.9 (36)
't' value	8.88*	4.31*	7.34*	64.60*
Chilla				
Raw mixture	748.5±8.5	308.0±3.8	1811.5±14.7	900.0±8.1
Cooked product	730.1±7.9 (3)	292.2±5.2 (5)	1712.3±15.9 (6)	529.3±5.9 (41)
't' value	3.52*	8.91*	7.90*	82.64*
Deep fried				
Pakora				
Raw mixture	740.4±3.9	309.8±5.7	1815.5±20.3	901.0±12.1
Cooked product	687.9±7.9 (7)	280.4±5.5 (9)	1654.0±17.7 (9)	451.0±9.8 (50)
't' value	8.67*	11.13*	8.09*	64.42*
Papad				
Raw mixture	725.6±3.7	307.9±7.9	1053.5±16.4	1002.1±7.8
Cooked product	702.7±5.3 (3)	298.6±2.5 (3)	1002.1±20.3 (5)	847.9±6.9 (15)
't' value	8.28*	7.87*	4.78*	33.09*

Values are means ± SD of three independent determinations.
*Significant at 5% level.
a-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 minutes at pH 7.6

Figures in parentheses indicate per cent decrease over control values.

Table 66. Phytic acid, polyphenols, saponin and trypsin inhibitor activity of baked and roasted fababean products (on dry matter basis)

Products	Phytic acid (mg/100 g)	Polyphenols (mg/100 g)	Saponins (mg/100 g)	Trypsin inhibitor activity (TIU/g)[a]
Cake				
Raw mixture	602.8±4.3	250.0±4.5	682.5±13.5	222.9±5.9
Baked product	539.2±1.4 (11)	217.9±5.6 (13)	598.0±12.7 (12)	57.3±4.3 (74)
't' value	31.20*	9.90*	15.46*	50.80*
Roasted dal				
Raw dal	879.0±4.2	312.1±8.1	1132.9±21.1	830.2±8.4
Roasted dal	453.7±7.6 (8)	240.9±4.0 (23)	948.4±18.2 (16)	84.4±6.0 (90)
't' value	108.79*	17.70*	8.99*	161.91*

Values are means ± SD of three independent determinations.

*Significant at 5% level.

[a]-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 minutes at pH 7.6.

Figures in parentheses indicate per cent decrease over control values.

Phytic acid is heat stable, reduction may not be due to destruction of the compound but perhaps to its ability to form compelx with proteins and minerals (Kratzer, 1965) which may not be extractable in 0.5M HNO_3. So the decrease observed is apparent and not true. Various cooking methods involved in preparing foods like baking (Tangkogchitr et al., 1981), roasting (Ayatse et al., 1983), fat frying (Khan et al., 1986), and autoclaving (Grewal, 1992) are known to reduce the level of phytic acid in the food products.

The overall picture of reduction in phytic acid levels revealed that fermentation was the most beneficial process for lowering down the level of phytic acid in both ricebean and fababean products followed by sprouting, boiling, baking and frying is ricebean products (Table 67) and sprouting, roasting, boiling, baking, frying in fababean products (Table 68, Fig. 3).

4.5.3.2 Polyphenols

The raw unprocessed mixtures of riceban dal, khichari and kadhi contained varying amount of polyphenolic compounds i.e. ranging from 833.0 mg/100 g in khichari to 1701.3 mg/100 g in dal (Table 58). After cooking, maximum reduction in polyphenol content was observed in khichari (21%) followed by dal (18%) and kadhi (17%) when compared with their respective control. The raw mixture of ricebean cake had 398.4 mg/100 g of polyphenols and baking could decrease it by 12 per cent.

The raw mixture of fababean dal, khichari and kadhi had lower amount of polyphenols then the ricebean. The raw mixtures

Table 67. Per cent decrease in phytic acid, polyphenols, saponins and trypsin inhibitor activity over the control values of ricebean products

Products	Phytic acid	Ranks	Poly-phenols	Ranks	Saponins	Ranks	Trypsin inhibitor activity	Ranks
Boiled products	13-15	III	17-21	II	9-12	V	79-81	II
Fermented products	29-49	I	49-54	I	32-39	I	66-84	I
Sprouted products	21-32	II	10-19	III	14-22	III	60-75	III
Fried products	4-5	V	5-10	V	8-15	IV	21-49	V
Baked product	14	IV	12	IV	23	II	73	IV

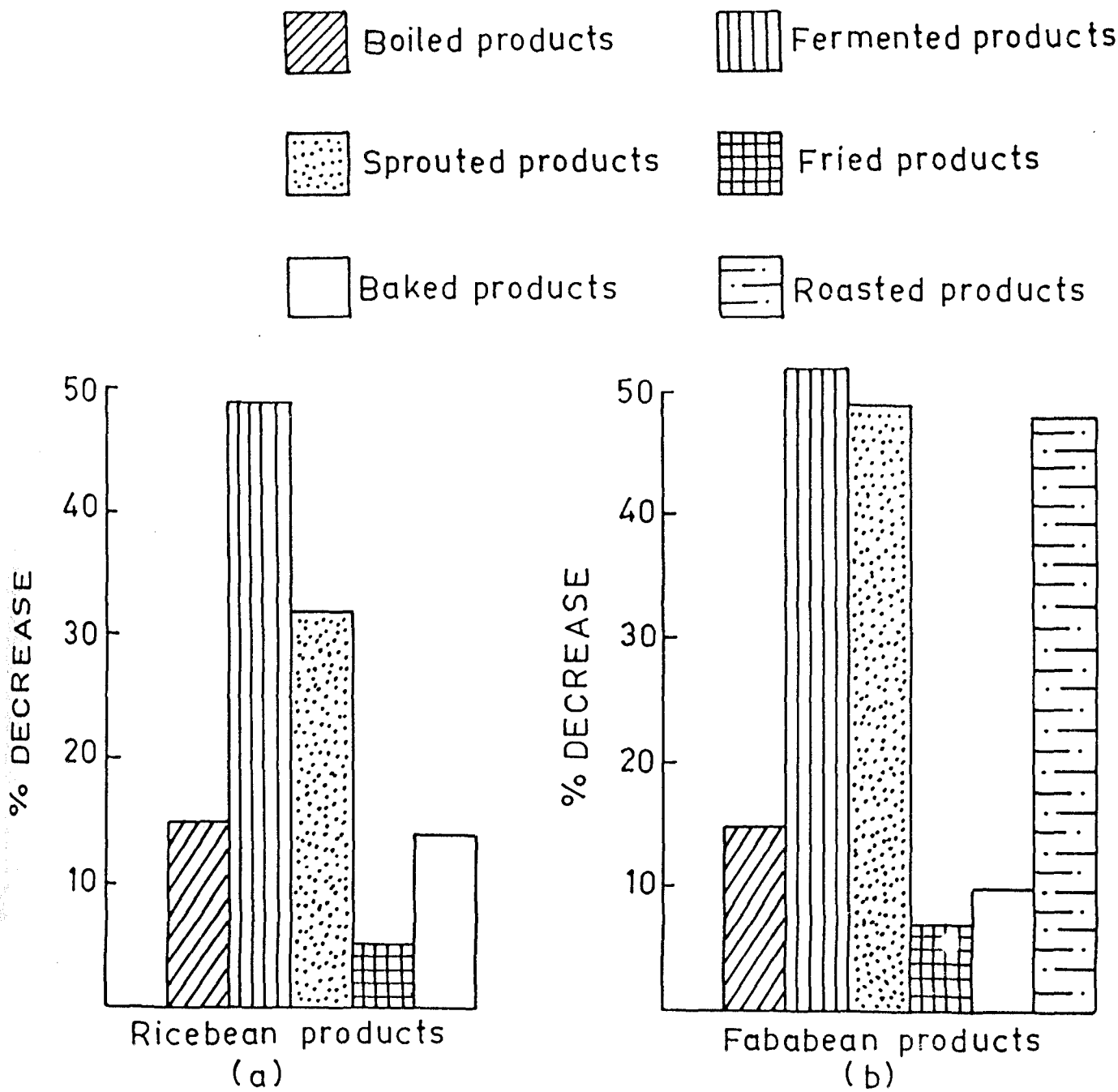

FIG. 3. EFFECT OF BOILING, FERMENTATION, SPROUTING, FRYING, BAKING AND ROASTING ON PHYTIC ACID CONTENT OF RICEBEAN (a) AND FABABEAN PRODUCTS (b)

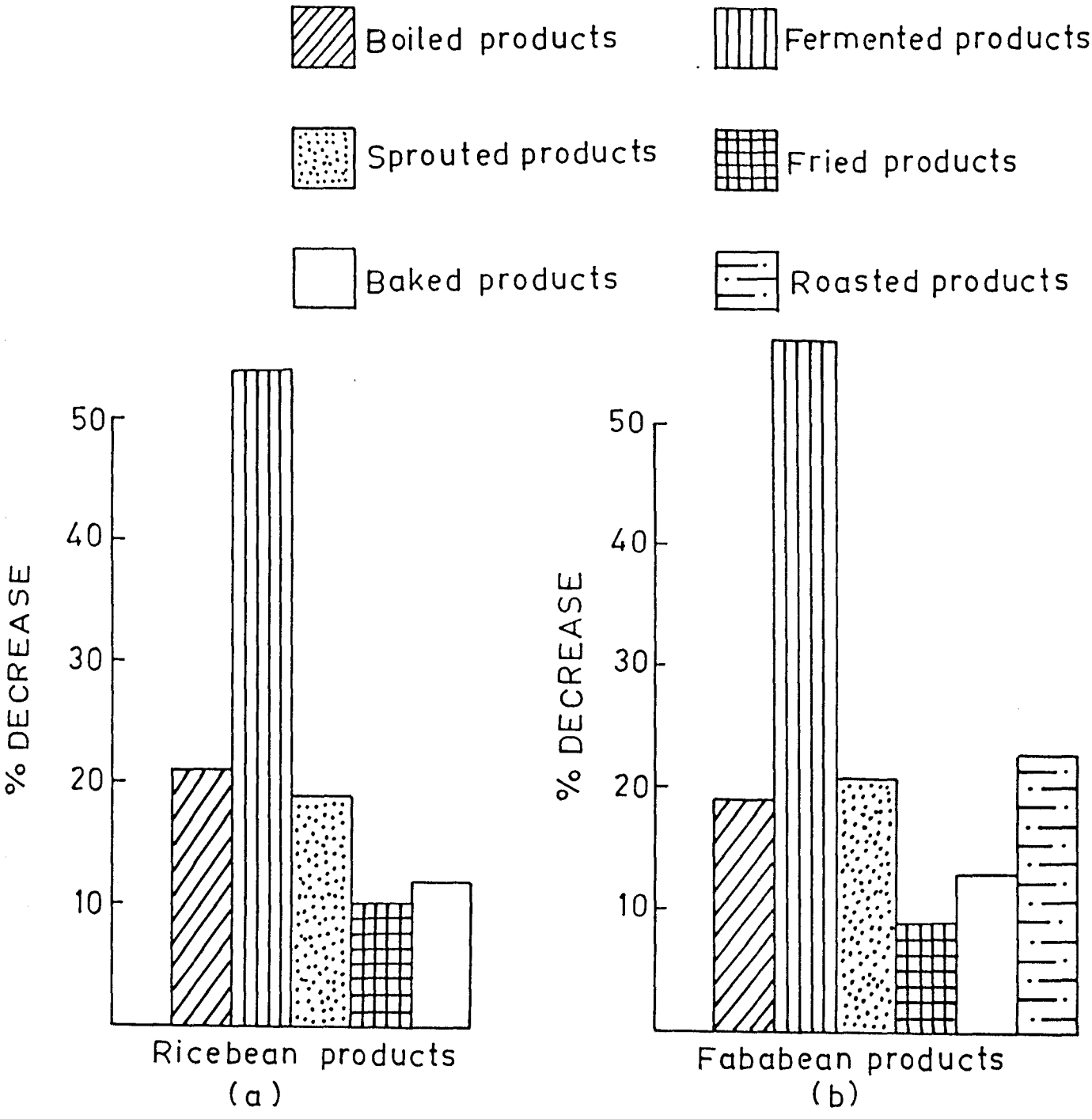

FIG. 4. EFFECT OF BOILING, FERMENTATION, SPROUTING FRYING BAKING AND ROASTING ON POLYPHENOL CONTENT OF RICEBEAN (a) AND FABABEEN PRODUCTS (b)

Table 68. Per cent decrease in phytic acid, polyphenols, saponins and trypsin inhibitor activity over the control values of fababean products

Products	Phytic acid	Ranks	Poly-phenols	Ranks	Saponins	Ranks	Trypsin inhibitor activity	Ranks
Boiled products	10-15	IV	14-19	IV	9-10	V	79	III
Fermented products	32-52	I	53-57	I	35-44	I	84-88	I
Sprouted products	24-49	II	10-21	III	17-31	II	59-78	IV
Fried products	2-7	VI	3-9	VI	5-9	VI	15-50	VI
Baked product	10	V	13	V	12	IV	74	V
Roasted product	48	III	23	II	16	III	80	II

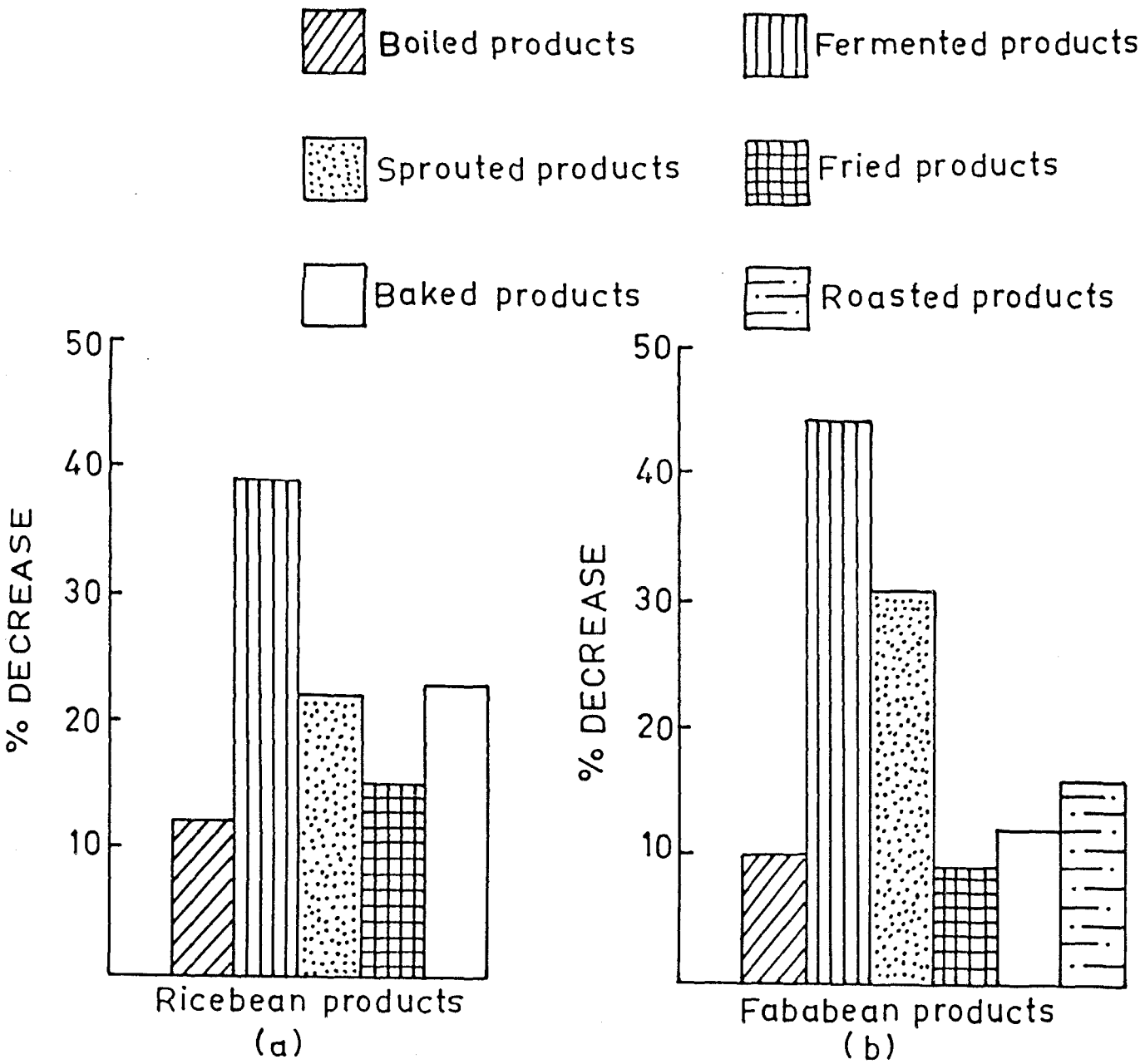

FIG. 5. EFFECT OF BOILING, FERMENTATION, SPROUTING, FRYING, BAKING AND ROASTING ON SAPONIN CONTENT OF RICEBEAN (a) AND FABABEAN PRODUCTS (b)

FIG. 6. EFFECT OF BOILING, FERMENTATION, SPROUTING, FRYING, BAKING AND ROASTING ON TRYPSIN INHIBITOR ACTIVITY OF RICEBEAN (a) AND FABABEAN PRODUCTS (b)

of various boiled fababean products had 310.9 to 357.8 mg/100 g of polyphenol with the highest value in khichari and the lowest in dal (Table 59). A decrease in polyphenols occurred to the extent of 19, 21 and 14 per cent over the control value on cooking of dal, khichari and kadhi, respectively.

Binding of polyphenols with other organic substances and proteins or to alterations in the chemical structure of polyphenols which cannot be extracted by available methods may explain a decrease in tannin of legume grain during cooking. Moist heating involved in ordinary or pressure cooking, may be responsible for destruction of polyphenols. The results are in line with those reported by earlier worker in ricebean (Kaur and Kapoor, 1990a), fababean (Sharma and Sehgal, 1992b; Moneam, 1990) and peas (Bishnoi et al., 1994).

Unprocessed mixtures of various fermented ricebean products had polyphenols ranging from 411.2 to 492.6 mg/100 g (Table 60). Soaking of raw mixture of ricebean idli, dosa and wadi reduced the polyphenol levels by 27 to 29 per cent, over the control values. Polyphenol content was reduced to almost half when the soaked mixtures of idli, dosa and wadi were fermented at 35°C for 12 h. Further steaming and drying of fermented slurries involved in the preparation of idli and wadi could not bring about significant ($P<0.05$) decrease in polyphenolic compounds. On the other hand, shallow frying of fermented mixture of dosa significantly ($P<0.05$) decreased the polyphenol content from 207.7 mg/100 g in fermented slurry to 189.9 mg/100 g in the final product.

Similar types of trend for reduction in polyphenolic contents various fababean fermented products was witnessed (Table 61). The raw mixture of idli, dosa and wadi prepared from fababean had 350.9, 299.9 and 305.7 mg/100 g of polyphenol content which was reduced to 149.6, 134.5 and 142.0 mg/100 g in the final products, respectively. Different processing treatments used to obtain the final product brought significant ($P<0.05$) reduction in the level of polyphenol. Soaking treatment reduced the polyphenol level by 29, 23 and 24 per cent in idli, dosa and wadi, respectively. Fermentation after soaking further reduced the level by 50 to 54 per cent in different fermented products. Hence all the final fababean fermented products had polyphenol content which was less than half of that present in the raw mixtures.

Cumulative effect of soaking, fermentation, steaming or shallow frying was found to be effective for lowering down the polyphenolic level of ricebean and fababean fermented products. As polyphenols are present in the periphery of seeds, hence, there is possibility of their passing out into the soaking medium through seed coat. Loss of polyphenols during soaking may be attributed to this effect. The diminishing effect on polyphenols may be due to the activity of polyphenol oxidase present in the legumes or microflora. A decrease in polyphenolic content during fermentation has been reported earlier for various fermented foods including rabadi (Dhankar and Chauhan, 1987a), pearlmillet fermented by pure culture of yeast and lactobacilli (Khetarpaul and Chauhan, 1990b), wadi

prepared from blackgram and greengram dal (Yadav, 1992), and in fermented blackgram (Chaudhary, 1993). Contrary to these results, some workers (Gupta, 1989; Goyal, 1991; Grewal, 1992) reported no increase in polyphenolic content of fermented foods.

The polyphenol level in raw mixtures of sprouted ricebean products ranged from 408.8 to 901.2 mg/100 g (Table 62). Sprouting together with frying significantly ($P<0.05$) decreased the level of polyphenol with maximum decrease occurring in tikki (19%) followed by cutlet and kachori (16%), kofta (15%) and sprouted chat (11%).

The raw mixtures of sprouted fababean products contained less amount of polyphenols than their ricebean counterparts. The raw mixture of sprouted chat, tikki, cutlet, kofta and kachori prepared from fababean contained 250.0, 223.4, 223.1, 322.3 and 203.0 mg/100 g of polyphenol, respectively and the level of polyphenol was reduced to 218.2, 198.0, 175.3, 275.3 and 183.2 mg/100 g, respectively in the final product (Table 63).

Before germination, soaking is also done and some loss of polyphenol during soaking is also expected because of its leaching into soaking water. Further decrease in polyphenol contents during germination may be attributed to the presence of polyphenol oxidase and enzymatic hydrolysis (Jood et al., 1987). Germination has been reported to decrease the tannin content of mothbean (Khokhar, 1984), fababean (Sharma and Sehgal, 1992a) and peas (Bishnoi et al., 1994).

Polyphenol content was the highest in the raw mixture of ricebean chilla (1251.2 mg/100 g) followed by pakora (1245.4 mg/100 g), nutritious parantha (988.7 mg/100 g) and papad (504.3 mg/100 g) in descending order. Shallow as well as deep frying reduced the polyphenol level of these above products significantly ($P<0.05$) and it ranged from 5 to 10 per cent over the control value (Table 64). Extent of decrease was the same in case of nutritious parantha and papad prepared from ricebean. In the fried fababean products maximum reduction in the level of polyphenol was witnessed in pakora (9 %) followed by chilla (5%) nutritious parantha (4%) and papad (3%) (Table 65).

The raw mixtures of cake and roasted dal contained 250.0 and 312.1 mg/100 g of polyphenols. Significant ($P<0.05$) decrease in polyphenol occurred after baking and roasting (Table 66). Baking of the cake mixture reduced the polyphenol level by 13 per cent whereas roasting could bring down the level of this antinutrient by 23 per cent, over the control value.

Frying, baking and roasting were found to lower the polyphenol content in ricebean and fababean products. A decreased amount of polyphenols in cooked heat treated products could result from their reduced extractability or change in chemical reactivity (Satwadhar et al., 1981). It may also be due to formation of some insoluble complex between proteins and tannins (Ekfenyog, 1985; Jood et al., 1987). Roasting had been earlier reported too to decrease the level of polyphenol in chickpea (Kakkar, 1992).

4.5.3.3 Saponins

Ricebean contained considerable amount of saponins. The saponin content of raw mixture of dal, khichari and kadhi prepared from ricebean was 2158.7, 1238.1 and 2581.3 mg/100 g, respectively (Table 58). Higher levels of saponin in ricebean as well as chickpea resulted in higher content of this antinutrient in dal and kadhi whereas addition of rice to dal lowered the level of saponin in khichari. Ordinary as well as pressure cooking significantly ($P<0.05$) reduced the saponin content in boiled products. The decreasse was maximum in cooked kadhi (12%) followed by dal (10%) and khichari (9%). Baking could lower down the saponin content of unprocessed ricebean cake mixture by 23 per cent.

The raw mixture of boiled fababean products contained 912.7 to 1898.8 mg/100 g of saponin content. Significant reduction i.e. 9 to 10 per cent over the control value occurred in boiled fababean products (Table 59).

Loss during cooking may perhaps, indicate, thermolabile nature of saponins. Not much is known about the formation of a poorly extractable complex between saponins and sugar or amino acid upon cooking (Khokhar and Chauhan, 1986). Similar reduction in legume grains following ordinary cooking, pressure cooking and autoclaving has been reported by earlier workers (Jood et al., 1986; Grewal, 1992; Kakkar, 1992; Sharma and Sehgal, 1992b; Bishnoi and Khetarpaul, 1994a). On the other hand, Fenwick and Oakenfull (1983) reported that saponins survive rigours of cooking and food processing.

The saponin content of raw mixtures of idli, dosa and wadi prepared from ricebean was 1121.0, 1091.3 and 2007.9 mg/100 g, respectively which was reduced to 1004.0, 994.0 and 1703.6 mg/100 g, respectively after soaking treatment (Table 60). Fermentation for 12 h at 35°C of soaked mixture further caused significant reduction in the saponin content. The decrease in saponin levels after fermentation ranged from 30 to 33 per cent over the control value in different fermented products. Both steaming of idli and shallow frying in case of dosa further reduced th level of saponin of the fermented slurry by 8 per cent. Non significant differences were observed for saponins in fermented slurry and in final product, i.e., wadi.

Raw mixture of idli, dosa and wadi incorporating fababean as pulse had 1037.7, 863.1 and 1129.0 mg/100 g of saponin content (Table 61). Soaking and fermentation treatments significantly ($P<0.05$) decreased the saponin content by 17 to 20 per cent and 35 to 37 per cent, respectively in different fermented fababean products. Steaming and shallow frying of the fermented slurries involved in the preparation of idli and dosa further reduced the saponin content by 7 and 5 per cent, respectively.

All the treatments used in formation of fermented products whether in isolation or in combination significantly ($P<0.05$) reduced the saponin content. The loss of saponin during soaking of raw mixture of idli, dosa and wadi may possibly be due to leaching out of saponins into water through

simple diffusion. Fermentation also tends to decrease the saponin content of legumes. Reduction in saponin content during fermentation may be due to metabolic changes occurring during this process. According to Fenwick and Oakenfull (1983) fermented soyabean product, i.e., tempeh has less than half the saponin content of raw soyabean. Grewal (1992) also reported the loss of saponin in rabadi prepared from autoclaved sprouted soyabean during fermentation.

The saponin content of sprouted chat, tikki, cutlet, kofta and kachori prepared from ricebean was 1672.6, 1121.0, 1236.9, 2513.9, 882.9 mg/100 g, respectively whereas their raw mixtures contained 2156.7, 1299.6, 1555.5, 2990.1 and 1117.1 mg/100 g of saponin, respectively (Table 62). Sprouting together with frying used for the preparation of different sprouted fababean products significantly ($P<0.05$) reduced the level of saponin in the final products. The decrease in saponin content was 31 per cent in sprouted chat, 22 per cent in tikki, 23 per cent in cutlets, 17 per cent in kofta, 20 per cent in kachori, over the control values (Table 63).

The saponin loss during germination may be due to enzymatic degradation but this explanation is still not well established (Kataria et al., 1989a). Various workers reported a reduction in saponin content of different legumes including mothbean (Khokhar and Chauhan, 1986c), blackgram (Sharma and Sehgal, 1992b) and peas (Bishnoi and Khetarpaul, 1994a).

Saponin content of raw mixture of fried ricebean products varied from 1403.7 to 2513.4 mg/100 g (Table 64). Shallow

frying as well as deep fat frying significantly ($P<0.05$) lowered down the levels of saponin in these products with maximum loss observed in pakora and parantha (15%) followed by chilla (12%) and papad (8%).

The raw mixtures of nutritious parantha and chilla prepared from fababean contained 996.0 and 1811.5 mg/100 g of saponin which were reduced to 914.8 and 1712.3 mg/100 g, respectively in the final products (Table 65). The decrease in saponin content in pakora and papad prepared from fababean was 9 and 5 per cent, respectively over the control values. Saponin content of raw mixture of cake was 682.5 mg/100 g which was reduced to 598.0 mg/100 g after baking. Roasting significantly decreased the saponin content, i.e., by 16 per cent in roasted dal (Table 66).

The decreases observed in saponin content in fried, baked and roasted products might be due to the thermolabile nature of saponin. Earlier worker (Kakkar, 1992) had also reported 42 per cent loss in saponin content over the control value in roasted chickpeas.

4.5 Trypsin Inhibitor Activity

The raw mixture of dal and khichari prepared from ricebean had 55.2 and 77.1 TIU/g, respectively whereas raw mixture of kadhi had comparatively higher TIA (341.7 TIU/g) (Table 58). Cooking brought a significant ($P<0.05$) reduction in TIA of the boiled ricebean products. the reduction in TIA was maximum in cooked dal (81%) followed by khichari (80%) and

kadhi (79%). Trypsin inhibitor activity of cake was decreased from 35.4 TIU/g to 9.4 TIU/g after baking.

As a result of ordinary and pressure cooking, similar trend in decrease of TIA was noticed in boiled fababean products. Trypsin inhibitor activity in raw mixture of dal, khichari and kadhi prepared from fababean was 832.3, 350.0 and 878.1 TIU/g, respectively and cooking of these products significantly ($P<0.05$) reduced the TIA by 80 per cent in dal and kadhi and by 79 per cent in khichari over the control value (Table 59).

Trypsin inhibitors are heat labile and this may explain the destroying effect of cooking on trypsin inhibitors. Similar destruction in different legumes including fababean and soyabeans have been reported by other workers (Hussain, 1986; Sharma and Sehgal, 1992a; Borowska, 1993; Sangle et al., 1993). Mulimani and Vadiraj (1991) reported that the trypsin and chymotrypsin inhibitory activities were lost by 45 and 54 per cent in khichari, respectively prepared from sorghum.

Trypsin inhibitor activity of raw mixtures of fermented ricebean products ranged from 52.1 to 88.5 TIU/g (Table 60). Soaking of raw mixture of idli, dosa and wadi reduced the TIA by 9, 9 and 10 per cent, respectively, over the control value. Further drastic decreases were noticed when soaked mixture of these products were fermented for 12 h at 35°C. In fermented slurries of idli and dosa, TIA was reduced to one-fifth of that present in raw unprocessed mixtures. Fermented slurry of wadi had only one-third trypsin inhibitor activity of that present

in raw unprocessed wadi mixture. Non-significant differences were observed in fermented slurries and final product of idli, dosa and wadi.

The raw mixtures of idli, dosa and wadi prepared from fababean had 385.4, 286.2 and 825.6 TIU/g which was decreased to 358.4, 268.5 and 792.9 TIU/g after soaking for 12 h at 35°C (Table 61). Further reductions in TIA were brought by fermentation of the soaked mixture at 35°C for 12 h. The maximum loss in fermented slurries was observed upto the extent of 85 per cent in idli and dosa and upto 84 per cent in wadi. Further reduction by 3 per cent was observed during steaming and shallow frying of idli and dosa, respectively.

A decrease in trypsin inhibitor activity in soaked mixture of fermented ricebean and fababean products could partly be attributed to leaching out of low molecular weight inhibitors during soaking and washign of raw mixture. Kaul and Bajwa (1987) noticed a decrease in antitryptic activity of blackgram after soaking and further decrease upon fermentation for 2 and 4 h. They suggested that decrease in activity seemed to be organism specific and it could thus be related to difference in degradation pattern of protein in different organism.

Similar decrease in trypsin inhibitor activity of fermented products including idli (Steinkraus, 1983; Mulimani and Vadiraj, 1990), shoyu (Khader, 1983) and imartie (Kaul and Bajwa, 1987) has also been reported. A decrease in trypsin

inhibitor activity of blackgram during fermentation carried at different temperatures and periods has been reported (Chaudhary, 1993).

The trypsin inhibitor activity of raw mixture of sprouted ricebean products including sprouted chat, tikki, cutlet and kachori varied from 46.9 to 70.8 TIU/g whereas unprocessed mixture of kofta had high TIA, i.e., 699.9 TIU/g. Sprouting, steaming and slight cooking used in the preparation of sprouted chat decreased th trypsin inhibitor activity by 69 per cent whereas in tikki the TIA was decreased by 75 per cent over the control value (Table 62). Trypsin inhibitor activity of cutlet, kofta and kachori which involved sprouting, steaming and deep fat frying decreased by 60 to 69 per cent.

Unprocessed mixtures of sprouted chat, tikki, cutlet, kofta and kachori prepared from fababean contained 845.8, 566.7, 515.6, 946.9 and 313.5 TIU/g of trypsin inhibitor activity. After soaking, sprouting, steaming, shallow or deep fat frying, loss in trypsin inhibitor activity ranged from 59 to 78 per cent over the control value, the maximum reduction in trypsin inhibitor activity being in tikki (78%) and the minimum being in kofta (59%) (Table 63).

The decrease in trypsin inhibitor activity of different sprouted products was mainly due to germination and frying. A decrease in TIA during germination may perhaps be due to mobilization and breakdown of chemical constituents including trypsin inhibitors. Similar finding have been reported in various legumes including chickpea (Bansal, 1988), ricebean

(Verma and Mehta, 1988) and fababean (Sharma and Sehgal, 1992a).

The trypsin inhibitor activity of raw unprocessed mixtures of nutritious parantha prepared from ricebean was 68.7 TIU/g which was reduced to 49.0 TIU/g in cooked product (Table 64). Raw mixture of chilla, pakora and papad contained 344.8, 343.7 and 577.1 TIU/g of TIA. Reduction in trypsin inhibitor activity after frying ranged from 21 to 49 per cent over the control value in various shallow and deep fried products.

Trypsin inhibitor activity of raw mixture of fried products prepared from fababean ranged from 540.6 to 1002.1 TIU/g (Table 65). Significant ($P<0.05$) reduction did occur in the trypsin inhibitor activity after frying of these products. Loss in trypsin inhibitor activity of nutritious parantha, chilla, pakora and papad was to the extent of 36, 41, 50 and 15 per cent, respectively over the control value in final product.

The reduction in trypsin inhibitor activity in fried products may be attribtued to the thermolabile nature of trypsin inhibitor. Estevez and Luh (1985) prepared ready to eat snack foods from red kidney and pinto dry beans and showed a decrease in trypsin and chymotrypsin inhibitor in cooked and fried products.

Raw unprocessed mixture of cake contained 222.9 TIU/g trypsin inhibitor activity which was reduced to 57.3 TIU/g after baking. Roasting of fababean seeds also decreased the TIA by 90 per cent (Table 66).

Decrease in trypsin inhibitor activity has been reported by Khader (1983) in germinated soyabean bread. Cooking, dry heating or deep frying could inactivate 40-50 per cent of trypsin inhibitor (Ayyagari et al., 1989; Saini, 1991). Roasting of raw soyabean caused 70.4 to 90 per cent loss in trypsin inhibitor activity (Aletor and Ojo, 1989; Sangle et al., 1993).

The overall view of decrease in trypsin inhibitor activity in various products over the control value indicated that maximum decrease was observed in fermented products followed by boiled, sprouted, baked and fried products in ricebean products (Table 67). In case of fababean maximum decrease in TIA was noticed in fermented products (84-88%) followed by roasted (80%), boiled (79%), sprouted (59-78%), baked (74%) and fried products (15-50%) (Fig. 6).

4.5.4 Minerals

4.5.4.1 Total minerals

The content of total calcium in the uncooked mixtures of dal, khichari and kadhi was 310.2, 120.2 and 271.7 mg/100 g, respectively (Table 69). The iron content was the highest in kadhi (7.3 mg/100 g) followed by khichari (7.0 mg/100 g) and dal (6.6 mg/100 g). Kadhi and dal had similar values for total phosphorus (257.9 mg/100 g) whereas khichari contained 189.5 mg/100 g of total phosphorus. The amount of total Ca, Fe and P varied in these products due to differences in type and amount of ingredients used in their preparation. Pressure cooking and boiling did not affect the total mineral content of ricebean

Table 69. Total calcium, iron and phosphorus contents of boiled and baked ricebean product (mg/100 g, on dry matter basis)

Products	Calcium	Iron	Phosphorus
Boiled products			
Dal			
Raw mixture	310.2±1.9	6.6±0.06	257.9±1.9
Cooked product	308.5±2.2	6.4±0.04	257.3±1.8
't' value	1.26NS	1.47NS	0.55NS
Khichari			
Raw mixture	120.2±3.0	7.0±0.05	189.5±1.2
Cooked product	118.2±1.3	7.0±0.06	188.5±1.6
't' value	1.35NS	1.81NS	1.12NS
Kadhi			
Raw mixture	271.7±3.2	7.3±0.06	257.9±3.0
Cooked product	270.0±2.8	7.1±0.04	257.8±2.2
't' value	0.86NS	2.53NS	0.46NS
Baked product			
Cake			
Raw mixture	96.3±2.6	6.5±0.06	202.4±2.8
Baked product	93.7±1.5	6.3±0.04	199.7±2.2
't' value	2.01NS	2.08NS	1.8NS

Values are means ± SD of three independent determinations.
NS - Non significant at 5% level.

products as non-significant differences existed between the raw mxiture and final product.

Raw mixture of cake prepared from ricebean contained Ca, Fe and P as 96.3, 6.5 and 202.4 mg/100 g, respectively. Baking seemed to have no effect the total Ca, Fe and P contents as no differences were found between total mineral contents of unprocessed and baked product.

The amount of total Ca, Fe and P content varied in different boiled products prepared from fababean too. Raw mixture of kadhi had almost double the amount of total Ca as that present in khichari (Table 70). Among the boiled products, the uncooked dal contained the highest amount of total Ca, i.e., 180.3 mg/100 g. The iron content of different boiled products ranged from 5.0 to 6.0 mg/100 g, maximum being in khichari and minimum in dal. The uncooked mixtures of dal, khichari and kadhi had 247.2, 186.1 and 250.3 mg/100 g of total phosphorus, respectively. Pressure cooking or boiling did not change the contents of total Ca, Fe and P in various boiled products prepared from ricebean and fababean.

The unfermented as well as fermented final products, i.e., idli, dosa and wadi prepared from ricebean and fababean were also analysed. The raw unprocessed mixture of idli had 169.2 mg/100 g, calcium and it was reduced to 167.7, 167.3 and 166.8 mg/100 g after soaking, fermentation of soaked mixture and steaming of the fermented slurry, respectively but these changes were non-significant (Table 71). Similar trend was

Table 70. Total calcium, iron and phosphorus contents of boiled fababean products (mg/100 g, on dry matter basis)

Products	Calcium	Iron	Phosphorus
Dal			
Raw mixture	180.3±2.5	5.2±0.05	247.2±5.2
Cooked product	180.0±3.0	5.0±0.06	245.6±3.1
't' value	0.19NS	1.72NS	0.59NS
Khichari			
Raw mixture	82.0±2.6	5.8±0.10	186.1±3.3
Cooked product	81.3±3.6	6.0±0.08	183.4±2.4
't' value	0.33NS	1.36NS	1.51NS
Kadhi			
Raw mixture	163.3±2.4	5.4±0.06	250.3±3.9
Cooked product	163.0±1.6	5.3±0.08	247.1±2.1
't' value	0.26NS	1.61NS	1.60NS

Values are means ± SD of three independent determinations.
NS - Non significant at 5% level.

observed in total Fe and P contents. Hence, various processing and cooking steps involved in idli preparation did not change the total Ca, P and Fe contents.

Raw mixture of ricebean dosa was found to have total Ca, Fe and P contents as 163.8, 5.4 and 178.2 mg/100 g, respectively and were not affected significantly ($P<0.05$) during soaking, fermentation and shallow frying. The total iron content was maximum in wadi followed by dosa and idli (Table 71). Total iron content did not alter significantly ($P<0.05$) during ricebean idli, dosa and wadi preparation. Total phosphorus content was the highest in wadi (248.9 mg/100 g) and the lowest in idli (174.7 mg/100 g).

Soaking, fermentation and steaming or shallow frying were not found to change significantly the total phosphorus in idli and dosa. On the other hand, during wadi making, soaking significantly ($P<0.05$) reduced the total phosphorus content from 251.6 mg/100 g in raw mxiture to 248.0 mg/100 g in soaked mixture. Significant ($P<0.05$) differences were not found between the total P content of soaked mixture and fermented slurry and of fermented slurry and final product. But when we compare the total P content of unprocessed wadi mixture and the soaked mixture or unproceseed mixture and final product, total P content reduced significantly ($P<0.05$). It shows that only the soaking process was responsible for some loss in total P and not the fermentation and drying process.

Table 71. Total calcium, iron and phosphorus contents of fermented ricebean products (mg/100 g, on dry matter basis)

Products	Calcium	Iron	Phosphorus
Idli			
Raw mixture	169.2±1.1	4.4±0.04	175.4±1.4
Soaked mixture	167.7±1.2	4.3±0.02	174.3±0.9
Fermented slurry	167.3±1.0	4.3±0.02	174.6±0.8
Final product	166.8±1.8	4.3±0.01	174.7±0.5
SE(m)	±1.85	±0.06	±1.34
CD (P<0.05)	3.86	NS	2.79
Dosa			
Raw mixture	163.8±1.3	5.4±0.04	178.2±1.2
Soaked mixture	162.8±1.5	5.3±0.05	177.7±1.3
Fermented slurry	162.2±1.8	5.3±0.03	177.8±1.3
Final product	162.2±1.2	5.3±0.03	178.9±0.7
SE(m)	±2.10	±0.06	±1.63
CD (P<0.05)	4.38	NS	3.40
Wadi			
Raw mixture	277.5±1.7	6.4±0.03	251.6±0.6
Soaked mixture	276.3±1.2	6.3±0.02	248.0±0.5
Fermented slurry	274.8±1.3	6.3±0.03	249.3±0.6
Final product	274.7±0.9	6.3±0.03	248.9±0.6
SE(m)	±1.86	±0.04	±0.81
CD (P<0.05)	3.88	NS	1.70

Values are means ± SD of three independent determinations.
NS - Non significant.

Similar trend was observed in the fermented fababean products. Raw as well as fermented products prepared from fababean had less total Ca than that of ricebean products. The total Ca content was maximum in the raw mixture of wadi (178.3 mg/100 g) followed by idli (63.2 mg/100 g) and dosa (62.7 mg/100 g). Soaking, fermentation and heat treatment used to obtain the final product did not affect the total Ca content. Total iron and phosphorus contents were the highest in wadi followed by dosa and idli (Table 72). None of the processing treatments, i.e., soaking, fermentation, steaming, shallow frying involved in preparation of fermented products of fababean affected the total Ca, Fe and P contents.

Soaking, fermentation and steaming or shallow frying involved in preparation of fermented products from ricebean and fababean could not change the concentration of total minerals, i.e., Ca, Fe and P in final products except in ricebean wadi where soaking caused reduction in total P content due to leaching out in water. Since no addition or deletion of minerals source took place during soaking, fermentation, steaming or shallow frying. Hence, no change in total minerals was expected. Earlier workers have also reported similar findings for fermented products prepared from pearlmillet (Khetarpaul and Chauhan, 1990a), cereal-legume blends (Goyal, 1991), blackgram and greengram wadi (Yadav, 1992) and soyabean (Grewal, 1992).

In the unprocessed mixtures of sprouted ricebean products, total Ca varied from 122.3 to 310.8 mg/100 g

Table 72. Total calcium, iron and phosphorus contents of fermented fababean products (mg/100 g, on dry matter basis)

Products	Calcium	Iron	Phosphorus
Idli			
Raw mixture	63.2±0.8	4.7±0.04	163.4±1.6
Soaked mixture	62.2±0.8	4.7±0.03	162.2±0.9
Fermented slurry	60.8±0.9	4.6±0.03	162.3±1.1
Final product	61.7±0.9	4.6±0.02	162.9±1.0
SE(m)	±1.20	±0.05	±1.69
CD (P<0.05)	2.50	NS	3.52
Dosa			
Raw mixture	62.7±0.8	4.8±0.04	171.7±1.1
Soaked mixture	61.8±0.8	4.7±0.06	170.6±0.7
Fermented slurry	59.8±1.0	4.7±0.04	170.6±1.3
Final product	59.5±1.1	4.7±0.03	169.7±0.6
SE(m)	±1.31	±0.06	±1.36
CD (P<0.05)	2.73	NS	2.83
Wadi			
Raw mixture	178.3±0.9	5.0±0.03	242.0±1.3
Soaked mixture	176.7±0.9	4.9±0.04	240.4±1.0
Fermented slurry	175.7±1.5	5.0±0.04	240.5±0.5
Final product	175.2±1.7	5.0±0.01	242.2±0.7
SE(m)	±1.88	±0.05	±1.31
CD (P<0.05)	3.92	NS	2.73

Values are means ± SD of three independent determinations.
NS - Non significant.

(Table 73). The total Ca content in the final product of sprouted chat, cutlets and kofta was significantly ($P<0.05$) less than their respective unsprouted and uncooked controls. Non-significant difference were observed between the total calcium content of raw mixture and final product of tikki and kachori. The total Ca content of raw mixtures of sprouted chat, cutlet and kofta was 310.8, 164.8 and 160.8 mg/100 g and was reduced to 292.7, 160.3 and 157.7 mg/100 g, respectively in the final product after sprouting, shallow or deep frying, etc.

The total Fe content in sprouted chat, tikki, cutlet, kofta and kachori was 6.5, 5.3, 8.5, 10.6 and 5.8 mg/100 g, respectively. The total phosphorus contents of different sprouted product ranged from 147.6 to 298.7 mg/100 g with the highest being in kofta followed by sprouted chat, kachori, cutlet and tikki (Table 73). Sprouting or frying involved in the preparation of sprouted ricebean products did not affect the total Fe and P contents as non-significant differences existed between the raw mixture and final product of all sprouted ricebean products.

Various ingredients except the source of pulse used in the preparation of sprouted products were same in both the sprouted legume products. Raw ricebean contained more of calcium, iron and phosphorus than fababean and this may be the reason for difference in the total Ca, Fe and P contents of sprouted ricebean and fababean prdoucts. The total calcium content of raw mixture of sprouted fababean products varied from 72.7 to 172.7 mg/100 g, respectively (Table 74). The total

Table 73. Total calcium, iron and phosphorus contents of sprouted ricebean products (mg/100 g, on dry matter basis)

Products	Calcium	Iron	Phosphorus
Sprouted chat			
Raw mixture	310.8±3.3	6.6±0.06	246.2±2.5
Cooked product	292.7±6.9	6.5±0.10	244.9±1.4
't' value	5.27*	1.37NS	1.01NS
Tikki			
Raw mixture	212.8±2.6	5.5±0.05	149.7±2.6
Cooked product	208.8±2.3	5.3±0.06	147.6±2.8
't' value	1.29NS	2.31NS	1.23NS
Cutlet			
Raw mixture	164.8±3.0	8.7±0.06	170.7±3.3
Cooked product	160.3±1.5	8.5±0.04	168.5±1.9
't' value	2.98*	2.62NS	1.30NS
Kofta			
Raw mixture	160.8±2.3	10.8±0.05	300.6±2.7
Cooked product	157.7±1.9	10.6±0.04	298.7±3.9
't' value	2.40*	2.30NS	0.89NS
Kachori			
Raw mixture	122.3±2.2	6.0±0.05	202.4±3.3
Cooked product	117.7±4.4	5.8±0.05	199.9±2.5
't' value	2.10NS	2.30NS	1.32NS

Values are means ± SD of three independent determinations.

*Significant at 5% level.

NS - Non significant at 5% level.

Table 74. Total calcium, iron and phosphorus contents of sprouted fababean products (mg/100 g, on dry matter basis)

Products	Calcium	Iron	Phosphorus
Sprouted chat			
Raw mixture	172.7±2.5	4.4±0.06	240.6±2.0
Cooked product	169.2±3.1	4.5±0.08	239.0±2.4
't' value	5.25*	1.61NS	1.16NS
Tikki			
Raw mixture	147.3±1.9	4.1±0.10	141.1±2.9
Cooked product	144.0±2.8	4.0±0.04	140.0±2.0
't' value	2.64*	1.07NS	0.67NS
Cutlet			
Raw mixture	121.5±2.7	7.0±0.05	152.0±2.7
Cooked product	117.3±1.9	7.1±0.02	151.2±2.8
't' value	2.75*	2.24NS	0.43NS
Kofta			
Raw mixture	130.0±2.9	9.6±0.22	285.8±2.9
Cooked product	126.8±2.8	9.5±0.08	283.4±1.7
't' value	2.74*	1.38NS	1.53NS
Kachori			
Raw mixture	72.7±2.1	5.1±0.05	199.9±2.14
Cooked product	71.0±3.1	4.9±0.06	198.6±1.20
't' value	0.98NS	1.92NS	1.02NS

Values are means ± SD of three independent determinations.

*Significant at 5% level.

NS - Non significant at 5% level.

Ca content of raw mixture sprouted chat, tikki, cutlet and kofta was 172.7, 147.3, 121.5 and 130.0 mg/100 g, respectively which was significantly ($P<0.05$) reduced to the extent of 2.0, 2.2, 3.5 and 2.5 per cent, respectively, over the control value after sprouting, slight cooking and frying involved in the preparation of these products. Non significant differences existed in the Ca content of raw mixture of kachori and that of final product.

The total Fe and P content in raw mixture of sprouted fababean products ranged from 4.1 to 9.6 and 141.1 to 285.8 mg/100 g, respectively (Table 74). Different processing methods used in the preparation of these products were not found to affect the total Fe and P content.

The loss observed in total Ca content in some of the sprouted products prepared from ricebean and fababean may be attributed to loss of this mineral during soaking (Kumar et al., 1978) done prior to the germination process. Similar losses during soaking prior to germination have been reported by earlier workers in ricebean (Kaur, 1986), blackgram (Chaudhary, 1993) and peas (Bishnoi and Khetarpaul, 1994c).

The total Ca content in the raw mixture of nutritious parantha and chilla prepared from ricebean was 200.8 and 249.7 mg/100 g, respectively (Table 75). Among the deep fried product total Ca content in the raw mixture of pakora and papad was 250.0 and 253.3 mg/100 g, respectively. The total iron content of nutritious parantha was maximum, i.e., 9.8 mg/100 g which may be due to addition of spinach which is rich source of iron.

Table 75. Total calcium, iron and phosphorus contents of fried ricebean products (mg/100 g, on dry matter basis)

Products	Calcium	Iron	Phosphorus
Shallow fried			
Nutritious parantha			
Raw mixture	200.8±3.2	9.8±0.04	309.9±2.8
Cooked product	199.5±4.4	9.6±0.08	306.8±1.4
't' value	0.54 NS	2.15NS	2.16NS
Chilla			
Raw mixture	249.7±2.4	9.4±0.10	269.0±2.9
Cooked product	247.0±4.5	9.2±0.06	266.8±1.6
't' value	1.16NS	1.96NS	1.50NS
Deep fried			
Pakora			
Raw mixture	250.0±3.6	9.2±0.06	268.3±2.9
Cooked product	247.8±3.2	9.1±0.08	266.8±1.4
't' value	1.00NS	1.56NS	0.96NS
Papad			
Raw mixture	253.3±2.6	6.5±0.02	271.2±1.8
Cooked product	253.2±2.5	6.4±0.04	270.4±3.0
't' value	0.11NS	2.50NS	0.47NS

Values are means ± SD of three independent determinations.
NS - Non significant at 5% level.

Chilla and Pakora which was prepared by mixing chickpea flour and ricebean flour also had high iron content as chickpea is also a good source of iron. The total iron content of raw mixture of papad was 6.5 mg/100 g. Total P contents of different fried products ranged from 266.8 to 306.8 mg/100 g. Shallow or deep frying did not alter the contents of total Ca, Fe and P in fried ricebean products.

Variations existed in the total Ca, Fe and P contents of shallow and deep fried fababean products due to the differences in the type and amount of ingredients used in their preparation. But processing treatment, i.e., frying did not bring about any difference in the total mineral content of the final fried product. Among the fried products the total Ca content was maximum in papad followed by pakora, chilla and parantha. The iron content was the highest in parantha and chilla and the lowest in papad. Total P content varied from 257.1 to 299.3 mg/100 g in various fried fababean products (Table 76).

Raw mixture of fababean cake contained 86.3 mg/100 g of Ca, 4.5 mg/100g Fe and 196.1 mg/100 g P and remained almost the same after baking in the final product due to non-significant differences between the raw mixture and final product (Table 77).

Roasted fababean dal contained more of total Ca (177.3 mg/100 g), P (257.9 mg/100 g) and Fe (5.0 mg/100 g) when compared with raw mixture of cake which is due to less amount of pulse flour used in cake preparation. Roasting had no effect on

Table 76. Total calcium, iron and phosphorus contents of fried fababean products (mg/100 g, on dry matter basis)

Products	Calcium	Iron	Phosphorus
Shallow fried			
Nutritious parantha			
Raw mixture	113.3±2.4	8.4±0.06	299.3±2.0
Cooked product	113.0±2.6	8.3±0.05	299.5±2.2
't' value	0.21NS	2.11NS	0.14NS
Chilla			
Raw mixture	141.5±2.6	8.4±0.04	257.1±1.9
Cooked product	140.3±3.1	8.4±0.06	255.4±1.9
't' value	0.64NS	0.31NS	1.47NS
Deep fried			
Pakora			
Raw mixture	142.3±2.7	7.4±0.06	258.5±2.2
Cooked product	140.5±3.2	7.3±0.06	255.9±1.3
't' value	0.97NS	0.80NS	2.21NS
Papad			
Raw mixture	161.5±2.5	5.0±0.04	264.0±5.0
Cooked product	160.2±1.9	4.8±0.08	262.9±2.5
't' value	0.58NS	2.32NS	0.45NS

Values are means ± SD of three independent determinations.
NS - Non significant at 5% level.

Table 77. Total calcium, iron and phosphorus contents of baked and roasted fababean products (mg/100 g, on dry matter basis)

Products	Calcium	Iron	Phosphorus
Cake			
Raw mixture	86.3±2.5	4.5±0.10	196.1±2.9
Baked product	86.1±2.6	4.4±0.08	193.1±1.1
't' value	0.10NS	0.90NS	1.56NS
Roasted dal			
Raw dal	177.3±1.9	5.0±0.02	257.9±1.9
Roasted dal	175.7±2.3	5.0±0.04	257.2±1.8
't' value	1.26NS	1.00NS	0.55NS

Values are means ± SD of three independent determinations.
NS - Non significant at 5% level.

total Ca, P and Fe contents as no addition or deletion of minerals occurred during roasted process.

4.5 Extractability of Minerals

HCl-extractability of calcium an index of it bio-availability in raw unprocessed mixture of dal, khichari and kadhi ranged from 68.6 to 70.5 per cent in boiled ricebean products (Table 78). After ordinary and pressure cooking, it improved to the extent 7-9 per cent over the control value. Significant improvements were also observed in the HCl-extractability of Fe and P in different boiled ricebean products viz., dal, khichari and kadhi. Fe-extractability of khichari and kadhi was maximum followed by dal. Improvement in Fe-extractability due to cooking ranged from 5-6 per cent over the control value. Phosphorus extractability was enhancement to a greater extent than that of Ca and Fe in different boiled ricebean producs and the improvement varied from 22 to 29 per cent over the control value.

The extractability of Ca, Fe and P in the raw mixture of ricebean cake was 64.7, 68.7 and 33.4 per cent, respectively. Baking did not improve the extractability of these minerals significantly.

The calcium extractability of uncooked mixtures of boiled fababean products varied from 56.9 to 61.8 per cent (Table 79). The extractability of calcium was higher from kadhi than that from dal and khichari. On boiling and pressure cooking, the extractability of calcium improved to the extent of 11 per cent

Table 78. HCl-extractability of calcium, iron and phosphorus contents of boiled and baked ricebean products (%, dry matter basis)

Products	Calcium	Iron	Phosphorus
Boiled products			
Dal			
Raw mixture	70.5±0.8	78.6±0.9	32.9±0.3
Cooked product	75.3±1.3 (7)	82.4±1.3 (5)	42.4±0.4 (29)
't' value	6.83*	3.38*	44.78*
Khichari			
Raw mixture	68.6±1.4	81.4±0.8	34.2±0.5
Cooked prdouct	73.1±2.4 (7)	86.0±1.4 (6)	42.8±0.4 (25)
't' value	3.56*	5.97*	27.64*
Kadhi			
Raw mixture	69.4±1.4	81.5±0.6	33.2±0.6
Cooked product	75.3±1.1 (9)	86.2±0.3 (6)	40.6±0.4 (22)
't' value	7.36*	3.76*	23.58*
Baked product			
Cake			
Raw mixture	64.7±2.8	68.7±0.6	33.4±0.5
Baked product	66.0±3.6	70.1±1.0	36.4±0.7
't' value	0.62NS	1.70NS	13.71*

Values are means ± SD of three independent determinations.

*Significant at 5% level.

NS - Non significant at 5% level.

Figures in parentheses indicate per cent increase over control values.

Table 79. HCl-extractability of calcium, iron and phosphorus contents of boiled fababean products (%, on dry matter basis)

Products	Calcium	Iron	Phosphorus
Dal			
Raw mixture	56.9±1.3	71.7±0.8	34.9±0.4
Cooked product	62.1±1.5 (9)	76.9±1.3 (7)	43.2±0.9 (24)
't' value	5.67*	4.93*	18.15*
Khichari			
Raw mixture	57.5±2.4	73.4±1.1	36.4±0.4
Cooked product	64.0±3.0 (11)	77.4±1.4 (5)	43.2±0.4 (18)
't' value	3.80*	3.24*	26.36*
Kadhi			
Raw mixture	61.8±1.3	72.9±1.2	36.0±0.4
Cooked product	67.6±1.1 (9)	77.4±1.5 (6)	40.4±0.5 (12)
't' value	7.41*	3.35*	16.21*

Values are means ± SD of three independent determinations.

*Significant at 5% level.

Figures in parentheses indicate per cent increase over control values.

in khichari and 9 per cent in dal and kadhi when compared with their respective controls. Raw mixtures of fababean dal, khichari and kadhi had 71.7, 73.4 and 72.9 per cent iron extractbaility. Significant ($P<0.05$) improvement was noticed in extractability of final cooked products (Table 79). Enhancement in iron extractability was 7, 5 and 6 per cent over the control values in dal, khichari and kadhi prepared from fababean. P-extractability in raw mixtures of dal, khichari and kadhi ranged from 34.9 to 36.4 per cent whereas it rose 40.4 to 43.2 per cent in cooked product. Maximum increase in P-extractability was observed in dal followed by khichari and kadhi.

As the divalent cations as Ca, Fe, etc., are 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 during ordinary and pressure cooking as observed in this study (Tables 58 and 59) and as reported by previous workers (Kataria, 1986; Bishnoi, 1991) may possibly release these metallic ions in free form and may account for their increased HCl-extractability.

The antinutrients including phytic acid in boiled ricebean and fababean products are found to have a significant negative correlation with extractability of Ca, Fe and P (Tables 89 to 94) and this further confirms our findings.

The HCl-extractability of Ca ranged from 64.0 to 70.9 per cent in unprocessed raw mixtures of fermented ricebean products including idli, dosa and wadi. Soaking (12 h, 35°C) of the raw mxitures caused significant ($P<0.05$) enhancement in

Ca-extractability varying from 5 to 6 per cent over the control values (Table 80). Fermentation carried out at 35°C for 12 h, steaming in case of idli, and shallow frying in case of dosa further brought an increase in extractability of calcium. Enhancement brought about by fermentation raised from 12 to 16 per cent over the control value. Steaming and shallow frying improved the extractability of Ca by only 2 and 3 per cent, respectively whereas drying did not alter the Ca-extractability of the fermented wadi slurry.

The iron extractability ranged from 64.1 to 78.5 per cent with maximum being in the raw mixture of wadi and minimum in that of dosa (Table 80). The extractability was enhanced from 64.3, 64.1 and 78.5 per cent in unprocessed raw mixture to 67.4, 68.1 and 85.3 per cent in soaked mixture of idli, dosa and wadi, respectively. Improvement in the Fe-extractability due to fermentation was to the extent of 12, 9 and 11 per cent, over the control value (Table 80) in idli, dosa and wadi, respectively. Steaming and shallow frying also improved the iron-extractability but drying had no effect.

The extractability of phosphorus in the raw mixture of idli, dosa and wadi prepared from ricebean was 34.1, 32.4 and 32.9 per cent, respectively which was increased to 43.3, 42.0 and 44.2 per cent in the final products, respectively. Maximum enhancement is P-extractability was observed in wadi followed by dosa and idli (Table 80).

The extractability of Ca, Fe and P improved significantly ($P<0.05$) due to different domestic processing and cooking

Table 80. HCl-extractability of calcium, iron and phosphorus contents of fermented ricebean products (%, on dry matter basis)

Products	Calcium	Iron	Phosphorus
Idli			
Raw mixture	66.4±0.9	64.3±1.3	34.1±0.2
Soaked mixture	70.5±0.5 (6)	67.4±0.4 (5)	36.8±0.4 (8)
Fermented slurry	76.9±0.7 (16)	71.8±0.5 (12)	41.7±0.4 (22)
Final product	78.5±0.9 (18)	73.6±0.4 (15)	43.3±0.3 (27)
SE(m)	±1.11	±1.11	±0.46
CD (P<0.05)	2.29	2.56	0.83
Dosa			
Raw mixture	64.0±1.0	64.1±1.0	32.4±0.3
Soaked mixture	67.7±0.6 (6)	68.1±0.7 (6)	34.6±0.2 (7)
Fermented slurry	73.7±1.0 (15)	70.1±0.7 (9)	39.9±0.3 (23)
Final product	75.2±1.3 (18)	73.0±0.1 (14)	42.0±0.3 (30)
SE(m)	±1.41	±1.03	±0.41
CD (P<0.05)	2.94	2.37	0.85
Wadi			
Raw mixture	70.9±0.6	78.5±0.4	32.9±0.3
Soaked mixture	74.1±0.3 (5)	85.3±1.0 (9)	37.1±0.2 (13)
Fermented slurry	79.4±0.5 (12)	87.0±0.5 (11)	43.8±0.1 (33)
Final product	80.0±0.6 (13)	87.0±0.1 (11)	44.2±0.1 (34)
SE(m)	±0.73	±0.84	±0.29
CD (P<0.05)	1.52	1.94	0.60

Values are means ± SD of three independent determinations.

Figures in parentheses indicate per cent increase over control values.

methods used in the preparation of fermented fababean products viz., idli, dosa and wadi (Table 81). The extractability of calcium in the raw mixture of idli, dosa and wadi prepared from fababean was 56.4, 57.5 and 58.0 per cent, respectively which was increased to 60.0, 61.1 and 62.0 per cent on soaking to 68.1, 67.9 and 69.3 per cent on fermentation and 69.7, 70.0 and 69.6 per cent in the final product.

Soaking as well as fermentation and steaming had a cumulative effect for bringing about improvement in iron extractability of fermented products. Maximum enhancement was observed in dosa (10%) followed by wadi (9%) and idli (8%). Drying and shallow frying did not further improve the Fe-extractability. Processing and cooking methods viz., soaking, fermentation, steaming and shallow frying could bring enhancement by 32, 24 and 22 per cent over the control value in the final products of idli, dosa and wadi, respectively, in P-extractability (Table 81).

Divalent cations, i.e., Ca, Fe, Cu, Zn, etc., are generally present in bound form with phytic acid and a legume protein-phytate-mineral complex is formed (Prattley et al., 1982). Reduction of phytic acid during fermentation (Tables 60 and 61) possibly through hydrolysis by inherent phytase in fermented microflora may release these metallic ions in free form and therefore, may amount for increased HCl-extractability of mineral in fermented products (Ramakrishan et al., 1976; Nolan and Duffins, 1987). The phytic acid and other antinutrients in the fermented products were found to have a

Table 81. HCl-extractability of calcium, iron and phosphorus contents of fermented fababean products(%, on dry matter basis)

Products	Calcium	Iron	Phosphorus
Idli			
Raw mixture	56.4±0.8	62.6±0.6	34.6±0.3
Soaked mixture	60.0±0.9 (6)	65.3±0.5 (4)	38.9±0.3 (12)
Fermented slurry	68.1±1.1 (21)	67.1±0.5 (7)	42.5±0.3 (23)
Final product	69.7±1.0 (24)	67.6±0.6 (8)	45.7±0.3 (32)
SE(m)	±1.57	±0.78	±0.43
CD (P<0.05)	3.27	1.80	0.90
Dosa			
Raw mixture	57.5±1.1	61.8±0.6	35.5±0.3
Soaked mixture	61.1±1.0 (6)	66.0±0.3 (7)	37.9±0.2 (7)
Fermented slurry	67.9±0.5 (18)	67.5±0.5 (9)	42.2±0.2 (19)
Final product	70.0±0.8 (22)	67.7±0.8 (10)	43.9±0.3 (24)
SE(m)	±1.51	±0.82	±0.39
CD (P<0.05)	3.15	1.89	0.81
Wadi			
Raw mixture	58.0±0.4	72.6±0.9	35.6±0.2
Soaked mixture	62.0±0.5 (7)	76.4±1.0 (5)	38.3±0.4 (8)
Fermented slurry	69.3±0.7 (20)	78.9±0.7 (9)	43.8±0.2 (23)
Final product	69.6±0.4 (20)	78.8±0.6 (9)	43.4±0.2 (22)
SE(m)	±0.77	±1.01	±0.36
CD (P<0.05)	1.61	2.33	0.75

Values are means ± SD of three independent determinations. Figures in parentheses indicate per cent increase over control values.

significant and negative correlation with extractable Ca, Fe and P (Table 89 to 94) which ascertain the role of these antinutrient in lowering the extractability of mineral in these foods.

Fermentation enhanced the extractability of iron in fermented corn meal and soybean (Chompreeda and Fields, 1984a; Grewal, 1992) in tef and wheat flour (Ramachandran and Balodia, 1984), in fermented blackgram sprouts (Chaudhary, 1993). Yadav (1992) observed an increase in extractability of Ca, Zn, P, Fe and Mn in wadies prepared from blackgram and greengram when fermented at 25, 30, 35°C for 12 and 18 h.

The HCl-extractability of Ca in control samples of sprouted ricebean products ranged from 64.3 to 72.4 per cent (Table 82). Extractability of Ca increased significantly ($P<0.05$) and varied from 6 to 9 per cent over the control value in different ricebean sprouted products. The iron extractability of raw mixtures of sprouted chat, tikki, cutlets, kofta, and kachori was 78.7, 82.9, 82.1, 82.0 and 82.6 per cent, respectively. Sprouting together with other treatments brought significant increase, i.e. upto the extent of 10 percent over the control value, the highest increase being observed in sprouted chat and the lowest in kachori. Phosphorus extractability was 32.5 to 34.0 per cent in unprocessed samples of ricebean sprouted products (Table 82). P-extractability improved to a greater extent (14 to 20%) than Ca and Fe.

The HCl-extractability of calcium in the raw mixtures of sprouted chat, tikki, cutlet, kofta and kachori prepared from

Table 82. HCl-extractability of calcium, iron and phosphorus contents of sprouted ricebean products (%, on dry matter basis)

Products	Calcium	Iron	Phosphorus
Sprouted chat			
Raw mixture	69.9±0.7	78.7±0.3	32.5±0.6
Cooked product	76.2±0.8 (9)	86.3±1.0 (10)	38.9±0.5 (20)
't' value	12.60*	10.50*	10.60*
Tikki			
Raw mixture	69.9±1.3	82.9±1.5	33.3±0.9
Cooked product	76.4±1.7 (9)	87.1±1.5 (5)	39.1±0.6 (17)
't' value	6.79*	2.78	11.79*
cutlet			
Raw mixture	72.4±1.6	82.1±1.2	34.0±0.7
Cooked product	78.6±1.8 (9)	86.5±0.7 (5)	39.7±0.5 (17)
't' value	5.70*	4.57*	14.90*
Kofta			
Raw mxiture	66.9±1.6	82.0±0.3	33.9±0.3
Cooked product	70.7±1.1 (6)	85.3±0.7 (4)	38.7±0.4 (14)
't' value	4.30*	6.16*	15.60*
Kachori			
Raw mixture	64.3±1.6	82.6±0.4	33.3±0.7
Cooked product	70.3±1.9 (9)	85.1±1.0 (3)	38.2±0.6 (15)
't' value	5.31*	3.09*	11.83*

Values are means ± SD of three independent determinations.

*Significant at 5% level.

Figures in parentheses indicate per cent increase over control values.

fababean was 58.5, 63.6, 62.4, 60.6 and 54.3 per cent, respectivley (Table 83). Sprouting together with other processing methods, i.e., shallow frying, deep frying, cooking, etc., used in the preparation of these above mentioned products incorporating fababean sprouts significantly ($P<0.05$) improved the Ca-extractability; maximum increases being observed in sprouted chat (10%) followed by kachori (6%), cutlets (6%), kofta (5%) and tikki (4%).

The enhancement in Fe-extractability after cooking of sprouted fababean products was 7 per cent in sprouted chat, 6 per cent in tikki, 7 per cent in cutlet, 9 per cent in kofta and 5 per cent in kachori over the control values. The P-extractability ranged from 34.4 to 36.5 per cent in the unprocessed mixture of sprouted fababean products (Table 83). The P-extractability increased from 34.6, 35.0, 34.4, 36.4 and 36.5 per cent in the raw mixtures to 40.2, 38.7, 38.3, 41.6 and 40.1 per cent in the final products of sprouted chat, tikki, cutlet, kofta and kachori, respectively. The maximum increase were observed in sprouted chat followed by kofta, tikki, cutlet and kachori.

The increase in the extractability of minerals observed in sprouted products prepared from ricebean and fababean could be due to germination. Decrease in the level of phytic acid by soaking and sprouting as reported by previous workers (Bishnoi, 1991; Yadav, 1992; Grewal, 1992; Chaudhary, 1993) and in this study too (Tables 62 and 63) may possibly release these

Table 83. HCl-extractability of calcium, iron and phosphorus contents of sprouted fababean products (%, on dry matter basis)

Products	Calcium	Iron	Phosphorus
Sprouted chat			
Raw mixture	58.5±1.5	71.9±0.9	34.6±0.5
Cooked product	64.1±2.0 (10)	76.7±1.8 (7)	40.2±0.4 (16)
't' value	4.97*	3.30*	19.39*
Tikki			
Raw mixture	63.6±1.3	73.5±1.1	35.0±0.8
Cooked product	66.2±1.0 (4)	77.9±1.9 (6)	38.7±0.5 (11)
't' value	3.47*	2.95*	8.06*
Cutlet			
Raw mixture	62.4±1.9	73.2±1.5	34.4±0.6
Cooked product	65.9±1.8 (6)	78.0±0.6 (7)	39.3±0.6 (11)
't' value	2.95*	4.95*	10.04*
Kofta			
Raw mixture	60.6±1.9	69.6±0.9	36.4±0.3
Cooked product	63.5±1.6 (5)	76.0±0.6 (9)	41.6±0.3 (14)
't' value	2.48*	8.49*	24.91*
Kachori			
Raw mixture	54.3±3.1	73.2±1.2	36.5±0.7
Cooked product	57.5±3.4 (6)	76.7±1.3 (5)	40.1±0.3 (10)
't' value	2.51*	2.80*	20.51*

Values are means ± SD of three independent determinations.

*Significant at 5% level.

Figures in parentheses indicate per cent increase over control values.

metallic ions in free form and may amount for their increased HCl-extractability.

The antinutrients including phytic acid in sprouted ricebean and fababean were found to have a significant negative correlation with extractability of minerals (Tables 89 to 94) which ascertained the role of phytic acid in lowering the extractability of these minerals in the sprouted products.

The raw mixtures of nutritious parantha, chilla, pakora and papad prepared from ricebean had 64.7, 67.2, 68.6 and 65.2 per cent of Ca-extractability, respectively (Table 84). Frying did not seem to affect the Ca-extractability in any of the product as non-significant differences existed between the raw mixtures and final products. The Fe-extractability was the highest in cooked samples of parantha (82.2%) and the lowest in chilla (74.8%). The iron extractability in case of nutritious parantha was significantly improved from 80.3 in the raw mixture to 82.2 per cent in cooked product but no effect of frying was observed in products like chilla, pakora and papad.

There was not much difference in phosphorus extractability of fried products as it varied from 32.3 to 33.4 per cent. Significant improvement were observed for P-extractability in nutritious parantha, chilla and pakora due to frying whereas in papad non-significant difference were observed between the raw papad and fried papad.

The Ca-extractability of raw mixture of nutritious parantha and chilla prepared from fababean was 55.4 and 59.2

Table 84. HCl-extractability of calcium, iron and phsophorus contents of fried ricebean products (%, on dry matter basis

Products	Calcium	Iron	Phosphorus
Shallow fried			
Nutritious parantha			
Raw mixture	64.7±1.5	80.3±0.6	32.3±0.3
Cooked product	65.2±1.6	82.2±0.3	38.0±0.5
't' value	1.23NS	3.91*	22.32*
Chilla			
Raw mixture	67.2±1.2	74.0±1.0	32.7±0.5
Cooked product	68.0±0.9	74.8±0.3	39.7±0.4
't' value	1.19NS	1.04NS	26.09*
Deep fried			
Pakora			
Raw mixture	68.6±1.4	74.1±0.7	32.5±0.4
Cooked product	69.7±1.2	75.0±0.4	37.8±4.4
't' value	2.12NS	2.48NS	20.19*
Papad			
Raw mixture	65.2±1.3	75.1±0.7	33.4±0.13
Cooked product	65.5±1.1	75.5±0.9	35.9±0.60
't' value	0.38NS	0.45NS	2.15NS

Values are means ± SD of three independent determinations.

*Significant at 5% level.

NS - Non significant at 5% level.

per cent, respectively. Non-significant differences were observed between Ca-extractability of the raw mixture and final fried product of parantha and chilla (Table 85). Similar observations were noticed for the deep fried products too. Hence, shallow or deep frying did not improve the extractability of Ca and Fe in the fried products except the Fe-extractability of nutritious parantha which was improved significantly ($P<0.05$), i.e., by 4 per cent over the control value.

The extractability of phosphorus in the raw unprocessed mixture of fried fababean products ranged from 34.3 to 36.0 per cent. Significant improvements were observed in the P-extractability among all fried products after frying except in papad which showed non-significant differences in raw mixture and cooked product. The increase in P-extractability was 6 per cent in nutritious parantha and chilla and 8 per cent in pakora.

The extractability of Ca, Fe and P was 56.4, 62.5 and 35.5 per cent, respectively in unprocessed mixture of fababean cake. Extractability of Ca and Fe did not improve after baking whereas extractability of P was significantly ($P<0.05$) increased to 10 per cent over the control values after baking (Table 86). Extractability of Ca was significantly increased by 11 per cent over the control values after roasting. For Fe and P-extractability non-significant differences existed in the raw mixture and roasted dal.

Table 85. HCl-extractability of calcium, iron and phosphorus contents of fried fababean products (%, on dry matter basis)

Products	Calcium	Iron	Phosphorus
Shallow fried			
Nutritious parantha			
Raw mixture	55.4±1.9	68.7±0.8	34.7±0.5
Cooked product	55.1±1.8	71.4±0.7	36.9±0.3
't' value	0.24NS	3.49*	8.54*
Chilla			
Raw mixture	59.2±1.0	64.7±0.6	35.4±0.3
Cooked product	60.0±1.0	65.0±1.0	37.5±0.4
't' value	1.17NS	0.45NS	10.11*
Deep fried			
Pakora			
Raw mixture	59.6±1.1	65.3±0.8	36.0±0.4
Cooked product	60.4±1.2	66.7±0.9	39.0±0.4
't' value	2.10NS	1.60NS	11.81*
Papad			
Raw mixture	52.9±1.0	66.3±1.2	34.3±0.4
Cooked product	53.7±1.3	66.7±1.3	35.2±0.4
't' value	1.20NS	0.26NS	2.01NS

Values are means ± SD of three independent determinations.

*Significant at 5% level.

NS - Non significant at 5% level.

Table 86. HCl-extractability of calcium, iron and phosphorus contents of baked and roasted fababean products (%, on dry matter basis)

Products	Calcium	Iron	Phosphorus
Cake			
Raw mixture	56.4±2.3	62.5±0.9	35.5±0.4
Baked product	57.4±2.0	62.9±1.4	39.2±0.5
't' value	0.80NS	0.31NS	12.26*
Roasted dal			
Raw dal	58.0±1.9	77.8±1.5	39.2±0.4
Roasted dal	64.5±1.5	82.7±2.1	39.5±0.4
't' value	5.91*	2.64NS	0.96NS

Values are means ± SD of three independent determinations.

*Significant at 5% level.

NS - Non significant at 5% level.

Not much improvement in minerals extractability was observed in fried, baked and roasted products. The reason may be that phytic acid, the major antinutrient affecting the availability of divalent cations, is thermostable and its loss observed in fried, baked and roasted product is only apparent and not true, therefore, the availability of Ca and Fe found unchanged during heat treatment is not expected. Similar results have been reported in autoclaved dehulled soyabean (Grewal, 1992).

Among different products prepared from ricebean, maximum increase in Ca and Fe-extractability was observed in fermented products followed by sprouted and boiled products (Table 87; Fig. 7 and 8), whereas P-extractability in ricebean products was maximum increased in fermented product (20-34%) followed by boiled product (22-29%), sprouted product (14-20%) and fried product (6-8%)(Fig. 9).

In case of fababean products the minerals extractbaility was maximum increased in fermented products, followed by boiled and sprouted products (Table 88).

4.5 In Vitro Availability of Ca and Fe

The Ca availability (in vitro) from the raw mixture of ricebean dal, khichari and kadhi was 62.0, 58.1 and 61.4 per cent, respectively whereas iron availability in these boiled and cooked products ranged from 32.2 to 37.3 per cent (Table 95). Significant improvements were observed in Ca and Fe availability in boiled ricebean product. The increase in availability of Ca and Fe were maximum in case of khichari

Table 87. Per cent increase in HCl-extractability of calcium, iron and phosphorus contents of ricebean products

Products	Calcium	Ranks	Iron	Ranks	Phosphorus	Ranks
Boiled products	6-8	III	5-6	III	22-29	II
Fermented products	13-18	I	11-14	I	20-34	I
Sprouted products	6-9	II	3-10	II	14-20	III
Fried products	NS		NS		6-8	IV
Baked product	NS		NS		NS	

NS - Non significant

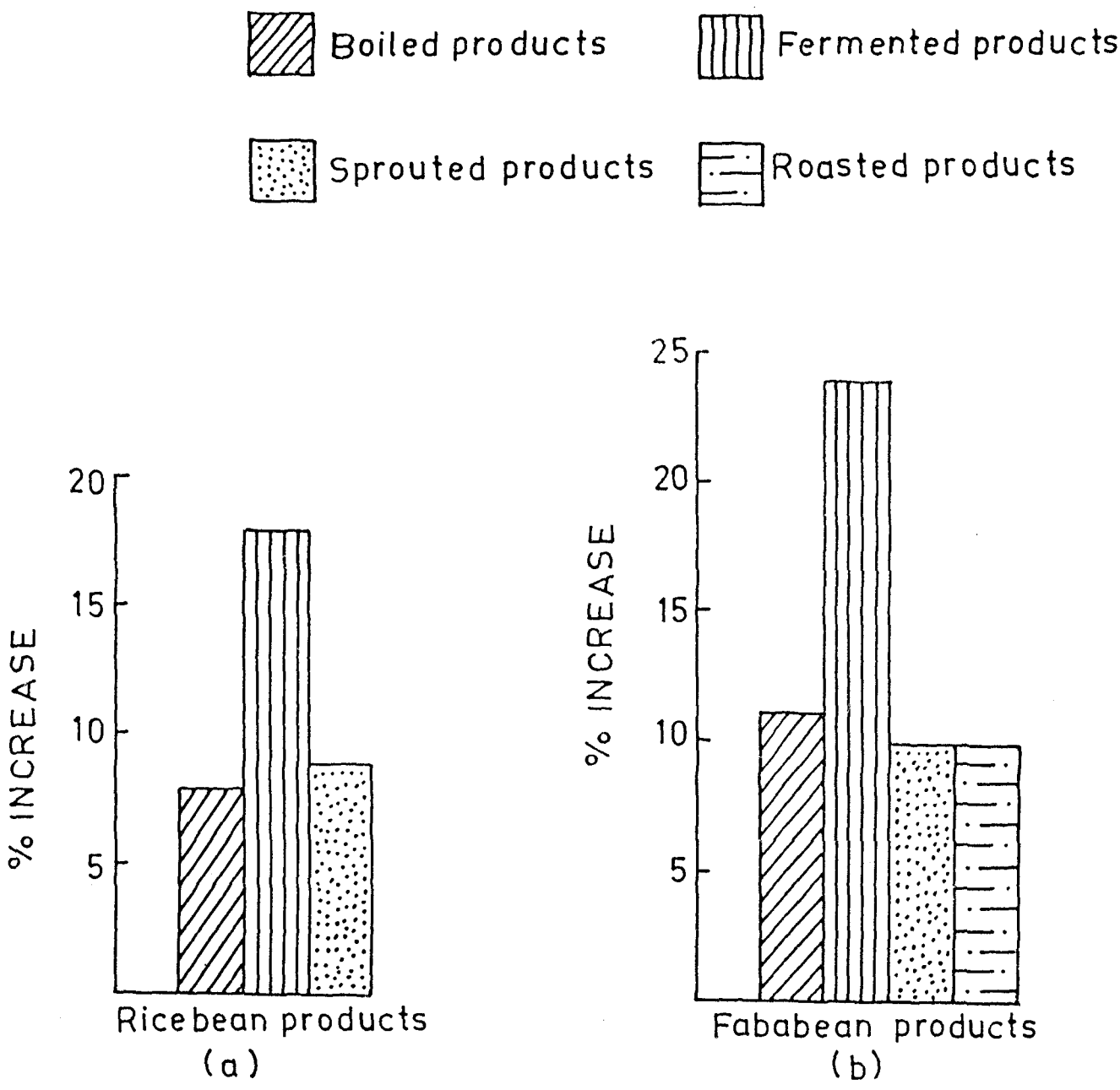

FIG. 7. EFFECT OF BOILING, FERMENTATION, SPROUTING, AND ROASTING ON HCl-EXTRACTABILITY OF CALCIUM OF RICEBEAN (a) AND FABABEAN PRODUCTS (b)

Table 88. Per cent increase in HCl-extractability of calcium, iron and phosphorus contents over the control values of fababean products

Products	Calcium	Ranks	Iron	Ranks	Phosphorus	Ranks
Boiled products	9-11	II	5-7	II	12-24	II
Fermented products	20-24	I	8-9	I	22-32	I
Sprouted products	4-10	III	5-9	I	10-16	III
Fried products	NS		NS		6-8	IV
Baked product	NS		NS		NS	
Roasted product	10	III	NS		NS	

NS - Non significant.

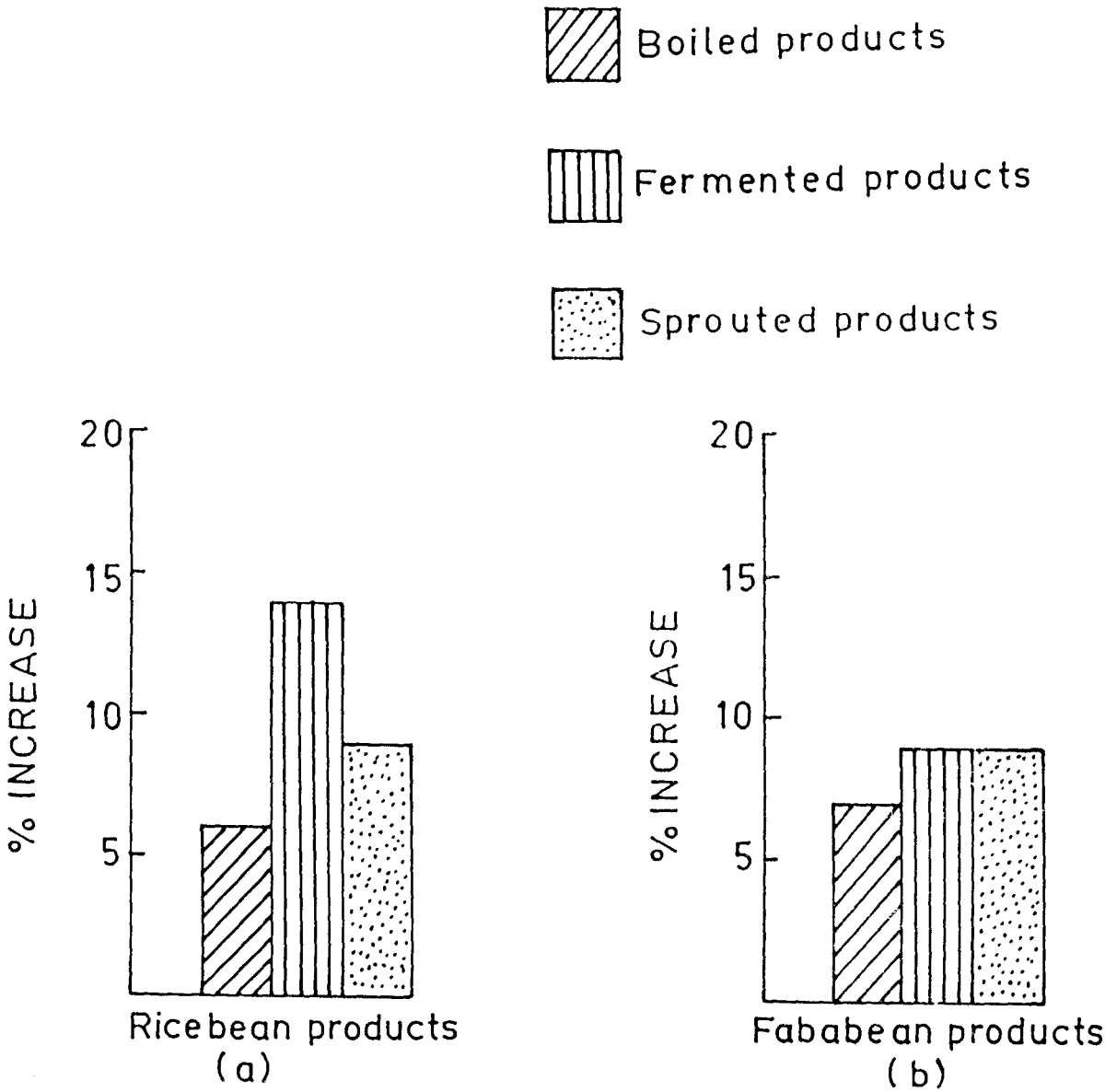

FIG. 8. EFFECT OF BOILING, FERMENTATION AND SPROUTING ON HCl-EXTRACTABILITY OF IRON OF RICEBEAN (a) AND FABABEAN PRODUCTS (b)

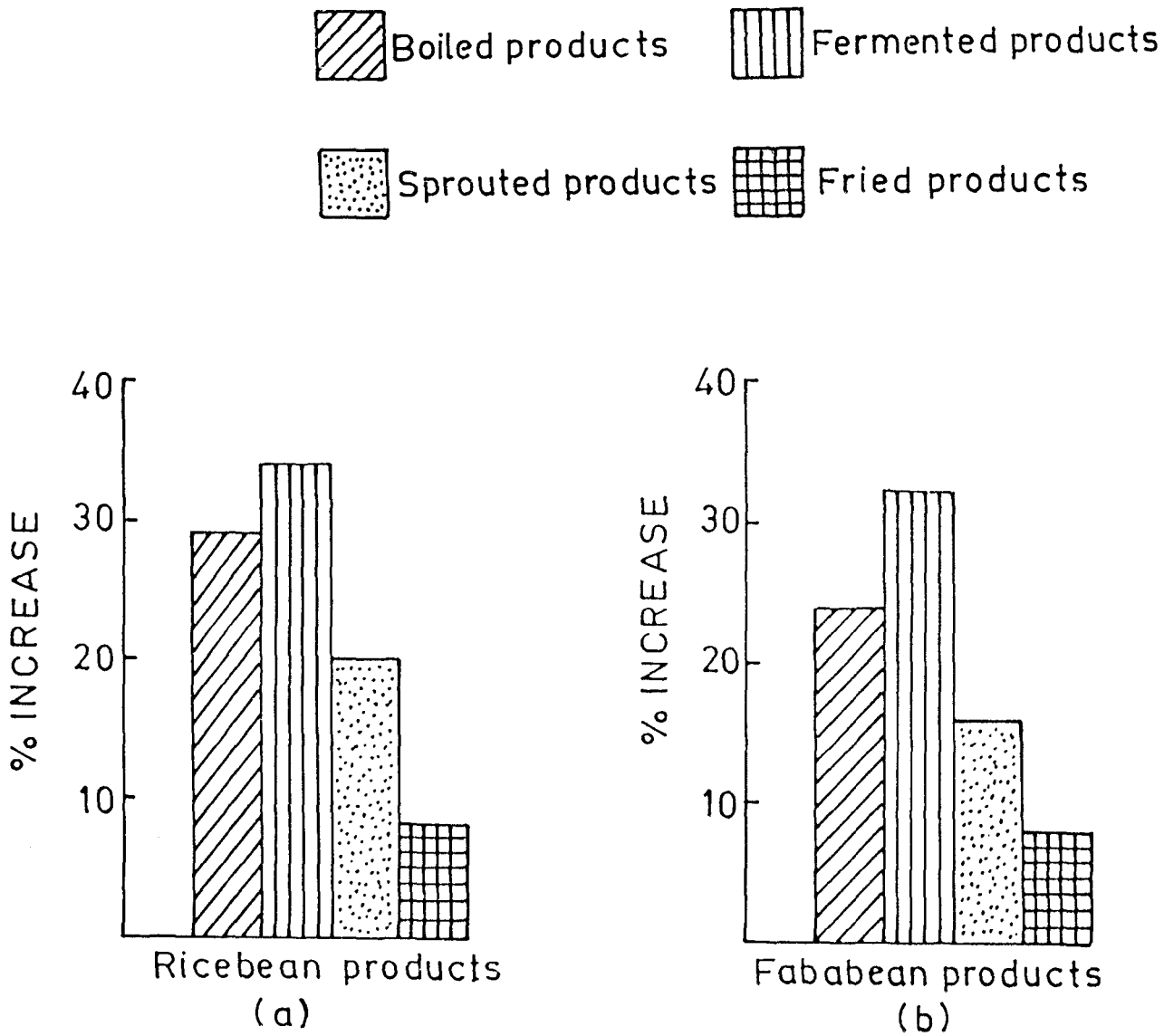

FIG.9. EFFECT OF BOILING, FERMENTATION, SPROUTING AND FRYING ON HCl - EXTRACTABILITY OF PHOSPHORUS OF RICEBEAN (a) AND FABABEAN PRODUCTS (b)

Table 89. Correlation coefficients of calcium extractability with antinutritional factors of ricebean and its products

	Anti-nutrients			
	Phytic acid	Poly-phenols	Saponins	Trypsin inhibitor activity
Raw	-0.7428*	-0.7124*	-0.7361*	-0.7415*
Soaked (12 h)	-0.8897*	-0.8923*	-0.9798**	-0.9787**
Sprouted (24 h)	-0.9063*	-0.8948*	-0.9128*	-0.9123*
Boiled products	-0.8214*	-0.8028*	-0.9320**	-0.9465**
Fermented products	-0.9321*	-0.8261*	-0.8928*	-0.8798*
Sprouted products	-0.9023*	-0.8364*	-0.8802*	-0.8569*
Fried products	-0.8213*	-0.8021*	-0.8302*	-0.8469*
Baked product	-0.7063*	-0.6803	-0.8123*	-0.8248*

* Significant at 5% level.

**Significant at 1% level.

Table 90. Correlation coefficients of calcium extractability with anti-nutritional factors of fababean and its products

	Anti-nutrients			
	Phytic acid	Poly-phenols	Saponins	Trypsin inhibitor activity
Raw	-0.8724*	-0.8619*	-0.8827*	-0.8641*
Soaked (12 h)	-0.9562*	-0.9328*	-0.9214*	-0.9126*
Sprouted (48 h)	-0.9610*	-0.9420**	-0.9028*	-0.8024*
Dehulled	-0.8623*	-0.8521*	-0.8024*	-0.9561**
Boiled products	-0.9124*	-0.9212*	-0.9127*	-0.8969*
Fermented products	-0.9028*	-0.9014*	-0.9214*	-0.9201*
Sprouted products	-0.9215*	-0.9078*	-0.8128*	-0.9607**
Fried products	-0.8012*	-0.7823*	-0.7474*	-0.8561**
Baked product	-0.7261*	-0.7305*	-0.7428*	-0.7842*
Roasted product	-0.7348*	-0.7561*	-0.7361*	-0.7528*

* Significant at 5% level

**Significnat at 1% level

Table 91. Correlation coefficient of iron extractability with anti-nutritional factors of ricebean and its products

	Anti-nutrients			
	Phytic acid	Poly-phenols	Saponins	Trypsin inhibitor activity
Raw	-0.7241*	-0.6894*	-0.7121*	-0.7063*
Soaked (12 h)	-0.8241*	-0.8037*	-0.8543*	-0.8934*
Sprouted (24 h)	-0.8430*	-0.8340*	-0.8724*	-0.9024*
Boiled products	-0.8621*	-0.8724*	-0.8971*	-0.9483*
Fermented products	-0.8791*	-0.8428*	-0.9203*	-0.9644**
Sprouted products	-0.9241*	-0.9067*	-0.9425*	-0.9347**
Fried products	-0.6563*	-0.6628	-0.7258*	-0.8125*
Baked product	-0.5924	-0.6041	-0.6928	-0.6591

* Significant at 5% level

**Significant at 1% level

Table 92. Correlation coefficient of iron extractability with anti-nutritional factors of fababean and its products

	Anti-nutrients			
	Phytic acid	Poly-phenols	Saponins	Trypsin inhibitor activity
Raw	-0.7621*	-0.7428*	-0.7241*	-0.7561*
Soaked (12 h)	-0.7728*	-0.7521*	-0.9634*	-0.7831*
Sprouted (48 h)	-0.8821*	-0.8767*	-0.9079*	-0.9248*
Dehulled	-0.7562*	-0.7624*	-0.7921*	-0.8041*
Boiled products	-0.8924*	-0.9031*	-0.9248*	-0.9428**
Fermented products	-0.9061*	-0.9268*	-0.9561**	-0.9327**
Sprouted products	-0.9241*	-0.9047*	-0.9179*	-0.9281**
Fried products	-0.6891*	-0.7024*	-0.8124*	-0.7943*
Baked product	-0.6424*	-0.6563*	-0.6428*	-0.6579*
Roasted product	-0.8021*	-0.7821*	-0.7423*	-0.7243*

* Significant at 5% level

**Significant at 1% level

Table 93. Correlation coefficients of phosphorus extractability with anti-nutritional factors of ricebean and its products

	Anti-nutrients			
	Phytic acid	Poly-phenols	Saponins	Trypsin inhibitor activity
Raw	-0.7283*	-0.7064*	-0.8124*	-0.8261*
Soaked (12 h)	-0.8124*	-0.7943*	-0.8249*	-0.8483*
Sprouted (24 h)	-0.8728*	-0.8547*	-0.8387*	-0.8314*
Boiled products	-0.8561*	-0.7978*	-0.7861*	-0.8681*
Fermented products	-0.8437*	-0.8260*	-0.8669*	-0.9241**
Sprouted products	-0.8374*	-0.8579*	-0.8528*	-0.9324**
Fried products	-0.6241	-0.7012*	-0.7229*	-0.8047*
Baked products	-0.5862	-0.6048	-0.6243	-0.7369*

* Significant at 5% level

**Significant at 1% level

Table 94. Correlation coefficients of phosphorus extractability with anti-nutritional factors of fababean and its products

	Anti-nutrients			
	Phytic acid	Poly-phenols	Saponins	Trypsin inhibitor activity
Raw	-0.8217*	-0.8410*	-0.8321*	-0.8268*
Soaked (12 h)	-0.9021*	-0.8924*	-0.9029*	-0.9179*
Sprouted (48 h)	-0.9128*	-0.9068*	-0.9283*	-0.9421**
Dehulled	-0.7928*	-0.8156*	-0.8021*	-0.7963*
Boiled products	-0.9321**	-0.9363**	-0.9021*	-0.9428**
Fermented products	-0.9461*	-0.9560**	-0.9376**	-0.9038*
Sprouted products	-0.9438**	-0.9321**	-0.8924*	-0.9147*
Fried products	-0.7012*	-0.7124*	-0.6828*	-0.7243*
Baked product	-0.6529*	-0.6621*	-0.6729*	-0.7039*
Roasted product	-0.7340*	-0.7289*	-0.7171	-0.6977*

* Significant at 5% level

**Significant at 1% level

Table 95. In vitro availability of calcium and iron of boiled and baked ricebean products (%, on dry matter basis)

Products	Calcium	Iron
Boiled products		
Dal		
Raw mixture	62.0±0.6	37.3±0.7
Cooked product	66.3±0.5 (7)	39.1±0.2 (5)
't' value	11.64*	3.01*
Khichari		
Raw mixture	58.1±1.5	38.6±0.1
Cooked product	65.6±2.0 (13)	41.1±0.3 (7)
't' value	6.72*	3.07*
Kadhi		
Raw mixture	61.4±0.77	32.2±0.1
Cooked product	68.1±0.98 (11)	34.2±0.2 (6)
't' value	11.95*	6.24*
Baked product		
Cake		
Raw mixture	53.8±2.2	31.0±0.4
Baked product	55.0±1.8	31.4±0.3
't' value	0.92NS	1.05NS

Values are means ± SD of three independent determinations

*Significant at 5% level

NS - Non significant at 5% level

Figures in parentheses indicate per cent increase over control values

followed by kadhi and dal. The increase in Ca and Fe availability ranged from 7 to 13 per cent and 5 to 7 per cent, respectively in different boiled products.

Calcium and iron availability from raw mixture of cake was 53.8 and 31.0 per cent, respectively which was not changed after baking indicating that baking could not improve the Ca and Fe availability.

The in vitro availability of Ca and Fe in the raw mixture of boiled fababean products ranged from 47.8 to 52.1 and 31.8 to 38.5 per cent, respectively (Table 96). Improvement were more in Ca availability than iron availability among these different boiled products. Maximum increase in calcium availability was observed in khichari (16%) followed by kadhi (15%) and dal (8%). The increases in iron availability was to the extent to 3 to 5 per cent over the control value in dal, khichari and kadhi.

The availability of Ca and iron in the raw mixture of idli prepared from ricebean was 57.6 and 31.7 per cent, respectively (Table 97). Soaking for 12 h at 35°C did not improve the availability of Ca as well as Fe but fermentation and steaming significantly ($P<0.05$) increased the iron and calcium availability. Availability of calcium and iron was increased due to fermentation by 13 and 12 per cent over the control value, respectively. Steaming of idli further increased the Ca availability by 6 per cent whereas non-significant differences were observed for iron availability in fermented

Table 96. In vitro availability of calcium and iron of boiled fababean products (%, on dry matter basis)

Products	Calcium	Iron
Dal		
Raw mixture	48.7±1.5	33.0±0.3
Cooked product	52.4±0.9 (8)	39.7±0.2 (5)
't' value	3.37*	7.09*
Khichari		
Raw mixture	47.8±1.6	38.5±0.4
Cooked product	55.6±2.6 (16)	39.8±0.3 (3)
't' value	5.64*	4.01*
Kadhi		
Raw mixture	52.1±2.4	31.8±0.3
Cooked product	59.7±1.1 (15)	32.9±0.3 (3)
't' value	8.10*	3.97*

Values are means ± SD of three independent determinations

*Significant at 5% level

Figures in parentheses indicate per cent increase over control values

Table 97. In vitro availability of calcium and iron of fermented ricebean products (%, on dry matter basis)

Products	Calcium	Iron
Idli		
Raw mixture	57.6±0.5	31.7±0.3
Soaked mixture	59.3±1.3 (3)	31.7±0.2
Fermented slurry	65.1±0.3 (13)	35.6±0.4 (12)
Final product	68.8±0.4 (19)	36.0±0.3 (14)
SE(m)	±1.09	±0.44
CD (P<0.05)	2.27	1.01
Dosa		
Raw mixture	55.2±0.5	32·4±0.2
Soaked mixture	57.7±0.5 (15)	32.8±0.2
Fermented slurry	63.9±0.4 (16)	37.3±0.1 (15)
Final product	66.6±0.7 (21)	37.8±0.2 (17)
SE(m)	±0.75	±0.29
CD (P<0.05)	1.56	0.67
Wadi		
Raw mixture	63.4±0.4	41.5±0.2
Soaked mxiture	65.3±0.3 (3)	42.2±0.2 (2)
Fermented slurry	70.7±0.3 (12)	46.3±0.3 (12)
Final product	70.3±0.3 (11)	46.3±0.1 (12)
SE(m)	±0.45	±0.23
CD (P<0.05)	0.94	0.53

Values are means ± SD of three independent determinations
Figures in parentheses indicate per cent increase over control values.

slurry and final product indicating that iron availability could not be increased due to steaming of idli batter.

The availability of calcium increased from 55.2 in raw unprocessed mixture to 57.7 per cent in soaked cereal legume mixture, 63.9 per cent in fermented slurry and 66.6 per cent in final fermented product, i.e., dosa (Table 97). Maximum increase was observed due to fermentation followed by soaking and shallow frying during dosa preparation. Iron availability was 32.4 per cent in raw mixture of dosa . Soaking and shallow frying did not increase the iron availability but fermentation significantly improved the iron availability, i.e., upto 15 per cent in dosa.

Soaking and fermentation significantly ($P<0.05$) increased the calcium and iron availability during wadi preparation too. Soaking increased the availability of Ca and Fe from 63.4 and 41.5 per cent in raw mixture to 65.3 and 42.2 per cent, respectively (Table 97). Improvement in the availability of Ca and Fe from ricebean wadi was almost the same, i.e., 11 and 12 per cent, respectively over the control value. Non-significant differences were observed in the fermented slurry and final product for Ca and Fe availability in wadi showing that drying did not affect the availability of these minerals.

The calcium availability (in vitro) in the raw mixture of idli, dosa and wadi prepared from fababean was 47.2, 46.4 and 48.9 per cent, respectively (Table 98). Soaking of the raw mixture of idli, dosa and wadi significantly ($P<0.05$) increased the Ca availability by 7, 8 and 8 per cent over the control

Table 98. *In vitro* availability of calcium and iron of fermented fababean products (%, on dry matter basis)

Products	Calcium	Iron
Idli		
Raw mixture	47.2±0.9	29.7±0.2
Soaked mixture	50.4±1.1 (7)	29.9±0.2
Fermented slurry	59.0±0.9 (25)	34.2±0.3 (15)
Final product	60.5±1.2 (28)	34.3±0.2 (16)
SE(m)	±1.30	±0.32
CD (P<0.05)	2.71	0·73
Dosa		
Raw mixture	46.4±1.0	30.0±0.2
Soaked mxiture	50.2±1.3 (8)	30.3±0.2
Fermented slurry	58.9±1.0 (27)	34.2±0.2 (14)
Final product	60.6±1.4 (31)	34.8±0.2 (16)
SE(m)	±1.67	±0.27
CD (P<0.05)	3.48	0·62
Wadi		
Raw mixture	48.9±0.5	38.2±0.2
Soaked mixture	52.8±0.3 (8)	38.4±0.2
Fermented slurry	61.4±0.5 (26)	43.3±0.2 (13)
Final product	61.5±0.4 (26)	43.3±0.2 (13)
SE(m)	±0.64	±0.30
CD (P<0.05)	1.33	0·69

Values are means ± SD of three independent determinations

Figures in parentheses indicate per cent increase over control values

value, respectively. Maximum improvement in the availability of Ca was observed due to fermentation. The increase in Ca availability was maximum in dosa (31%) followed by idli (28%) and wadi (26%).

Among all the final fermented fababean products the iron availability from wadi was the maximum (43.3%) followed by dosa (34.8%) and idli (34.3%) (Table 98). Soaking and heat treatments used in preparation of fermented products did not improve the iron availability but fermentation brought significant enhancement in iron availability of fermented fababean products.

Fermentation significantly enhanced the calcium and iron availability in fermented products incorporating ricebean and fababean pulses. The decrease in the level of phytic acid, tannin, etc., during fermentation may partly be responsible for the increasing the availability of these minerals, as those are known to inhibit their availability.

The in vitro availability of Ca and Fe in the raw mixtures of recipes incorporating ricebean sprouts ranged from 55.9 to 62.8 per cent and 36.9 to 38.1 per cent, respectively (Table 99). The availability of Ca and Fe was significantly enhanced due to different processing methods used in preparation of sprouted products. The Ca availability of sprouted chat was increased from 60.8 per cent in raw mixture to 67.5 per cent in cooked product. Sprouting, steaming and shallow frying involved in preparation of tikki increased the calcium availability by 12 per cent over the control value.

Table 99. *In vitro* availability of calcium and iron contents of sprouted ricebean products (%, on dry matter basis)

Products	Calcium	Iron
Sprouted chat		
Raw mixture	60.8±0.7	38.1±0.2
Cooked product	67.5±0.9 (11)	42.5±0.3 (12)
't' value	13.49*	28.08*
Tikki		
Raw mixture	60.5±0.9	36.9±0.4
Cooked product	67.7±0.8 (12)	41.3±0.4 (12)
't' value	12.45*	11.06*
Cutlet		
Raw mixture	62.8±1.0	37.6±0.4
Cooked product	70.0±1.9 (12)	43.4±0.3 (15)
't' value	7.45*	14.47*
Kofta		
Raw mixture	58.6±1.5	37.0±0.2
Cooked product	62.6±1.5 (7)	43.4±0.2 (16)
't' value	4.19*	32.06*
Kachori		
Raw mixture	55.9±1.6	37.4±0.4
Cooked product	58.2±2.3 (4)	41.2±0.2 (10)
't' value	4.99*	11.81*

Values are means ± SD of three independent determinations

*Significant at 5% level

Figures in parentheses indicate per cent increase over control values

Calcium availability was improved by 4 to 12 per cent over the control value due to sprouting, steaming and deep frying in cutlet, kofta and kachori. The improvement in iron availability was maximum in kofta (16%), followed by cutlet (15%), tikki (12%), sprouted chat (12%) and kachori (10%).

Sprouting of fababean in combination with other cooking methods, i.e., steaming, slight cooking, shallow and deep frying of various products brought significant ($P<0.05$) changes in the availability of calcium and iron. Improvements in Ca availability was the highest from sprouted chat followed by cutlet, kofta, tikki and kachori. The per cent increase in Ca availability in these products ranged from 6 to 18 per cent, over the control value. The iron availability (in vitro) of raw unprocessed control of different sprouted fababean products varied from 33.9 to 39.2 per cent (Table 100) and that of final cooked products ranged from 35.8 to 43.5 per cent. Significant improvements in Fe availability were observed in all sprouted products after cooking. The increases in iron availability was 12, 9, 11, 9 and 6 per cent over the control value of sprouted chat, tikki, cutlet, kofta and kachori, respectively.

The combination of cooking methods used in the development of sprouted products using ricebean and fababean pulses showed significant improvements in Ca and Fe availability. During germination individual mineral elements are translocated (Lorenz, 1980). The increase would also be due to increase in phytase activity of sprouts (Chen and Pan, 1977).

Table 100. *In vitro* availability of calcium and iron of sprouted fababean products (%, on dry matter basis)

Products	Calcium	Iron
Sprouted chat		
Raw mixture	47.2±2.1	37.5±0.2
Cooked product	55.7±0.8 (18)	41.9±0.3 (12)
't' value	4.48*	17.50*
Tikki		
Raw mixture	54.7±1.2	35.1±0.3
Cooked product	59.2±1.2 (8)	38.2±0.4 (9)
't' value	3.34*	16.30*
Cutlet		
Raw mixture	52.7±1.1	39.2±0.2
Cooked product	57.5±1.4 (9)	43.5±0.2 (11)
't' value	6.15*	24.60*
Kofta		
Raw mixture	50.9±1.9	37.1±0.2
Cooked product	55.4±1.7 (9)	40.3±0.3 (9)
't' value	3.92*	12.05*
Kachori		
Raw mixture	43.5±2.1	33.9±0.2
Cooked product	45.9±2.3 (6)	35.8±0.3 (6)
't' value	3.21*	10.00*

Values are means ± SD of three independent determinations.

*Significant at 5% level

Figures in parentheses indicate per cent increase over control values

Reduction in the levels of antinutrients as phytate, polyphenol etc., in sprouted products as noticed in this study (Tables 62 and 63) and as reported by previous workers (Reddy and Salunkhe, 1978; Grewal, 1992) may also be responsible for increased bioavailability of minerals as they are known to hinder the availability of minerals.

Similar results of increase in iron availability on sprouting were also observed by previous workers in various cereals and legumes (Prabhavathi et al., 1979; Giri et al., 1981), soyabean (Grewal, 1992), chickpea (Kakkar, 1992).

The calcium availability (in vitro) or raw mixtures of nutritious parantha, chilla, pakora and papad prepared from ricebean was 55.7, 58.8, 58.7 and 55.5 per cent, respectively (Table 101). Shallow frying on deep frying did not alter the availability of calcium in fried products as non-significant differences existed between the raw mixture and cooked product of above mentioned all products. Non-significant differences were noticed in the raw mixture and cooked product of fried products indicating no effect of frying on iron availability of these products.

Similar trend was observed in final fababean products (Table 102). The calcium and iron availability of raw mixture of fried fababean products ranged from 43.7 to 50.1 per cent and 32.0 to 41.8 per cent. The calcium availability was maximum in nutritious parantha and minimum in pakora. Non-significant differences for Ca and Fe availability were seen between the

Table 101. *In vitro* availability of calcium and iron of fried ricebean production (%, on dry matter basis)

Products	Calcium	Iron
Shallow fried		
Nutritious parantha		
Raw mixture	55.7±0.8	40.9±0.2
Cooked product	56.2±1.0	41.7±0.2
't' value	2.14NS	3.57*
Chilla		
Raw mixture	58.8±0.7	32.8±0.2
Cooked product	69.5±0.8	33.9±0.2
't' value	2.02NS	0.57NS
Deep fried		
Pakora		
Raw mixture	58.7±0.8	32.9±0.2
Cooked product	59.6±0.8	33.2±0.1
't' value	2.20NS	2.60NS
Papad		
Raw mixture	55.5±0.9	32.6±0.3
Cooked product	56.4±1.5	32.8±0.3
't' value	1.06NS	0.71NS

Values are means ± SD of three independent determinations

*Significant at 5% level

NS - Non significant at 5 % level

Table 102. *In vitro* availability of calcium and iron of fried fababean products (%, on dry matter basis)

Products	Calcium	Iron
Shallow fried		
Nutritious parantha		
Raw mixture	43.7±0.8	41.8±0.1
Cooked product	44.0±1.1	42.7±0.1
't' value	1.68NS	±3.91*
Chilla		
Raw mixture	49.1±1.2	32.1±0.1
Cooked product	50.8±0.8	32.6±0.1
't' value	2.16NS	2.28NS
Deep fried		
Pakora		
Raw mixture	50.1±1.2	32.0±0.2
Cooked product	51.2±0.9	32.4±0.1
't' value	2.10NS	2.23NS
Papad		
Raw mixture	45.1±1.0	32.8±0.3
Cooked product	46.0±0.8	33.1±0.2
't' value	1.95NS	1.41NS

Values are means ± SD of three independent determinations

*Significant at 5% level

NS - Non significant at 5% level

raw mixture and final fried products showing no improvements in the availability of these minerals due to frying.

The calcium and iron availability did increase during baking but was not significant in fababean cake (Table 103). Roasting caused improvement in iron availability and had no effect on Ca availability (Table 103). Similar increase in iron availability has been reported in roasted bengal gram and peas (Annapurani and Murthy, 1985) and chickpea (Kakkar, 1992). Reduction in the phytate due to heat treatment may improve the availability of minerals (Ellias and Morris, 1981). This might have been responsible for increased iron availability in roasted dal. Overall picture of increase in Ca and Fe availability (in vitro) over the control value in different products prepared from ricebean and fababean revealed that maximum increase was observed in fermented products followed by sprouted and boiled products (Tables 104 and 105; Fig. 10 and 11). Fried, baked and roasted products showed no increase in availability of these minerals.

4.5 Ascorbic Acid

The whole unprocessed ricebean and fababean contained 1.1 and 0.82 mg/100 g of ascorbic acid content and it was increased to 5.2 and 4.8 mg/100 g (Table 106), respectively when ricebean and fababean were sprouted at 35°C for 24 and 48 h, respectively. Longer the period of germination, more was the increase in ascorbic acid content.

The ascorbic acid content of the raw mixture of sprouted ricebean and fababean products ranged from 2.1 to 9.6 and 1.9

Table 103. *In vitro* availability of calcium and iron of baked and roasted fababean products (%, on dry matter basis)

Products	Calcium	Iron
Cake		
Raw mixture	46.6±1.8	30.8±0.2
Baked product	47.4±1.5	31.2±0.3
't' value	0.75NS	1.52NS
Roasted dal		
Raw dal	47.6±0.7	36.1±0.3
Roasted dal	47.7±1.1	38.1±0.7
't' value	0.31NS	3.61*

Values are means ± SD of three independent determinations
*Significant at 5% level
NS - Non significant at 5% level

Table 104. Per cent increase in *in vitro* availability of calcium and iron over the control value of ricebean products

Products	Calcium	Ranks	Iron	Ranks
Boiled products	7-13	III	5-7	III
Fermented products	11-21	I	12-17	I
Sprouted products	4-21	II	10-16	II
Fried products	NS		NS	
Baked product	NS		NS	

NS - Non significant

Table 105. Per cent increase in *in vitro* availability of calcium and iron over the control value of fababean products

Products	Calcium	Ranks	Iron	Ranks
Boiled products	8-16	III	3-4	III
Fermented products	26-31	I	13-16	I
Sprouted products	5-18	II	5-12	II
Fried products	NS		NS	
Baked products	NS		NS	
Roasted product	NS		NS	

NS - Non significant

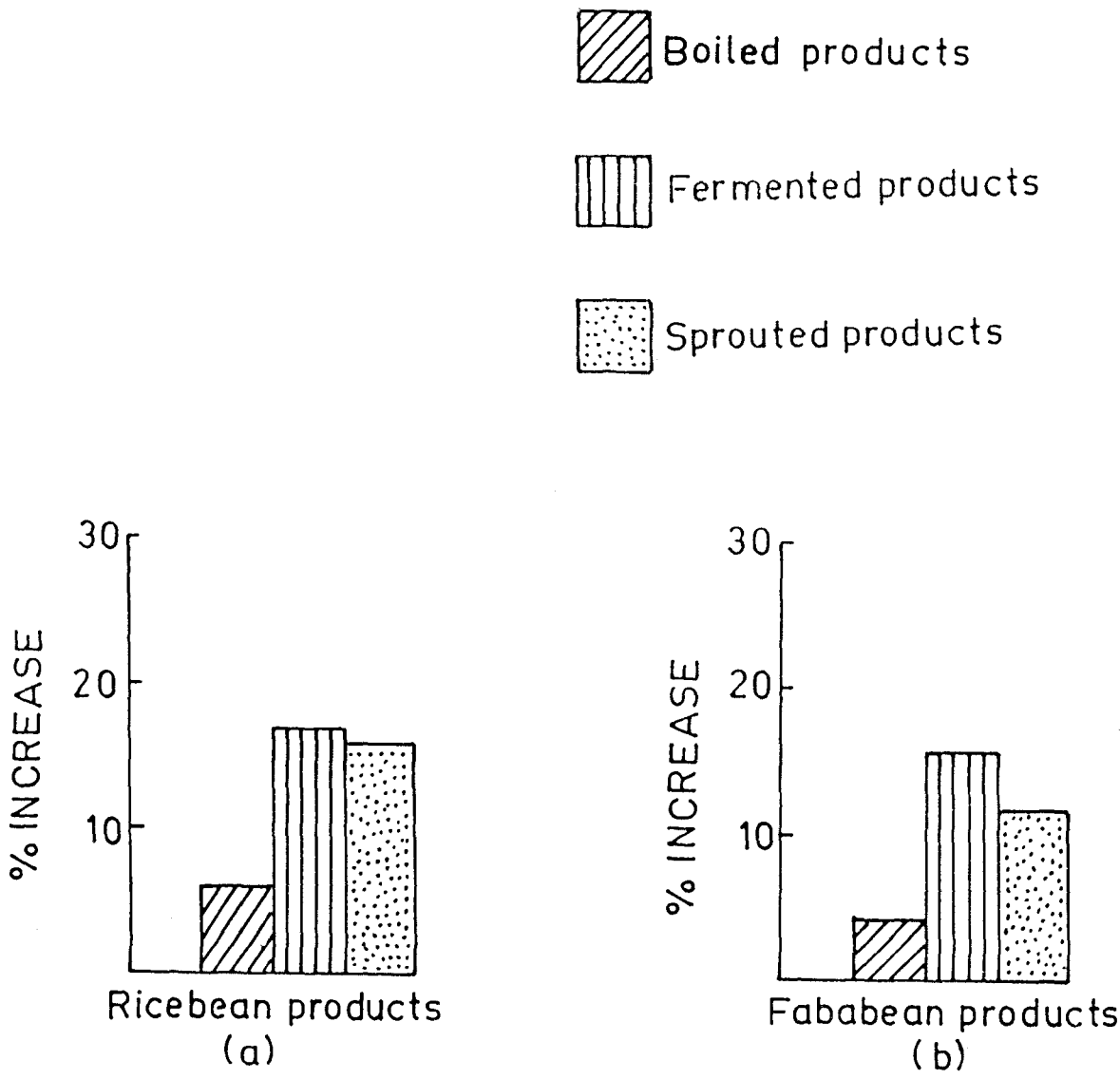

FIG. 10. EFFECT OF BOILING, FERMENTATION AND SPROUTING ON IRON AVAILABILITY (in vitro) OF RICEBEAN (a) AND FABABEAN PRODUCTS (b)

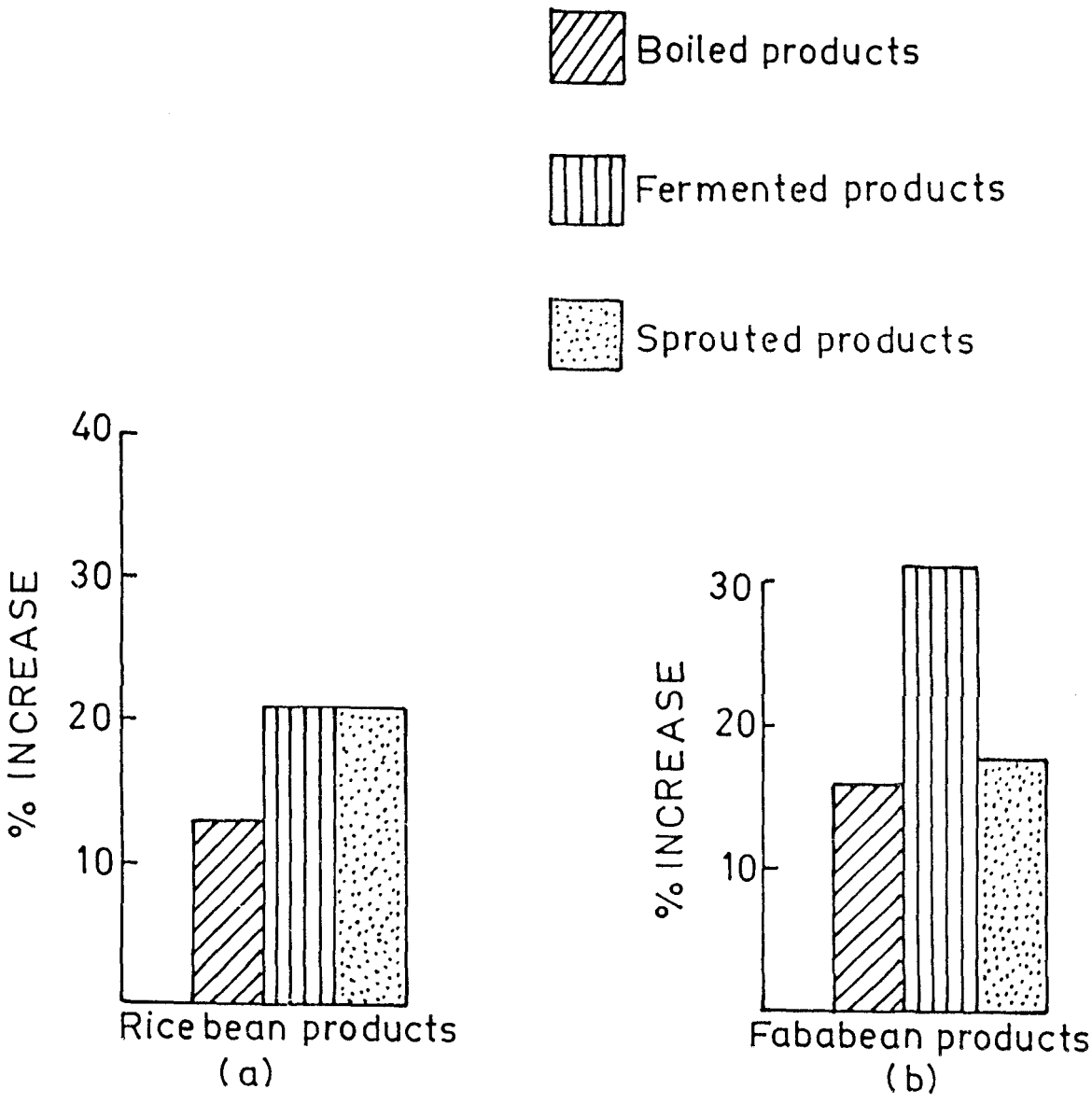

FIG. 11. EFFECT OF BOILING, FERMENTATION AND SPROUTING ON CALCIUM AVAILABILITY (*in vitro*) OF RICEBEAN (a) AND FABABEAN PRODUCTS (b)

Table 106. Ascorbic acid content of sprouted products prepared from ricebean and fababean (mg/100 g, on dry matter basis)

Products	Ricebean	Fababean
Raw legume (Control)	1.1±0.06	0.82±0.04
Sprouted dal	5.2±1.00	4.82±0.09
't' value	78.85*	89.69*
Sprouted chat		
Raw mixture	5.3±0.05	5.0±0.03
Cooked product	2.2±0.03 (59)	1.8±0.03 (64)
't' value	114.81*	158.43*
Tikki		
Raw mixture	9.6±0.08	9.2±0.06
Cooked product	3.3±0.04 (66)	3.0±0.03 (67)
't' value	168.37*	212.90*
Cutlet		
Raw mixture	7.5±0.04	7.2±0.03
Cooked product	3.0±0.03 (63)	2.7±0.02 (47)
't' value	185.60*	269.19*
Kofta		
Raw mixture	2.4±0.14	2.1±0.06
Cooked product	1.3±0.06 (46)	1.1±1.06 (48)
't' value	16.13*	26.30*
Kachori		
Raw mixture	2.1±0.04	1.9±0.04
Cooked product	1.1±0.08 (48)	0.9±0.06 (53)
't' value	23.08*	28.49*

Values are means ± SD of three independent determinations

*Significant at 5% level

Figures in parentheses indicate per cent decrease over control values

to 9.2 mg/100 g, respectively. Various types of cooking methods involved in the preparation of products incorporating ricebean and fababean significantly reduced the ascorbic acid content. The reduction in ascorbic acid in cooked products ranged from 46 to 66 per cent in ricebean products over the control value.

Losses for ascorbic acid were more in tikki (66%) followed by cutlet (63%), sprouted chat (59%), kachori (48%) and kofta (46%) prepared from ricebean sprouts. Similar findings were observed for sprouted fababean products. Reduction in ascorbic acid content ranged from 47 to 67 per cent in various products incorporating fababean sprouts. Almost half and more than half of ascorbic acid content was lost during the preparation of cutlet, kofta, sprouted chat and tikki incorporating ricebean and fababean sprouts.

CHAPTER - 5

SUMMARY AND CONCLUSIONS

Legumes not only complement nutritionally the staple foods but the many appetizing products made from them alleviate the diet of communities whose variety of diets is restricted. The present study was planned to develop the different products involving processing techniques viz., soaking, sprouting, boiling, fermentation, frying, baking, roasting, etc., from high yielding varieties of less conventional legumes, i.e., ricebean (RB-32) and fababean (VH-82-1) and to find out their acceptability and nutritive.

Hydration capacity and swelling capacity of ricebean were higher than those of fababean. Hence, the time for cooking ricebean was also less (87 min) than that for fababean (108 min). Crude protein, fat and ash contents of ricebean were 18.2, 0.83 and 4.8 whereas that of fababean were 25.5, 2.7 and 4.8 per cent, respectively. Soaking and sprouting of both the legumes had no effect on their protein, fat and ash content. Dehulling of fababean significantly increased the relative protein content.

No effect of soaking and sprouting was observed on dietary fibre constituents, i.e., NDF, ADF, hemicellulose, cellulose, lignin and pectin of ricebean and fababean. Husk had significantly higher levels of NDF, ADF, hemicellulose and lignin contents. Dehulling of fababean reduced the level of NDF, ADF, hemicellulose, cellulose and lignin.

Phytic acid, polyphenols and saponin contents of ricebean were 2018.2, 1698.9 and 2168.6 mg/100 g, respectively. Trypsin inhibitor activity was 55.2 TIU/g. Processing methods viz., soaking and sprouting reduced the levels of phytic acid, polyphenols, saponins and trypsin inhibitor activity upto 26 and 36; 31 and 49; 9 and 16 and 72 per cent, respectively in ricebean. In case of fababean, reductions upto 33 per cent due to soaking, 69 per cent due to sprouting and 58 per cent due to dehulling were observed in the above mentioned antinutrients.

Due to soaking, sprouting and dehulling, a significant ($P<0.05$) improvement occurred in <u>in vitro</u> starch and protein digestibility, HCl-extractability and availability of Ca and Fe of ricebean and fababean. The total calcium, iron and phosphorus contents of raw ricebean were 311.7, 6.6 and 257.1 mg/100 g, respectively whereas that of raw fababean were 201.2, 5.2 and 245.8 mg/100 g, respectively. A significant ($P<0.05$) and negative correlation was found between the protein and starch digestibility and antinutrients in ricebean and fababean.

Different types of products involving various domestic processing and cooking methods viz., boiling, fermentation,

sprouting, frying, baking and roasting, etc., were prepared by incorporating ricebean and fababean pulse. The boiled products included dal, khichari and kadhi, whereas fermented products included idli, dosa and wadi. Sprouted products like sprouted chat, tikki, cutlets, kofta and kachori were prepared. Baked product included cake. Both shallow and deep fried products were also prepared. Among shallow fried products, nutritious parantha which contained wheat flour, pulse flour and spinach and chilla containing chickpea flour and ricebean/fababean flour were prepared. Deep fried products included pakora and papad. Roasted dal was prepared from fababean only.

In khichari, kadhi, dosa, idli, wadi, nutritious parantha, chilla, pakora, papad and cake, ricebean or fababean were incorporated at various levels, i.e., 50, 60, 70 and 100 per cent and all the products were organoleptically evaluated using 9-point hedonic scale by a panel of 10 judges. The products having the highest acceptability score were selected for further chemical analysis.

The moisture content of different products prepared from ricebean and fababean ranged from 6.2 to 87.2 and 6.5 to 86.8 per cent, respectively. The crude and true protein contents of boiled ricebean products varied from 11.5 to 18.6 per cent and 11.1 to 18.3 per cent, respectively. The fat and ash content of these products ranged from 6.2 to 9.7 and 3.7 to 7.7 per cent, respectively. Cooking involved in the preparation of riceban as well as fababean boiled products did not alter the crude and true protein, NPN, fat and ash contents.

Fermented products like idli, dosa and wadi prepared from ricebean and fababean were analysed at different stages involved in their preparation, i.e., soaked, sprouted and final product. The combination of various processing treatments, i.e., soaking, fermentation and steaming or shallow frying or drying involved in the preparation of products like idli, dosa and wadi did not affect the proximate composition of the above mentioned fermented ricebean and fababean products.

The sprouted products i.e sprouted chat, tikki, cutlet, kofta and kachori developed from ricebean and fababean involved sprouting, steaming, slight cooking, and shallow or deep frying. Sprouting was done for 24 h at 35°C for ricebean whereas fababean was sprouted for 48 h at 35°C. The crude protein, true protein, fat and ash contents of final cooked sprouted ricebean products ranged from 10.9 to 19.4, 10.4 to 19.1, 1.0 to 20.8 and 5.0 to 6.0 per cent, respectively. Non-significant differences were observed between the raw mixture and the cooked sprouted product of ricebean as well as fababean indicating that none of the processing methods involved affected the crude and true protein, NPN, fat and ash contents in these products. Similarly, no effect of frying, baking or roasting was observed on crude protein, true protein, fat and ash content in fried, baked and roasted products prepared from both the pulses.

All the boiled, fermented, sprouted, fried, baked and roasted products made from ricebean and fababean were analysed for various dietary fibre constituents viz., NDF, ADF,

hemicellulose, cellulose, lignin and pectin. It was noticed that different dietary fibre constituents were not affected by any of the processing or cooking methods involved in the preparation of different ricebean and fababean products.

Starch digestibility (in vitro) was significantly ($P<0.05$) enhanced in all the cooked products prepared from ricebean as well as fababean when compared to the respective unprocessed raw controls. The maximum increase in starch digestibility over the control value was observed due to sprouting (18 to 146%) followed by fermentation (53 to 72%), boiling (30-70%), baking (35%) and frying (9 to 31%) in ricebean products. In case of fababean the maximum increase was noticed in fermented products (47 to 71%) followed by sprouted (17 to 64%), boiled (23 to 54%), roasted (36%), fried (10 to 19%) and baked products (14%). The improvement occurred to a greater extent in starch digestibility of ricebean products than that of fababean products.

The protein digestibility (in vitro) of all the raw unprocessed mixtures and the final cooked products differed significantly ($P<0.05$) indicating that different domestic processing and cooking methods like pressure or ordinary cooking, soaking, fermentation, steaming, shallow or deep frying, sprouting, roasting, baking, etc., involved in the formation of various ricebean and fababean products significantly ($P<0.05$) enhanced the protein digestibility.

The increase in protein digestibility occurred upto the extent of 6 to 40 and 6 to 33 per cent over the control values

in ricebean and fababean products, respectively. The enhancement in protein digestibility was maximum in fermented products followed by sprouted and boiled products, prepared from ricebean and fababean.

The antinutrients of various ricebean and fababean products differed because of the difference in the amount and type of ingredients used in development of these products. Significant ($P<0.05$) reductions were observed in the level of phytic acid, polyphenols, saponins and trypsin inhibitor activity in various cooked ricebean and fababean products. Among all the antinutrients, TIA was reduced to the highest extent as a result of processing and cooking treatments.

The phytic acid content of boiled ricebean products was lowered by 13 to 15 per cent over the control value with maximum decrease observed in khichari followed by dal and kadhi. Among the fermented ricebean products, maximum reduction was noticeable in dosa (49%) followed by idli (47%) and wadi (29%). Among ricebean sprouted products, reductions in phytic acid content was the highest in sprouted chat (32%) followed by tikki (24%), cutlet (23%), kofta (21%) and kachori (21%). Cake showed a reduction of 14 per cent in phytic acid over the control value whereas in fried ricebean products, decrease was upto only 4 to 5 per cent. In fababean products, the reduction in phytic acid content was maximum in fermented products followed by sprouted, roasted, boiled, baked and fried products.

Polyphenolic compounds were significantly lowered down after cooking of various products prepared from ricebean and fababean, maximum decrease in polyphenol content was noticed in fermented products (49 to 54%), followed by boiled (17 to 21%), sprouted (10 to 19%), baked (12%) and fried products (5 to 10%). In fababean products, polyphenols were decreased to a greater extent due to fermentation, followed by roasting, sprouting, boiling, baking and frying treatments.

Saponin content was decreased to a greater extent in products prepared from fababean than those from ricebean. The decrease in saponin content was upto the extent of 39 and 44 per cent over the control values in ricebean and fababean products, respectively. Maximum reduction was noticed due to fermentation followed by sprouting, baking, frying and boiling in ricebean products. Among fababean products, the reduction in saponin content was the highest in fermented products followed by sprouted, roasted, baked, boiled and fried products.

The trypsin inhibitor activity was destroyed to a greater extent by fermentation, i.e., 66 to 84 and 84 to 88 per cent, over the control value in fermented ricebean and fababean products, respectively. Among the fermented ricebean products, maximum lowering effect observed in dosa (84%) followed by idli (83%) and wadi (66%). In fermented fababean products, the decrease was the highest in idli and dosa (88%) followed by wadi (84%).

TIA reduction in sprouted ricebean and fababean chat which involved sprouting, steaming and slight cooking was 68

and 73 per cent over the control values, respectively. The reduction in TIA in cutlet, kofta and kachori developed from ricebean and fababean which involved sprouting, steaming and deep fat frying ranged from 60 to 69 and 59 to 77 per cent over the control values, respectively. Decrease in TIA was more in baked than fried ricebean products. In fababean, roasted dal showed more decrease in TIA than baked and fried products.

The total calcium, iron and phosphorus contents were more for ricebean products than fababean products. The total calcium, iron and phosphorus contents of different ricebean products ranged from 96.3 to 310.2; 4.3 to 10.6 and 147.6 to 306.8 mg/100 g, respectively. It was noticed that boiling, baking, fermentation, frying and roasting did not alter the total mineral profile in ricebean and fababean products. Significant decrease in total Ca content was noticed in sprouted ricebean and fababean products viz., sprouted chat, cutlet, tikkis and kofta.

The HCl-extractability of calcium and iron was more than phosphorus in different ricebean and fababean products. Enhancement in Ca, Fe and P extractability was noticed in boiled, fermented and sprouted ricebean and fababean products. The Ca-extractability was increased to the highest in fermented ricebean products (13 to 18%) followed by sprouted (6 to 9%) and boiled products (6 to 8%). Among fababean products, the increase in Ca-extractability from 20 to 24 per cent in fermented products, 9 to 11 per cent in boiled products, 4 to

10 per cent in sprouted products and 10 per cent in roasted fababean dal.

Non-significant differences in HCl-extractability of Ca, Fe and P were observed among the raw mixtures and their final baked and fried ricebean as well as fababean products. P extractability was increased by 6 to 8 per cent over the control value both in fried ricebean and fababean products. No improvements due to roasting was observed in Fe and P extractability.

Regarding the availability of minerals (in vitro), significant ($P<0.05$) improvements were observed in boiled, fermented and sprouted products but baking, frying and roasting brought no change in availability of minerals. Calcium availability was enhanced to the maximum in fermented ricebean as well as fababean products. The improvements in Ca availability ranged from 11 to 21 and 26 to 31 per cent over the control values in fermented ricebean and fababean products, respectively. An increase of 7 to 13 and 4 to 12 per cent over the control value was noticed in boiled and sprouted ricebean products in Ca availability. The Ca-availability was increased by 8 to 16 and 5 to 18 per cent in boiled and sprouted fababean products, respectively.

Fe availability was enhanced by 5 to 6, 12 to 17 and 10 to 16 per cent over the control value in boiled, fermented and sprouted ricebean products, respectively. In case of fababean products, maximum improvement in iron availability was observed

due to fermentation (13 to 16%) followed by sprouting (5 to 12%) and boiling (3 to 4%).

Overall, it can be concluded that unconventional pulses like ricebean and fababean were found to be quite acceptable in development of boiled, fried, sprouted, baked, roasted and fermented products. These can be easily used in place of traditional pulses in development of various products. As the production of traditional pulses is static from last 25 years so the use of these pulses in various recipes could increase the per capita availability in our country as well as other developing countries. As the protein content of fababean is higher than the traditional pulses like bengal gram, green gram, etc., so it can be used as a potential source in the development of protein rich recipes to raise the nutritional status of masses. Consumption of products incorporating such unconventional pulses can decrease the incidence of PEM in our country.

Among the different processing and cooking methods, fermentation was found to be the best for lowering down the level of antinutrients, improving the in vitro digestibility of protein and starch and enhancing the availability of dietary essential minerals of ricebean and fababean. Using this fermentation technology, further more products which are nutritionally superior and organoleptically acceptable can be developed from ricebean and fababean.

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*Original not seen.

APPENDIX I

Score sheet for taste panel/data under hedonic scale

Name _____ Dated:

Product _____

Test these samples and check how much you like or dislike each one. Use appropriate scale to show your attitude by assigning points that best describe your feeling about the sample. An honest expression of your feeling will help us.

Code No.	Colour	Appearance	Flavour	Texture	Taste	Over all acœptability

Rate	Organoleptic score
Very desirable	9
Desirable	8
Moderately desirable	7
Slightly desirable	6
Neither desirable nor undesirable	5
Slightly undesirable	4
Moderately undesirable	3
Undesirable	2
Very undesirable	1

Note: Please rinse your mouth before and after tasting each product.

Signature

STUDIES ON THE DEVELOPMENT OF PRODUCTS FROM RICEBEAN AND FABABEAN : THEIR SENSORY AND NUTRITIONAL EVALUATION

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(An abstract of the dissertation presented in partial fulfilment of the requirements for the degree of Ph.D. in the subject of Foods and Nutrition, CCS Haryana Agricultural University)

An investigation was conducted to study the development of products from ricebean and fababean, their acceptability and nutritional analysis. The effect of different processing techniques, viz., soaking, sprouting, boiling, fermentation, frying, baking, roasting, etc., was investigated on proximate composition, starch and protein digestibility, the level of antinutritional factors, HCl-extractability and availability of minerals.

Crude protein, fat and ash contents of ricebean and fababean were 18.2 and 25.5; 0.83 and 2.7 and 4.8 and 4.8 per cent, respectively. Soaking and sprouting of both the legumes had no effect on their protein, fat, ash and dietary fibre constituents whereas dehulling of fababean significantly increased the relative protein content. Due to soaking, sprouting and dehulling, a significant ($P<0.05$) improvement occurred in _in vitro_ starch and protein digestibility, HCl-extractability and availability of mineral in both the pulses. These processing treatments significantly reduced the level of antinutrients, i.e, phytic acid, polyphenols, saponins and trypsin inhibitor activity.

Different types of products, viz., khichari, kadhi, idli, dosa, cutlet, kofta, kachori, chilla, pakora cake, etc. involving various domestic processing and cooking methods viz., boiling, fermentation, sprouting, frying, baking and roasting, etc., were prepared by incorporating ricebean and fababean pulse. All the products prepared were found to be organoleptically acceptable to the human palate.

In boiled, fermented, sprouted, fried, baked and roasted products, no effect of any processing or cooking method involved was seen on protein, fat, ash and dietary fibre constituents and total minerals whereas the level of antinutrients were significantly decreased in the final cooked product when compared to their respective unprocessed controls. A significant ($P<0.05$) enhancement was observed in the digestibility of starch and protein, and extractability and availability (in vitro) of minerals in different products prepared from both the pulses.

Among all the domestic processing and cooking methods, fermentation was found to be the most beneficial one followed by sprouting, boiling, frying, roasting, etc., in lowering down the level of antinutrients and improving the in vitro digestibility of protein and starch and enhancing availability of minerals in ricebean and fababean products.