STUDIES ON THE PREPARATION AND UTILIZATION OF SOYAPANEER (TOFU)

THESIS

By

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HIMACHAL PRADESH KRISHI VISHVAVIDYALAYA

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IN

Partial fulfilment of the requirement for the degree

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DEDICATED
TO
MY
REVEREND
PARENTS

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CERTIFICATE - I

This is to certify that the thesis entitled **"Studies on the preparation and utilization of soya paneer (tofu)"** submitted in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE** in the subject of **Food Science and Nutrition** of Himachal Pradesh Krishi Vishvavidyalaya, Palampur, is a record of *bonafide* research work carried out by Ms. Geetika Singh (Admission number H-95-30-02) daughter of Dr. B.M. Singh, under my supervision and that no part of this thesis has been submited for any other degree.

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

Palampur (H.P.)
Dated :

(H. R. Sharma) 22/11/97
Chairman
Advisory Committee

CERTIFICATE - II

This is to ceritfy that the thesis entitled **"Studies on the preparation and utilization of soya paneer (tofu)"** submitted by Ms. Geetika Singh (Admission No. H-95-30-02) daughter of Dr. B.M. Singh to Himahal Pradesh Krishi Vishvavidyalaya, Palampur in partial fulfilment of the requirements for the award of degree of **MASTER OF SCIENCE** in the subject of **Food Science and Nutrition** has been approved by the student's Advisory Committee after an oral examination of the same in collaboration with the external examiner.

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Needless to say all errors and omissions are mine.

Place: Palampur

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Geetika Singh
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Chapter 1

INTRODUCTION

Soybean (*Glycine max*) is the lowest priced legume and has a very high protein content among various legumes, besides being rich in oil, vitamins, minerals and dietary fibre. It is superior to other legumes as it has twice as much protein as pulses, groundnut, meat and fish, three times as much as eggs and more than ten times that of milk. Being an excellent source of valuable nutrients and negligible levels of cholesterol, the legume contributes to human nutrition by improving colonic functions, lowering of blood cholesterol, guarding against various diseases like cancer, chronic heart disease, diabetes mellitus, etc. Soybean being rich in protein and calories has a great potential to tackle the problem of protein energy malnutrition in India and many other developing countries.

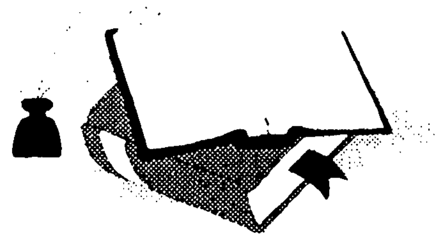
Cereal based diets are generally deficient in proteins. The supplementation of cereal based diets with soybean can play an important role in combating the protein energy malnutrition. Although animal products are desirable sources of high quality protein but their higher costs and vegetarian habits of people limit their use in diet. The world wide use of soybean as food ingredient has been increasing gradually during the last fifty years. Nearly about 40 per cent of world soy produce in developing countries is consumed in the form of temphe, tofu, meso and soymilk etc.

India produces about 4 million tons of soybean annually with an average yield of one ton/hectare (FAO 1996). Himachal Pradesh has an undulating topography and congenial climate for soybean cultivation during kharif season. The State has a potential to produce 200 tons of soybeans annually (HPKV 1997). A number of varieties such as Bragg, Shivalik, Lee, Punjab 1, PK 416, PK 472 etc. have been recommended for cultivation in the State by Himachal Pradesh Krishi Vish-vavidyalaya, Palampur. In spite of high yield potential, superior seed quality and low input cost, soybean has not been adopted by hill farmers in a big way as it deserves because neither are they aware of its domestic use nor is there a regular and remunerative market for it. Therefore, there is a need to promote domestic use of soybean in the form of various products so that nutrition of people and economy of the farmer in the State improves by taking up soybean cultivation.

Soy paneer, popularly known as tofu is a coagulated and pressed soy protein. Soy paneer can substitute milk paneer with marked reduction in cost, in a variety of popular domestic food preparations and can be a good source of nutrients at very low price compared to milk paneer.

Soymilk residue left after extraction of milk from soybean can also be used in nuggets (*bari*), a traditional food product of Himachal Pradesh. The present study was undertaken with the following objectives :

1. To assess the suitability of soybean varieties and full fat soy flour for soy paneer manufacture.
2. To assess the effect of household coagulants (curd and citrus juice) compared to commercial coagulant (magnesium sulphate) on the physico-chemical and sensory characteristics of soy paneer.
3. To assess the acceptability of soy paneer in household food preparations.
4. To assess the effect of soy paneer on nutrient composition of soy paneer based food products.
5. To try utilization of soy paneer residue in traditional nuggets (*bari*) and assess the acceptability and nutrient composition of nuggets.



Review of Literature

Chapter 2

REVIEW OF LITERATURE

The present investigation has been carried out to compare four varieties of soybean viz. Bragg, Shivalik, Lee and PK 416, recommended for cultivation in Himachal Pradesh, with respect to their physico-chemical characteristics and tofu making quality and utilization of tofu for nutritional enrichment of the locally prepared household foods. The related literature covering the physico-chemical characteristics of soybean varieties, method of preparation of soymilk, coagulation of soymilk for the preparation of tofu, chemical composition of soymilk and tofu and utilization of tofu in various forms has been reviewed under the following sub-heads :

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2.1 SOYBEAN

Soybeans are well known for variation in colour, size, shape and other physical properties as well as chemical composition. The physical and chemical differences are considerably modified by heredity of variety and the influence of climatic conditions in which they are grown. The reported literature on physical of chemical characteristics of soybean is reviewed in the following sub- sections.

2.1.1 Physical characteristics

The 1,000 kernel weight, bulk density and density are important parameters which affect the quality of soybean varieties. Lim *et al.* (1990) reported the weight of soybean to range from 15.24 to 35.51g/100 beans

According to Sexena *et al.*(1994), six new varieties of soybean showed 0.69 to 0.74 g/cc bulk density, 1.05 to 1.18 g/cc true density and 94.30 to 14.56 g/1,000 grain weight and they concluded that bulk and true densities of different varieties did not differ significantly but three varieties varied in their weight.

2.1.2 Chemical characteristics

2.1.2.1 Protein and amino acids

Piper and Morse (1923) reviewed the early literature on soybean. Their report on 500 samples of soybean showed a range of 30 to 30.46 per cent in protein content, whereas Bailey *et al.* (1935) stated that the composition of soybean is dependent on the soil and climatic conditions under which it is grown. They reported the protein content of soybean to vary from 29 to 43 per cent. Dies (1942) reported a range of 32.4 to 50.2 per cent in protein content for 128 varieties of soybean. Cartter and Hopper (1942) studied the influence of variety, environment and fertility level on chemical composition of soybean. Their data on moisture free basis showed that the average protein values for 10 varieties ranged from 40.59 to 46.42 per cent. They concluded from their investigation that variation in protein content is the result of influence of locality where the soybeans are grown and the variety of soybean . Sexena *et al.* (1971) gave a range of protein values to vary from 39.5 to 43.0 per cent. Gupta *et al.* (1976) studied the grain type and vegetable type varieties of soybean and gave the mean value of protein as 38.6 per cent for all the varieties. In a study of varietal difference in protein content of various varieties viz. late sown and spring varieties, Sood *et al.* (1977) revealed that protein content ranged from 36.90 to 53.35 per cent and only 10 varieties contained less than 40 per cent protein. The average protein content of late sown varieties was 44.85 per cent whereas for spring varieties it was 40.51 per cent. Lim *et al.* (1990) studied various varieties and concluded that average protein content ranged from 36.87 to 45.10 per cent.

Nutritive value of proteins depends upon the amino acid composition of the protein source and the ability of the protein to supply essential amino acids to the requirement of the body. Rose (1957) established the fact that adult man requires a dietary source of eight amino acids for the maintenance of nitrogen equilibrium.These are leucine, isoleucine, lysine, methionine phenylalanine, threonine, tryptophan and valine. Since methionine and phenyalanine are utilized by the body for the synthesis of cystine, the requirement for these two amino acids can be particularly met by cystine and tyrosine in the diet. Vanelten *et al.* (1967) made a comparison of an amino acid package of soy protein with the 1965 FAO amino acid pattern based on the composition of whole egg- protein. They reported close correspondence between their two patterns with the exception of two sulphur containing amino acids, cystine and methionine, both of which were low in soybean protein and they limit the nutritive value of soybean protein.

The extent to which protein supply limits amino acids in comparison with their reference protein such as whole egg protein is referred to as chemical score. From the chemical score of soybean Altschul(1974) stated that the soybean protein is about 70% as effective as egg protein in meeting the human requirement for amino acids. Liner (1972) compiled the data on the nutritive value of soybean proteins as compared to egg proteins. The PER, BV and NPU of soybean were 0.7 to 1.8, 58 to 69 and 48 to 61 respectively whereas those of egg protein were reported to be 3.8, 87 to 97 and 91 to 94, respectively.

2.1.2.2 Fat and fatty acids

Cartter and Hopper (1942) studied 10 varieties of soybean and reported the average fat content on moisture free basis as 19.63 per cent whereas in a study by Smith *et al.* (1960) the average oil content of 22 soybean varieties was 20.1 per cent. In another study Sexena and Pandey(1971) gave oil content values to range between 18.2 to 23.8 per cent. In trials conducted at IARI, Gupta *et al.* (1972) found the fat content of various varieties to range from 21.68 to 28.70 per cent. Gupta *et al.* (1975) studied grain and vegetable type varieties and gave the mean value of fat content as 20.5 per cent for all varieties. Gupta *et al.* analysed soybean oil using gas chromatography. The fatty acid composition was : palmitic acid 10.5 to 13.0, stearic acid 8 to 3.5, oleic acid 23.0 to 37.2, linoleic acid 43.7 to 55.0 per cent. The studies indicated that linoleic acid is the major fatty acid in soybean oil. The highest content of linoleic acid was reported in the oil of "Kalitur" variety (55.10%) followed by Bragg (52.4%).

2.1.2.3 Carbohydrates and sugars

MacMasters *et al.* (1941) reviewed the early work on carbohydrates of soybean and gave the various ranges for total sugars, reducing sugars, pentosans and galactans. Kawamura and Tada (1967) reported that in soybeans the sugars are mainly present in the form of sucrose (4.5%), raffinose (1.1%) and stachyose (3.7%), whereas verbascose, arabinose and glucose were reported to be present in minor amounts. Gupta *et al.* (1976) reported the average sugar content to be 4.3 per cent whereas polysaccharides were 13.8 per cent. Gupta and Kapoor (1978) reported the carbohydrate content in soybean seeds to be 26 per cent. Orthoefer (1978) reported that soybeans contained both water soluble and water insoluble carbohydrates, about one third of its original weight fractions. The principal sugars consist of 5 per cent sucrose, 1.1 per cent raffinose and 3.8 per cent stachyose. The total soluble sugars in defatted soybean flakes has been reported as 11.6 per cent. Kosson and Bakowski (1986) also reported raffinose and stachyose in soybeans to range from 0.24 to 0.70 per cent and 2.0 to 2.5 per cent respectively. According to Lo (1989) fibre from soybean cotyledons consisted largely of non-cellulosic polysaccharides in contrast to hull fibre which contained a high level of cellulosic residue. Lim (1990) examined nine varieties of soybean and reported the carbohydrate content to range from 35.52 to 39.80 per cent.

2.1.2.4 Ash and mineral content

Cartter and Hopper (1942) investigated ten varieties of soybean and gave the average values for ash 4.99 per cent, phosphorus 0.659 per cent, potassium 1.67 per cent and calcium 0.275 per cent. In an another investigation reported by Nelson (1950) the ash content of soybean was reported to be 5.7 per cent whereas Sanella and Whistler (1962) reported 4.9 per cent ash content in soybean. Banwar (1970) reported the total ash content to range from 3.8 to 6.8 per cent while Gupta *et al.* (1972) gave a relatively higher range of 5.30 to 7.02 per cent for ash content of soybeans. Osborn (1977) studied trace element content for defatted soybeans and reported the values for iron as 137 ppm, zinc 52 ppm, copper 20 ppm, iodine 0.84 ppm and fluorine 1.9 ppm.

Gupta *et al* (1976) reported the mean value for calcium, phosphorus, potassium zinc, copper, iron and magnesium to be 0.38, 0.59, 1.20, 4.08, 1.90, 9.08 and 3.31 per cent respectively. In another study by Sood *et al.* (1977) the total mineral matter reported in spring sown varieties of soybean was 7.00 per cent whereas that of late sown varieties was 6.18 per cent. Lo (1978) gave values for total ash as 5.0 per cent, potassium 1.7 per cent, calcium 0.3 per cent, magnesium 0.3 per cent and phosphorus 0.7 per cent. Lim *et al.* (1990) reported ash content to range from 4.96 to 5.75 per cent and phosphorus content 0.57 to 0.68 per cent.

2.1.2.5 Vitamins

According to Sherman (1940) *beta* carotene is present in green immature soybeans to the extent of 207 ug/g, whereas mature beans contain a significantly lesser amount. According to Smith and Circle (1972) mature soybeans contain 0.2 to 2.4 ug/g of B-carotene, 11.0 to 17.5 ug/g thiamine, 2.3 ug/g riboflavin, 20.0-25.9 ug/g niacin, 12 ug/g pantothenic acid, 6.4 ug/g pyridoxine, 0.6 ug/g biotin, 2.3 ug/g folic acid, and 0.2 mg/g ascorbic acid. According to Gopalan (1995) soybean contains 426 ug carotene, 0.73 mg thiamine, 0.39 mg riboflavin, 3.2 mg niacin and 8.65 ug free folic acid. on per cent basis

2.1.3 **Limitations of utilization of soybeans**

2.1 3.1 Antinutritional factors

According to Rackis *et al* (1962) several trypsin inhibitors are present in soybeans but much of the activity is due to protein SBT1-A2. Konijn *et al* (1972) have reported a goitrogenic agent obtained by fractionating soy flour. It appears to be a peptide comprised of two or three amino acid residues or a glycopeptide containing one or two amino acid residues linked to a sugar residue. Turner and Liener (1975) demonstrated that soybean haemaglutinin is a minor factor contributing to poor nutritive value of soybean.

Whitington and Gibson (1977) studied soy protein intolerance after oral challenge with soy protein isolate in four infants. Response to challenge included diaorrhea, vomiting, hypertension, lethargy and fever.

Ortheofer (1978) suggested that trypsin inhibitor activity of soybean is readily inactivated by heating at 100°C for 15 min or by atmospheric steaming at 25% moisture for 20 min.

2.1.2.6.2 Beany flavour

Beany flavour is one of the limiting factors in the consumption of soybeans. According to Sessa *et al.* (1969) odour or flavour associated with carbonyl compounds contributed little to overall soybean flavour. Mattick and Hand (1969) isolated and identified ethyl venyl ketone, a volatile compound responsible for beany flavour of soybean and this was derived from linolenic acid through lipoxidase enzyme action.

Matsuura *et al.* (1989) reported that the beany flavour can be removed by soaking of soybeans in low temperature water with glucono-5-lactone. In this stage B-glycosidases are inhibited by glucono-5-lactone and as a result the production of diazein and genistein responsible for objectionable aftertaste is depressed. The second stage is the hot grinding stage in which B- glucosidases are inactivated completely and at the same time lipoxygenases responsible for the development of rancid flavour are also inactivated.

2.1.3.3 Flatulence

Another limitation of soybean utilization is flatulence. According to Orthoefer (1978) raffinose, a trisaccharide and stachyose, a tetrasaccharide cause flatulence in humans because of absence of a-galactosidase enzymne. Anderson *et al.* (1979) tabulated the data indicating that average volume of flatus produced by man on daily consumption of 146 g of full fat soy flour and defatted soy flour is 30 cm^3/hr and 71 cm^3/hr, respectively.

Smiley *et al.* (1976) gave the remedy for flatus producing oligosaccharides by describing an immobilized enzyme technique involving the use of hollow fibre reactor. Soy milk is circulated around hollow fibres which contain a-galactosidase. Raffinose and stachyose diffuse into the fibres and are hydrolyzed, thereby freeing the soy milk from these oligosaccharides.

2.2 SOYMILK

2.2.1 Methods of preparation

Nelson *et al.* (1976) described the Illinois process for preparation of soymilk in which whole soybeans were soaked overnight and then blanched for 30 min in 0.5 per cent sodium bicarbonate solution, ground, heated to

93°C, diluted to desired protein level and sugar was added to taste. The milk was pasteurized and homogenized prior to consumption.

Smith and Circle (1978) described how soymilk can be processed from whole soybeans or full fat soy flour. However, the traditional product was made from good quality whole soybeans. The beans were thoroughly washed and soaked for about 13 hours. The soaked seeds were ground and slurry obtained was homogenized with water in the ratio of 10:1 (ten parts water and one part soybean). The slurry was heated for 15-20 min near its boiling point to get milk.

Grover and Tyagi (1989) prepared soymilk from defatted soyflour. Hundred g soy flour was soaked in tap water in the ratio of 1:10, 1:12.5 and 1:15 for one hour at room temperature (20-22°C). The soaked flour was then blended in waring blender for 5 min. The resulting suspension was filtered through double layered cheese cloth and the filtrate (milk) was boiled for 10 min with continuous stirring to prevent sticking of solids.

Arora and Mittal (1991) soaked soy dal in tap water (1:3 w/v) for 16-18 hrs at room temperature. The soaked water was decanted and dal was washed with fresh water. It was then ground for 3-5 min in a blender with hot water (85-90°C) using bean to water ratio of 1: 9 (w/v). The resulting suspension was filtered through a double layer of cheese cloth. The soy milk thus obtained contained approximately 6.0% of total solids.

2.2.2 Physico-chemical characteristics

Kulkarni *et al.* (1985) showed that soy milk has 88.20 per cent moisture, 7.70 per cent protein, 3.80 per cent fat, 1.0 per cent carbohydrates and 0.60 per cent ash. Nasim *et al.* (1986) studied the effect of different levels of soy dal in water on yield, total solids and protein content of soymilk. They reported that 100 g of ground soydal in one litre of water yielded 820 ml of milk with 6.0 per cent total solids and 3.00 per cent protein whereas 170 g of soy dal in one litre of water gave 700 ml of milk yield with 8.80 per cent total solids and 3.93 per cent protein content.

In an another study by Lim *et al.* (1990) the total solids of soymilk ranged from 9.09 to 9.90 per cent and protein content from 47.93 to 54.40 per cent on dry weight basis. The pH of the soymilk ranged from 6.42 to 6.55 and the range for phosphorus content was 0.69 to 0.86 per cent. In the study conducted by Jain and Mittal (1992) soymilk with 6.0 per cent total solids contained 2.9 per cent protein.

Reddy and Mittal (1992) studied the physico-chemical characteristics of soymilk and reported that total solids and protein ranged from 5.16 to 5.96 per cent and 2.38 to 2.95 per cent respectively. The pH and per cent titrable acidity values for different soymilk samples were in the range of 6.30-6.70 per cent and 0.13-0.17 per cent respectively. The viscosity of different soymilk samples ranged from 4.5 to 5.0 cp whereas surface tension ranged from 102.10 to 111.79 dynes/cm.

Sexena and Singh (1997) studied various soybean cultivars and reported the yield of soymilk to range from 725.00 to 802.50 ml/100 g of beans, total solids from 5.78 to 6.48 per cent, protein from 2.81 to 3.45 per cent, fat from 1.42 to 1.65 per cent, calcium from 20.34 to 27.12 mg/100 g, phosphorus from 30.81 to 40.9 mg/100g, iron from 0.67 to 0.95 mg/100 g and specific gravity from 1.02 to 1.4. They reported the titrable acidity to vary from 0.12 to 0.16 per cent and pH to range from 6.31 to 6.71.

2.3 TOFU (SOY PANEER)

2.3.1 Use of coagulants and preparation of tofu

Grover *et al.* (1983) prepared tofu by heating soy milk to 85°C, dding calcium sulphate (0.4 per cent w/v) and stirring vigorously. The contents were left undisturbed for 10-15 min. in a water bath maintained at 85°C. Later the vessel was kept at room temperature till the setting of the curd and the whey was siphoned off. The curd was pressed by applying pressure equivalent to 10 times the weight of soybeans.

Kulkarni *et al.* (1985) prepared tofu by heating soymilk for 3, 5, 7 and 10 min. in order to study the effect of heating on quality of pressed curd. The soymilk was coagulated by using 0.5, 1.0, 1.5 and 2.0 per cent $CaCl_2$ of original weight of soybean. The coagulant was added at 70°C with constant stirring. The coagulated mass was pressed in a wooden press by loading specific weights.

Nasim *et al.* (1986) heated soymilk to coagulation temperature (75°C) and the coagulants (lactic acid, citric acid, tartaric acid and gluconic acid) were added with gentle and continuous stirring. The contents were left undisturbed at coagulation temperature for 30 min. in a water bath and thereafter allowed to cool at room temperature. The whey was removed by filtration using double layered cheese cloth. The coagulum thus obtained was pressed at 1 psi to expel whey. It was placed in cold water for 1 hr, the water drained and tofu stored at 4-5°C prior to use.

Gandhi and Nawab (1987) developed a method in which whole and sound soybeans were cleaned and splitted into dal. The dal was then soaked in water containing sodium bicarbonate for 4 hrs. The milk was extracted, boiled and cooled, and $CaSO_4$/$MgSO_4$ solution or sufficient quantity of lime juice/curd was added for coagulation.

Preparation of cheese like product from soybean has been described by Lim *et al.* (1990).Three hundred ml of fresh soymilk was heated on a hot plate to boiling with constant stirring. A suspension of 2.7 g $CaSO_4$ in 7.5 ml distilled water was prepared. The hot soy milk and coagulant were poured simultaneously into a 500 ml plastic container ensuring mixing without stirring. The curd was left at 20°C to coagulate for 15 min. The curd was transferred to perforated plastic container and pressed to 15.7 g/cm^2 pressure for 15 min. Tofu was then stored at 5°C.

In another study by Arora and Mittal (1991) tofu was prepared by heating the soymilk for 10 min, cooling to 75°C and then coagulated, using appropriate amount of 2% solution of tartaric acid. The coagulum thus obtained was pressed using 0.1 kg/cm^2 pressure, sliced into blocks of appropriate size and stored at 5°C.

2.3.2 Physico-chemical and organoleptic characteristics of tofu

Grover *et al* (1983) prepared tofu by heating soymilk to 85°C and coagulating the milk protein with calcium sulphate (0.4 per cent w/v). The curd was pressed and the tofu thus obtained deep fried and evaluated for compositional characteristics. Fresh tofu contained 79.8 per cent moisture, 11.33 per cent protein, 5.16 per cent fat, 1.28 per cent ash, 2.1 per cent carbohydrates and 197.5 mg per hundred g calcium whereas fried tofu contained 25.87 per cent moisture, 21.29 per cent protein, 33.91 per cent fat, 1.99 per cent ash, 16.94 per cent carbohydrates and 450 mg per hundred g calcium. They also studied the effect of different treatments like immersion in water or aquous solution of citric acid (2 %), NaCl (5%) or a combination of both for 24 hrs and daily replacement of solution with fresh water and deep fat frying at 180°C for 4 min. on the shelf life of tofu at 5 and 30°C. The treated samples were analyzed for changes in chemical composition and microbiological status and were also evaluated organoleptically. It was found that the curd kept immersed in water or five per cent sodium chloride solution at 30°C was acceptable for a single day. However, the curd immersed in citric acid and sodium chloride solutiion remained wholesome for 6 days at 30°C and 15 to 18 days when stored at 5°C. Curd deep fried in fat and stored at 5°C was found acceptable upto 12 days.

Kulkarni *et al.* (1985) studied the effect of pressing conditions on the quality of soybean pressed curd. Soaked dehulled soybeans were ground to a thin paste. The milk was extracted and treated with calcium chloride. It was observed that boiling the milk for 7-10 min and using the coagulant at 2.0 per cent concentration gave better yield and textural property to the pressed curd. The pressed curd contained 49.0 per cent moisture, 34.2 per cent protein, 6.0 per cent fat, 9.87 per cent carbohydrates and 5.0 per cent ash. The acceptability of tofu was reported to be vary good by the judges.

Nasim *et al.* (1986) studied the effect of different coagulants and their concentrations on yield, total solids, proteins and chemical composition of soy paneer. A decreasing trend in all these was observed with increasing concentration of lactic, citric and tartaric acids,whereas reverse was observed when gluconic acid was used as coagulant. The lactic acid, tartaric acid or citric acid coagulated tofu contained 74.03 to 75.38 per cent moisture and 15.53 to 15.75 per cent protein. In contrast gluconic acid yielded a product with higher moisture (81.20%) and lower protein (11.15%). The total solids in tofu varied from 17.50 to 28.00 per cent among different treatments.

Lim *et al.* (1990) reported that the fresh yield of tofu varied from 4.45 to 5.60 kg /kg beans. The moisture content of fresh tofu varied from 86.58 to 88.58 per cent whereas protein ranged from 46.03 to 52.50 per cent, the fat content from 16.69 to 23.54 per cent, ash content from 11.18 to 12.43 per cent and carbohydrate content from 16.47 to 20.05 per cent. The hardness and firmness of tofu ranged from 1.80 to 2.62 N/mm and 0.23 to 0.29 N/mm respectively. The whey volume was reported to vary from 59 to 93 ml per 300 ml of milk containing 2.75 to 3.40 per cent solids among 10 varieties of soybean.

Arora and Mittal (1991) reported that tofu contained moisture 74.85 per cent, protein 16.63 per cent, fat 4.26 per cent, ash 0.37 per cent and carbohydrates 3.89 per cent.One hundred g of soybean yielded 166 g of tofu containing 25.15 per cent total solids.

Jain and Mittal (1992) revealed that coagulation of soymilk with salts yielded a product with high moisture content (84-88%) resulting in higher yield, but low protein content (7-8%) whereas acid coagulated product resulted in higher protein content (15-16%) and less moisture (74-75%). The coagulation with citric acid, lactic acid or tartaric acid gave maximum yield of tofu solids.. The tofu yield among different varieties ranged from 122 to 148 per cent. They also reported the tofu sensory attributes of the soybean varietiees. The colour was reported to vary from whitish to grayish white. Pb-1 was reported to be the best variety among nine varieties tested for tofu sensory attributes. In general soy paneer samples were devoid of beany flavour and the overall acceptability scores were reported to range from 5.0 to 6.4 on a nine point hedonic scale.

Pant *et al.* (1993) compared the chemical composition of tofu and milk paneer. They concluded that tofu contained higher moisture (74.%), protein (57.8%) and ash (24.0%) as compared to milk paneer which had 61.5 per cent moisture, 42.8 per cent protein and 2.8 per cent ash. However, tofu was much lower in fat (4.0%) as compared to milk paneer which contained 47.2 per cent fat. The tofu was reported to contain 35 per cent solids whereas milk paneer was reported to contain 38 per cent solids.

2.3.3 Utilization of tofu

Vijaylakshmi and Vaidehi (1982) prepared tofu and utilized it in various snacks like *burfi* and *pakoda.* Tofu and snacks were evaluated for appearance, texture, flavour, and overall acceptability. It was observed that commercial paneer scored as highly acceptable whereas pure tofu and tofu with soy-skim milk (60:40) were moderately acceptable to acceptable. *Burfi* and *pakoda* preparations received fairly high scores and were almost at par with standard (cow's milk) preparations.

Chakrabarti and Gangopadhay (1990) prepared soy rasogulla by utilizing soymilk. Chemical and sensory evaluation of soy rasogulla was done. It was reported that rasogulla contained 46.12 to 48.07 per cent moisture, 1.83 to 2.31 per cent fat, 9.86 to12.68 per cent protein and 38.27 to 39.58 per cent sucrose. The preparation was evaluated for colour, appearance and body texture.

Pant *et al.* (1996) prepared four fast foods i.e., bread rolls, cutlets, burgers and sandwiches, prepared by incorporating milk paneer and soy paneer and the products were compared for their protein content and sensory properties. The protein content of various products viz. bread rolls, cutlets, burgers and sandwiches was 11.4, 11.3 7.4 and 13.9 per cent, respectively whereas the moisture content was 49.0, 50.2, 57.7 and 58.0 per cent respectively. The mean scores for all the sensory attributes ranged from 6.6 to 7.7 on a 9 point hedonic scale.

2.4 SOYMILK RESIDUE

2.4.1 Chemical composition

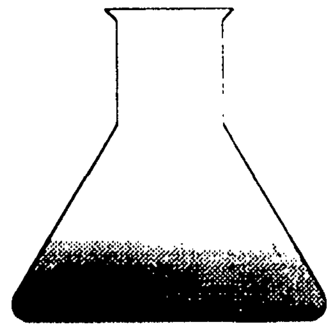
Smith *et al.* (1960) reported the chemical composition of soymilk residue obtained from Japanese and United States soybean. The average moisture content of the soymilk residue obtained from various varieties was reported to be 76 per cent whereas protein content was reported to vary from 20.9 to 26.7 per cent and the oil content varied from 6.1 per cent to 15.7 per cent. From the data it was revealed that about 29 per cent of the original beans on a dry weight basis were recovered in the residue.

In another study by Kulkarni *et al.* (1985) the moisture content in soymilk residue was reported to be 45 per cent. It was also reported that soymilk residue contained 11.44 per cent protein, 9.90 per cent fat, 3.49 per cent ash and 30.17 per cent carbohydrates by difference and the soymilk residue contained 55% solids.

Nasim *et al.* (1986) studied the effect of different levels of soy dal on total solids, protein content and yield of soymilk residue. It was reported that 100 g ground soy dal/litre of water yielded 86 g soymilk residue with 15.67 per cent total solids and 5.68 per cent protein, whereas 170 g ground soy dal/litre of water yielded 127 g soymilk residue, 17.90 per cent total solids and 7.65 per cent protein.

2.4.2 Utilization

Parihar *et al* (1977) prepared various snacks utilizing soymilk residue. Various recipes like cake, *khurma, sev, samosa* etc. were prepared and were evaluated for acceptability. The products were evaluated for appearance, flavour, palatability and texture. The preparations were rated as good.



Materials and Methods

Chapter 3

MATERIALS AND METHODS

The present investigation entitled "Studies on the preparation and utilization of soya paneer (tofu)" was conducted in the postgraduate laboratory of College of Home Science, Himachal Pradesh Krishi Vishvavidyalaya, Palampur. Materials used and methods employed are described in the following sections :

3.1 MATERIALS

3.1.1 Soybeans

The seeds of four varieties of soybean viz. Bragg, Shivalik, Lee and PK 416 were procured from the Seed Production Unit of Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The seeds were cleaned manually, dried in sun and stored in plastic containers for further use.

3.1.2 Soyflour

Two kg seed of each variety of soybean was ground in Hammer mill and flour was prepared so as to pass through 20 mesh sieve. The flour was stored in air tight plastic containers for further use and analysis.

3.1.3 Soymilk coagulants

Three coagulants viz. curd, citrus juice and magnesium sulphate were used for coagulation of milk. Citrus juice was extracted from *galgal* with the help of an electric juicer and was pasteurized in 200 ml juice bottle at 90 ^{0}C for 15 min and the bottle stored for further use.

3.1.4 Chemicals

Analytical grade chemicals and reagents were procured from the reputed suppliers and used in chemical analysis.

3.1.5 Other ingredients

Other ingredients like wheat flour, Bengal gram flour, black gram dal, spices, oil, onion, tomatoes, and peas were purchased from the local market.

3.2 METHODS

3.2.1 Tofu from whole soybeans

The following sequence of operations was followed in the preparation of tofu from whole soybeans which is shown in Plate 1.

i) Washing and soaking of soybeans: Well cleaned 300 g soybean seeds from each variety were washed and soaked in tap water maintained at 30-35°C for 16-17 hrs. Water to bean ratio was taken as 3:1. The water was changed twice during soaking to avoid the development of off flavour due to fermentation during soaking.

ii) Draining and rinsing: After the completion of soaking process the water was drained and beans were again rinsed 2-3 times in fresh water.

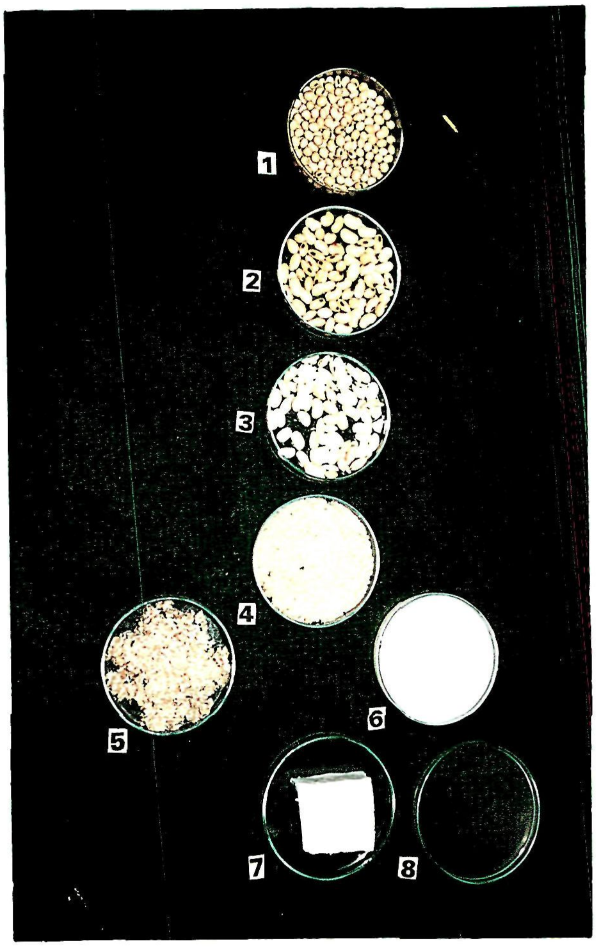


Plate 1. Steps in the preparation of tofu from whole soybeans
1. Dry beans 2. Soaked beans
3. Dehulled beans 4. Soypaste
5. Soymilk residue 6. Soymilk
7. Tofu 8. Whey

iii) Dehulling: Hull of soaked soybeans was removed by rubbing the beans between hands and removing the hull floating on water by subsequent washing and decanting.

iv) Grinding : Grinding of dehulled soybeans was achieved with the help of a waring blender using 50 g dehulled beans each time. To facilitate grinding and to minimize the development of beany flavour, hot water (50 ml) was added to the beans in the blender to obtain a paste like mass.

v) Preparation of soymilk: The ground paste was diluted with hot water by maintaining dry bean to water ratio as 1:9 (w/v). The resultant slurry (diluted paste) was mixed thoroughly and boiled for 10 min. The milk slurry was then filtered through double layered muslin cloth to obtain soymilk and soymilk residue. The soymilk residue was dried in tray drier at a temperature of 45°C and was stored for further use. The soymilk was boiled for 15 min with continuous stirring.

vi) Coagulation of soymilk: The soymilk from each variety was coagulated with three different coagulants (curd, citrus juice and magnesium sulphate) at 85-90°C using 2.5 per cent of each coagulant on milk weight basis. The coagulants were poured and mixed gently with the soymilk. The milk was kept undisturbed until clear whey was separated from the coagulated milk solids.

vii) Separation of whey and moulding of tofu: Coagulated tofu was separated from whey by filtering through muslin cloth on a cheese moulder. In order to remove extra water a weight of 1.5 kg was kept over cheese moulder for 30 minutes.

viii) Cutting: The tofu was removed from the moulder and cut with help of sharp knife into equal pieces of 1.5 x 1.5 x 1.0 cm for the preparation of various snacks and sensory evaluation.

3.2.2 Tofu from full fat soyflour

The following sequence of operations was followed in the preparation of tofu from full fat soyflour :

i) Soaking : Full fat soyflour (500 g) was soaked in 1 litre of water at a temperature of 28-30°C for 3 hrs. Soyflour to water ratio was maintained as 1: 9 (w/v) by adding water.

ii) Homogenization : The slurry was homogenized in waring blender for 2 min in small lots using hot water to minimize the development of beany flavour.

iii) Preparation of milk : The slurry was boiled for 15 min and was then filtered through double layered muslin cloth to obtain soymilk and soymilk residue. The soymilk was then boiled for 15 min.

The rest of the steps for preparation of tofu were similar to the preparation of tofu from whole soybeans (Section 3.1).

3.2.3 Preparation of tofu based food products

The tofu prepared from Bragg (whole soybeans) was rated superior to the tofu prepared from other varieties with all the coagulants tested. Therefore this tofu was used in the preparation of various products as described below. Recipes were standardized for the preparation of various tofu products using cow's milk paneer in the product as control for comparison .

i) Tofu/paneer *pakoda*

Ingredients	Quantity
Bengal gram flour	250.00 g
Tofu/paneer slices (1.5x1.5x1.0 cm)	200.00 g
Garam masala	2.00 g
Black pepper powder	2.00 g
Red pepper powder	1.00 g
Salt	8.00 g
Water	200 ml
Oil for frying	1 litre

All the ingredients except tofu/paneer slices were mixed with 200 ml water and the mixture was heated continuously for 15 min with the help of a heater. Then tofu/paneer was dipped in it. Each slice with sufficient coating was deep fried in refined groundnut oil for about 5 min so as to give golden brown appearance to *pakodas*

ii) *Matar* tofu/paneer curry

Ingredients	Quantity
Green peas (blanched for 2 min)	100.00 g
Tofu/paneer slices (1.5x1.5x1.0 cm)	100.00 g
Tomato paste	50.00 g
Onion paste	50.00 g
Garam masala	2.50 g
Black pepper powder	2.00 g
Salt	5.00 g
Turmeric	2.00 g
Water	400 ml
Oil	25 ml

Tofu/paneer slices were fried in refined oil for 30 seconds. Twenty five ml of oil was heated in a pan and onion paste was added to it and fried for 2 min till light brown in colour. After this, tomato paste was added and the mixture was fried for another 30 seconds. To this mixture spices, salt and turmeric powder were added. After 20 seconds blanched peas and fried tofu/paneer slices were added. After frying the whole mixture for 1 min, water was added and boiled for 1 min to obtain a tofu/paneer based curry.

iii) Tofu/paneer *parantha*

Ingredients	Quantity
Wheat *atta*	100.00 g
Tofu/paneer grated	100.00 g
Onion chopped	25.00 g
Water	65 ml
Salt	2.50 g
Black pepper	2.50 g
Garam masala	2.50 g
Oil	20 ml

Wheat *atta* dough was prepared by kneading 100 g wheat *atta* with 65 ml of water. The dough (165 g) was prepared by kneading whereas stuffing *masala* was prepared by mixing chopped onion, grated tofu/paneer, *garam masala*, salt and black pepper. Two *chapaties* of 25 g and 15 cm diameter each were prepared with the help of a pin and roll. The stuffing *masala* (30 g) was stuffed between these two *chapaties* uniformly. The *chapati* ends were sealed with the help of pin and roll. The *paranthas* were shallow fried with little oil on *tawa* for 30 seconds on one side, 30 seconds on the other side and then again for 20 seconds on each side to a light brown colour.

iv) Nuggets (*Bari*) : Dehulled black gram dal was soaked in water overnight and the water was drained. The dal was ground in a waring blender to a fine paste. The paste was supplemented with soymilk residue at 10, 20, and 30 per cent level of substitution on dry solids basis. The batter was whipped with hand to a fluffy mass after the addition of *garam masala* (5.0 g) and black pepper (5.0 g). Small balls of batter were poured over greased tray of drier and were dried at 45°C in the cabinet drier to a constant weight.

v) Nuggets (*Bari*) curry

Ingredients	Quantity
Bari	60.00 g
Onion paste	100.00 g
Tomato paste	78.00 g
Turmeric	1.00 g
Jeera	1.50 g
Garam masala	2.00 g
Salt	3.00 g
Oil	30 ml

The nuggets were roasted in oil till light brown in colour and were kept aside. Twenty five ml of oil was heated and to this *jeera* was added followed by onion paste, tomato paste, *garam masala*, turmeric and salt. The mixture was fried for 1 min and to this *bari* was added and pressure cooked for 10 min. The resultant curry was subjected to organoleptic evaluation by a panel of ten judges.

3.2.5 Physico-chemical analysis

3.2.5.1 Physical characteristics

i) 1,000 kernel weight : One thousand kernels of soybean were counted randomly in duplicate and weighed separately. The average weight was recorded in grams.

ii) Hull content : Soy hulls were separated by splitting the grains with the help of a splitter and the hull content of 50 g soybean was recorded in triplicate in grams and reported in per cent.

iii) Water uptake : Sample of whole soybean (10 g) were soaked in water (20 ml) at room temperature. The water uptake by the samples was recorded at one hr interval till the weight became constant. Then the water uptake in relation to time was calculated from the increase in the weight of samples after soaking and reported as g/100g of soybean.

iv) Soymilk yield and soymilk residue : The yields of milk extracted from the whole soybeans and full fat soyflour were recorded and expressed as ml/100 g soybean, whereas soymilk residue recovered was recorded and expressed as g/100 g soybean.

v) Milk solids and residue solids : These were calculated after drying milk and residue samples in oven at 105°C to a constant weight. The contents of milk solids are reported as g/100 g soybean and g/100g milk. Residue solids are reported as g/100 g soybean and g/100 g residue.

vi) Tofu yield and whey volume : The yield of tofu was recorded after coagulation and pressing and reported as g/100 g soybean. Whey volume was also measured and reported as ml/100 g soybean.

vii) Tofu solids and whey solids : Tofu and whey samples (100 g) were dried in oven to a constant weight and the amount of residues left after drying was recorded. The tofu solids were calculated and are reported as g/100 g soybean and g/100 g tofu. Whey solids are reported as g/100 g soybean and g/100 ml whey.

3.2.5.2 Chemical analysis

i) Proximate composition : Proximate principles viz. moisture, protein, crude fat, crude fibre and ash were determined according to AOAC methods (AOAC, 1990). Conversion factor of 6.25 was used to convert nitrogen in to protein in soybean and other products. Carbohydrates were determined by difference.

ii) Neutral detergent fibre (NDF) : NDF was determined according to Van Soest (1963) method. The method depends on extraction of food with hot neutral solution of detergent, sodium lauryl sulphate and 2-ethoxy ethanol. The residue NDF contains lignin, cellulose and hemicellulose of cell wall.

Following reagents were prepared for NDF analysis

a) Neutral detergent solution : Ethylene diamine tetra acetic acid dehydrate (18.61 g) and sodium borate decahydrate (6.81 g) were dissolved in some hot distilled water and this solution was added to a solution of sodium lauryl sulphate (30 g) and 2-ethoxy ethanol (2 ml). Then 4.56 g of disodium hydrogen phosphate was taken and dissolved in some distilled water by heating and added to the solution of other chemicals. The volume was finally made to 1 litre with distilled water and pH adjusted between 6.9 and 7.1.

b) Decahydronaphthalene (reagent grade)

c) Sodium sulphate anhydrous

d) Acetone

The samples were ground to pass through 1 mm sieve. Sample (1 g) were taken in beakers and 100 ml of neutral detergent solution , 2 ml decahydronaphthalene and 0.5 g sodium sulphate were added. The mixture was heated to boiling in 5 to 10 min. The samples were refluxed gently for one hour. The mixture was filtered through sintered glass crucibles. The samples in the crucibles were rinsed with hot water (90-100 °C) and filtered with the help of a suction pump. The sample were then washed twice with acetone and dried by applying suction. The crucibles with sample residue were finally dried in the oven at 105 °C to a constant weight. The neutral detergent fibre was calculated as :

$$NDF\ (\%) = \frac{\text{Weight of dried residue}}{\text{Weight of sample}} \times 100$$

iii) Acid detergent fibre (ADF) : This was also determined by Van Soest method (1963). The method involves heating the sample with normal sulphuric acid containing Cetyl trimethyl ammonium borate (CTAB). The residue after filtration is composed primarily of lignin and cellulose and is termed as ADF.

The reagents for analysis were prepared as described below :

a) Acid detergent solution : This solution was prepared by dissolving 20 g CTAB in one litre of water

b) Sulphuric acid

c) Acetone

d) 72% sulphuric acid (w/v)

e) Decahydronaphthalene (reagent grade)

Samples (one g) were weighed into beakers (1,000 ml). To each one of these, 100 ml of acid detergent reagent was added together with 2 ml decahydronaphthelene. The sample mixtures were heated to boiling for 5-10 min and refluxed for one hr. The mixtures were filtered through sintered glass crucibles using gentle sunction. The beakers and residues on the crucibles were washed twice with hot water and then washed and dried with acetone. The crucibles were finally dried in the oven at 105°C to a constant weight. Acid detergent fibre was determined as:

$$ADF = \frac{\text{Weight of residue}}{\text{Weight of sample}} \times 100$$

iv) Trypsin inhibitor activity (Kakade *et al* , 1969) : This method is based on the use of synthetic substrate, benzoyl-DL-arginine-p- nitroanilide hydrochloride (BAPA). The inhibition is measured in extracts.

One g of finely ground sample was extracted with 50 ml of 0.01 N NaOH for three hrs at room temperature. The pH of the resulting suspension was adjusted within 8. 4 to 10.0 with 1 N HCl or NaOH. This suspension, then, was diluted with distilled water to the point where 2 ml of the sample extract produced trypsin inhibition of 40-60% of trypsin used as a standard in the analysis. To a test tube, 2 ml of the diluted sample extract was added. A second tube was prepared for the trypsin standard by adding 2 ml of distilled water. To the tube containing sample extract and the tube containing distilled water, 2 ml of trypsin solution were added, mixed and placed in water bath at 37°C for 10 min. A 5 ml solution of benzoyl-DL-arginine-p-nitroanilide hydrochloride (BAPA) was added to both the tubes, mixed and returned back into the water bath. The reaction was terminated 10 min later by blowing in 1 ml of 30% acetic acid with immediate mixing. After mixing, the contents of tubes were filtered and absorbance of the filtrate was measured at 410 nm vs sample blank. Sample blank was prepared by the same procedure except that trypsin solution was added after the reaction was terminated by addition of acetic acid.

$$\text{T 1 mg/g of sample} = \frac{\text{A Std - A Sample}}{\text{1 g}} \times \text{Dilution factor}$$

v) Nitrogen solubility index : Nitrogen solubility index (NSI) was determined according to Inklaar and Fortuin (1969) by weighing exactly 2.5 g sample, adding 100 ml water and stirring for 1 hr at a controlled temperature of 80°C. The solution was then centrifuged for 30 min at 3,000 rpm. The supernatant was poured into a 250 ml volumetric flask. The extracting procedure was repeated on the residue and this was added to the 250 ml volumetric flask and made upto volume. Then 100 ml of liquid was pipetted in to a Kjeldahl flask and nitrogen was determined according to Kjeldahl method.

$$\text{NSI (\%)} = \frac{\text{Water soluble protein}}{\text{Total protein}} \times 100$$

3.2.5.3. Sensory evaluation

Tofu samples and tofu based food samples were subjected to sensory evaluation by a laboratory panel of 10 judges. The panel was presented the samples and requested for rating colour, flavour and texture on a nine point hedonic scale using numerical values ranging from 1 to 9, where 1 represented "disliked extremely" and 9 represented "liked extremely". The evaluation card for rating test is given in Appendix-I.

into the water bath. The reaction was terminated 10 min later by blowing in 1 ml of 30% acetic acid with immediate mixing. After mixing, the contents of tubes were filtered and absorbance of the filtrate was measured at 410 nm vs sample blank. Sample blank was prepared by the same procedure except that trypsin solution was added after the reaction was terminated by addition of acetic acid.

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3.3 STATISTICAL ANALYSIS

The data of different experiments were analysed, wherever necessary, using completely randomised block design as per Gomez and Gomez (1984). The differences in mean values were compared at $P \leq 0.05$.

Results and Discussion

Chapter 4

RESULTS AND DISCUSSION

The investigation was conducted to compare four varieties of soybean viz Bragg, Shivalik, Lee and PK 416 recommended for cultivation in Himachal Pradesh with respect to their physico-chemical characteristics and tofu making quality and utilization of tofu for nutritional enrichment of locally prepared household foods. The results obtained have been described and discussed in the following sections.

4.1 SOYBEAN

4.1.1 Physical characteristics

The data for 1,000 kernel weight and hull content of the four varieties are presented in Table 4.1. The 1,000 kernel weight differed significantly among the different varieties. Bragg variety showed highest weight (200.58 g) followed by Lee (193.70 g), Shivalik (166.94 g) and PK 416 (164.16 g). The differences in 1,000 kernel weight of different varieties may be due to differences in seed size as the seeds of Bragg were observed to be bolder in size as compared to other varieties. It was also observed that Bragg with highest 1,000 kernel weight had the lowest hull content (7.95%). On the other hand, PK 416 with lowest 1,000 kernel weight had the highest hull content (9.08%). The varietal differences in seed weights of different varieties of soybean have also been reported by Wang *et al.* (1983) and Lim *et al.* (1990). The variation in the seed weights and hull contents of different varieties of soybean may be attributed to differences in genetic make up of the varieties and environmental influences on the varieties during their growth and maturation.

Table 4.1 : Varietal differences in the hull content and 1,000 kernel weight of soybean

Variety	Hull (%)	1,000 kernel weight (g)
Bragg	7.95	200.58
Shivalik	8.85	166.94
Lee	8.15	193.70
PK 416	9.08	164.16
Mean	8.51	181.34
LSD	0.98	2.05
SE.d.	0.39	0.82

The hydration characteristics of various varieties have been shown graphically in Fig. 1 and the related data are tabulated in Table 4.2. It is clear from Fig. 1 that Bragg had the highest hydration characteristics as compared to other three varieties at room temperature.

4.1.2 Chemical characteristics

4.1.2.1 Proximate composition

The four varieties tested for various proximate principles differed significantly with respect to moisture, protein, ash, crude fibre and carbohydrates (Table 4.3). The moisture content of different varieties varied from 8.70 to 7.99 per cent. Crude protein was found to be significantly highest in Bragg (41.96%) followed by Lee (40.01%), Shivalik (38.11%) and PK 416 (35.34%). The fat content was found to be highest in Lee (21.97%) and lowest in Shivalik (19.01%). All varieties differed significantly in their fat content. Crude fibre and crude ash were found to be highest in PK 416 (5.01%) and lowest in Bragg (3.96%) as compared to other varieties. It was observed that crude fibre was related to the hull content of the varieties as the variety with highest hull and ash content also contained highest crude fibre.

Lim *et al* (1990) also reported the range for chemical composition of nine varieties of soybean as : moisture content 6.62 to 11.02 per cent, protein content 36.87 to 45.10 per cent, fat content 14.45 to 19.13 per cent, carbohydrate content 32.52 to 39.40 per cent and ash content 4.96 to 5.75 per cent.

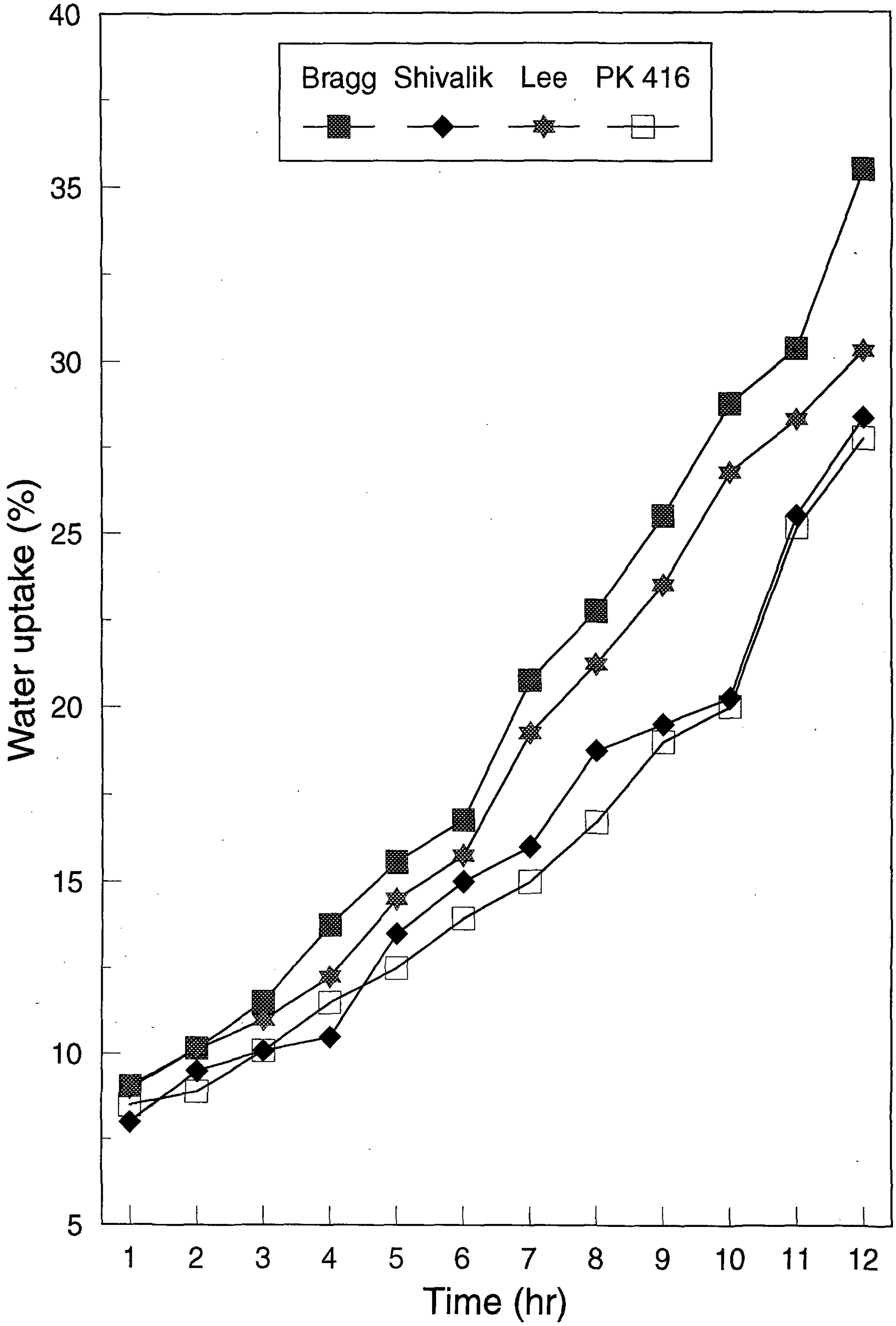


Fig 1. Hydration characteristics of four soybean varieties at room temperature

Table 4.2 : Varietal differences in hydration characteristics of soybean at room temperature

Variety	Water uptake (%) after hr											
	1	2	3	4	5	6	7	8	9	10	11	12
Bragg	9.05	10.17	11.52	13.75	15.56	16.76	20.75	22.75	25.50	28.75	30.35	35.50
Shivalik	8.00	9.50	10.10	10.50	13.50	15.00	16.00	18.75	19.50	20.25	25.50	28.35
Lee	9.00	10.15	11.00	12.25	14.50	15.75	19.25	21.22	23.50	26.75	28.29	30.30
PK 416	8.50	8.90	10.10	11.50	12.50	13.95	15.00	16.70	19.00	20.00	25.15	27.75

Table 4.3 : Varietal differences in proximate composition of soybean

		Proximate composition (dry matter basis)					
Variety	Moisture (%)	Dry matter (%)	Crude protein (%)	Crude fat (%)	Crude fibre (%)	Ash (%)	Carbohydrate (by difference)
Bragg	8.05	91.95	41.96	20.02	3.96	4.63	29.43
Shivalik	8.70	91.30	38.11	19.01	4.06	4.01	34.81
Lee	8.11	91.89	40.01	21.07	4.67	4.00	30.25
PK 416	7.99	92.01	35.34	19.89	5.01	4.17	35.59
Mean	8.21	91.78	38.85	19.99	4.42	4.20	32.52
LSD	0.02	0.06	0.03	0.02	0.02	0.02	0.05
SE.d.	0.01	0.03	0.01	0.01	0.01	0.01	0.02

4.1.2.2 Mineral composition

The mineral constituents of four varieties of soybean are shown in Table 4.4. Calcium, phosphorus and potassium were found to be the principal macro mineral components of soybeans and their values (g/100 g) ranged from 0.35 to 0.39, 0.57 to 0.71, and 0.96 to 1.16 respectively, whereas the values for the micro elements viz; zinc, copper, iron and manganese varied from 4.17 to 4.36, 1.97 to 2.06, 8.40 to 9.43 and 2.13 to 2.97 mg/100 g. Significant varietal differences however, existed with respect to various macro and micro mineral elements between the varieties. Gupta *et al.* (1976) reported that calcium, phosphorus and potassium ranged from 0.311 to 0.437, 0.407 to 0.855 and 0.900 to 1.50 g/100 g respectively whereas zinc, copper, iron and manganese varied from 3.75 to 4.62, 1.33 to 2.20, 6.66 to 14.00 and 2.16 and 4.66 mg/100 g, respectively. These values are in close agreement with the values observed in this study. The importance of various macro and micro mineral elements in human nutrition is very well documented (Swaminathan, 1993).

4.1.3 Chemical characteristics

Data in Table 4.5 show neutral detergent fibre (NDF), acid detergent fibre (ADF), nitrogen solubility index (NSI) and trypsin inhibitor activity of four varieties of soybean. It was found that varieties differed significantly in ADF and NDF values. PK 416 had the highest NDF (26.57%) followed by Bragg (26.32%), Lee (25.449%) and Shivalik (25.12%). On the other hand, Shivalik was found have highest ADF (13.37%) followed by Bragg (13.15%), PK 416 (12.30%) and Lee (12.19%). Nitrogen solubility index (NDI) was found to be highest in Bragg (86.06%) and lowest in Lee (82.50%). The trypsin inhibitor activity

Table 4.4 : Varietal differences in the mineral composition of soybean

Variety	Ca	P	K	Zn	Cu	Fe	Mn
Bragg	0.39	0.57	1.16	4.36	1.97	9.43	2.85
Shivalik	0.35	0.62	1.15	4.17	1.99	8.40	2.13
Lee	0.38	0.61	0.96	4.35	2.06	8.66	2.97
PK 416	0.37	0.71	0.98	4.21	1.98	8.47	2.92
Mean	0.37	0.62	1.06	4.27	2.00	8.74	2.71
LSD	0.01	0.03	0.03	0.05	0.06	0.44	0.05
SE.d.	0.002	0.01	0.01	0.02	0.03	0.18	0.02

Table 4.5 : Varietal differences in NDF, ADF, NSI and trypsin inhibitor activity of soybean

Variety	NDF (%)	ADF (%)	NSI (%)	Trypsin inhibitor (TIU/g sample)
Bragg	26.32	13.15	86.06	95.81
Shivalik	25.12	13.37	83.00	97.05
Lee	25.49	12.19	82.50	96.69
PK 416	26.57	12.30	84.33	97.03
Mean	25.87	12.75	83.97	96.64
LSD	0.09	0.05	0.08	0.06
SE.d.	0.04	0.02	0.03	0.02

in the four varieties differed significantly. It was found to be highest in Shivalik (97.05 TIU/g sample) followed by PK 416 (97.03 TIU/g sample). Shivalik (96.69 TIU/g sample) and Bragg (95.81 TIU/g sample) respectively.

Smith *et al.* (1960) reported the NSI of various soybean varieties to vary from 77.30 to 89.40 per cent. Sharma (1994) reported the trypsin inhibitor activity of varieties Bragg and Shivalik to be 95.90 TIU/g sample and 97.65 TIU/g sample respectively. These values are in close agreement with the values observed in the present investigation.

4.2 SOYMILK AND SOYMILK RESIDUE

4.2.1 Yield and total solids

Soymilk was extracted from whole soybeans and full fat soyflour of four varieties of soybean according to the procedure described in Sections 3.2.1 and 3.2.2, respectively. The milk yield, milk solids, amount of residue and residue solids obtained were recorded. The data are presented in Table 4.6.

The varieties did not differ significantly in soymilk yield and the whole soybeans of all the varieties gave almost identical milk yield varying from 802.5 ml to 815 ml/100 g. However, the processing of beans (bean form) prior to their conversion into milk affected the soymilk yields. In general, higher milk yields were recorded when the milk was extracted from whole beans and lower yields were obtained when milk was extracted from full fat soyflour. The milk yield, in general, varied from 797.50 to 815.00 ml/100 g soybean irrespective of variety and bean form. The lower yields obtained from full fat soyflour could be due to the filtration problem

Table 4.6 : Varietal differences in soymilk yield, soymilk solids, residue yield and residue solids of whole soybeans and full fat soyflour

Variety	Bean form	Soymilk (ml/100 g soybean)	Milk solids (g/100 g soybean)	Milk solids (g/l milk)	Residue (g/100 g soybean)	Residue solids (g/kg soybean)	Residue solids (g/100 g residue)
Bragg	Whole bean	815.00	72.65	8.99	78.22	38.90	49.74
	Soyflour	797.50	65.47	8.21	80.22	30.02	37.42
Shivalik	Whole bean	802.50	66.20	8.25	81.10	38.99	48.69
	Soyflour	800.05	64.32	8.04	83.31	29.28	35.25
Lee	Whole bean	810.05	64.96	7.02	79.22	36.18	45.72
	Soyflour	801.05	63.73	8.01	82.12	29.36	35.75
PK 416	Whole bean	802.50	66.20	8.25	80.10	38.95	48.02
	Soyflour	800.30	64.62	8.00	85.05	30. 36	35.17
LSD	Varieties	NS	1.52	0.17	0.26	0.48	0.52
LSD	Bean forms	1.91	1.07	0.12	0.18	0.34	0.37
LSD	Variety x Bean form	1.81	2.15	0.24	0.37	0.68	0.74

posed by the full fat soyflour which probably held the water more strongly and hindered the filtration efficiency, resulting in holding of more water compared to whole bean slurry residue.

Whole beans of Bragg yielded the highest content of milk solids (72.65 g/100 g beans) and the resultant milk contained 8.99 per cent solids whereas the whole beans of rest of the varieties yielded 64.96 to 66.20 g milk solids from one hundred grams of beans with milk containing 7.02 to 8.25 per cent solids. The milk extracted from full fat soyflour of different varieties in general gave significantly lower yields of milk solids (63.73 to 65.47 g/100 g flour) as well as lower yields of per cent solids in milk (8.00 to 8.21 g/100 ml milk) as compared to the solid yields given by whole beans (64.96 to 72.65 g/100g beans) with milk containing 7.02 to 8.99 per cent solids.

The effects of different varieties and bean forms used in extraction of soymilk as well as the interaction between the varieties and bean form for milk residue and residue solids were also found to be significant. The amount of wet residue obtained from whole beans varied from 78.22 to 81.00 g/100 g beans whereas amount of residue obtained from full fat soyflour varied from 80.20 to 85.05 g/100g flour. In general, whole beans of Bragg produced lowest residue (78.22g/100 g beans) and the whole beans of Shivalik produced the highest residue (81.10 g/100 g beans) whereas the full fat soyflour of Bragg produced the lowest residue (80.22 g/100 g flour) and the full fat soyflour of PK 416 yielded highest amount of residue per 100 g flour (85.05 g). The residue solids on bean flour weight basis varied from 29.28 to 38.95 g/100 g whereas the residue solids on residue weight basis varied from 35.17 to 49.74 g/100 g among all the treatments.

From the data it appears that the solids in full fat soyflour held more water and gave lower yield of milk as compared to the solids in whole beans which held less water and gave higher yield of milk. Sexena and Singh (1997) reported that under the identical conditions of extraction, soymilk yield from six varieties of soybean varied from 725.0 to 802.5 ml/100 g of beans. The milk yield data obtained from whole beans or full fat soyflour of four varieties in the present investigation are in close agreement with those of Saxena and Singh (1997). The soymilk solids were found to vary from 6.0 to 7.3 per cent in eight varieties (Jain and Mittal, 1989), from 9.09 to 90 per cent in nine varieties of soybean (Lim *et al*, 1990), from 5.40 to 5.96 per cent in five varieties of soybean (Reddy and Mittal, 1992) and from 5.78 to 6.48 per cent in six varieties of soybean (Sexena and Singh, 1997). The variability in yield of milk solids may be attributed to the differences in race materials and processing conditions used in the present investigation and in other studies as well.

4.3 TOFU

4.3.1 Yield and total solids

Table 4.7 depicts the varietal differences in tofu yield, tofu solids, whey yield and whey solids from whole soybeans and full fat soyflour. The effects of variety, bean form and the coagulants used in the preparation of tofu were significant for the various parameters as shown in Table 4.7. The tofu yield ranged from 172.30 to 187.52 g/100 g soybean, tofu solids ranged from 35.41 to 54.09 g/100 g soybean and tofu from 20.21 to 28.85 g/100 g among different treatments, whereas the whey volume ranged from 615.75 to 709.02 ml/100 g soybean and the whey solids ranged from 18.53 to 28.00 g/100 g soybean and 2.90 to 3.95 g/100 ml whey. The milk obtained from whole beans and coagulated with different types of

Table 4.7 : Varietal differences in tofu yield, tofu solids, whey yield and whey solids from whole soybeans and full fat soyflour

			Tofu and Tofu solids			Whey and whey solids		
Variety	Bean form	Coagulant	Tofu (g/100 g soybean)	Tofu solids (g/100 g soybean)	Tofu solids (g/100 g tofu)	Whey (ml/100 g soybean)	Whey solids (g/100 g soybean)	Whey solids (g/100 ml whey)
Bragg	Whole bean	Curd	183.45	48.77	26.59	653.22	22.99	3.52
		Citrus juice	187.52	54.09	28.85	645.87	18.53	2.90
		$MgSO_4$	180.29	47.55	25.27	665.25	22.15	3.33
	Soyflour	Curd	179.25	41.26	23.02	687.52	24.06	3.50
		Citrus juice	180. 85	43.23	24.02	682.55	20.88	3.06
		$MgSO_4$	175.57	42.89	24.51	690.79	21.41	3.10
Shivalik	Whole bean	Curd	183.47	40.49	22.07	680.30	23.38	3.50
		Citrus juice	185.22	43.82	23.66	653.20	21.94	3.30
		$MgSO_4$	174.02	44.04	25.31	685.52	22.00	3.11
	Soyflour	Curd	178.00	41.10	23.09	615.75	23.15	3.76
		Citrus juice	175.35	41.64	23.75	658.20	22.11	3.36
		$MgSO_4$	172.30	39.42	22.88	690.50	25.89	3.75
Lee	Whole bean	Curd	182.77	43.40	23.75	629.53	20.96	3.33
		Citrus juice	185.06	44.41	24.00	683.85	20.37	2.98
		$MgSO_4$	176.50	43.06	24.40	706.65	21.62	3.06
	Soyflour	Curd	179.25	39.50	22.04	662.57	22.85	3.45
		Citrus juice	180.77	39.82	22.03	697.50	22.18	3.18
		$MgSO_4$	175.00	36.12	20.64	704.50	27.61	3.92
PK 416	Whole beans	Curd	179.00	45.60	25.48	676.62	20.56	3.04
		Citrus juice	183.75	45.31	24.66	689.80	20.69	3.00
		$MgSO_4$	174.57	43.11	24.70	699.40	21.19	3.03
	Soyflour	Curd	177.75	36.14	20.53	684.00	24.89	3.64
		Citrus juice	179.77	38.48	21.41	660.00	23.76	3.60
		$MgSO_4$	175.25	35.41	20.21	709.02	28.00	3.95
LSD	Varieties		1.73	1.07	1.03	5.40	0.30	0.04
LSD	Bean forms		1.22	0.70	0.72	3.80	0.20	0.03
LSD	Coagulants		1.50	0.93	1.46	4.60	0.30	0.06

coagulants gave higher yield of tofu with high content of tofu solids as compared to the milks obtained from full fat soyflour and this held true for all the varieties. Bragg in general produced higher yield of tofu and tofu solids as compared to the other three varieties used in this investigation. Citric acid in general produced highest coagulation giving highest yield of tofu and tofu solids followed by curd and $MgSO_4$ respectively. The tofu processed from whole beans gave lower yield of whey and whey solids as compared to yield given by full fat soyflour irrespective of the coagulant used. Citrus juice in general gave lowest yield of whey and whey solids followed by $MgSO_4$ and curd, respectively. From the results of this part of experiment it may be concluded that Bragg is the most suitable variety for tofu making particularly when the whole beans are used in extraction of milk and precipitation of tofu with citrus juice.

The mean effects on tofu yield, tofu solids, whey yield and whey solids of variety, beanform and coagulant used are presented in Table 4.8. The means of tofu yield from different varieties ranged from 178.96 to 181.15 g/100 g soybean with Bragg recording the highest yield of 181.15 g/100 g soybean, followed by Lee 179.89g/100 g soybean, PK 416 178.35 g/100 g soybean and Shivalik 178.06 g/100 g soybean. Similar trend was observed in the yield of tofu solids, with Bragg giving highest content of tofu solids i.e., 46.30 g/100 g soybean and 25.38 g/100 g tofu. Tofu solids in other varieties were lower than Bragg irrespective of the bean form and coagulants used in this investigation. Tofu prepared from whole beans recorded higher yield of 181.30 g/100 g soybean with tofu solids 45.30g/100g soybean and 24.70g/100 g tofu than the tofu prepared with full fat soyflour which recorded a yield of 177.42 g/100 g soybean, tofu solids 39.58 g/100 g soybean and tofu 22.34 g/100 g irrespective of variety and coagulants used in the study. Citrus juice coagulated tofu recorded the highest yield of 182.28 g/100 g soybean with tofu solids 43.85 g/100 g

Table 4.8 : Mean effects of varieties, bean forms and coagulants on tofu yield, tofu solids, whey yield and whey solids

Variety/ bean form/ coagulent	Tofu (g/100 g soybean)	Tofu solids (g/100 g soybean)	Tofu solids (g/100 g tofu)	Whey (ml/100 g soybean)	Whey solids (g/100 g soybean)	Whey solids (g/100 ml whey)
Variety						
Bragg	181.15	46.30	25.38	670.86	26.67	3.23
Shivalik	178.06	41.75	23.46	673.91	23.31	3.46
Lee	179.89	41.05	22.42	680.76	22.56	3.32
PK 416	178.35	40.67	22.83	686.47	27.33	3.38
Bean form						
Whole bean	181.30	45.30	24.70	677.80	21.48	3.17
Soyflour	177.42	39.58	22.34	678.57	23.89	3.52
Coagulant						
Curd	180.37	42.03	23.32	661.18	22.85	3.46
Citrus juice	182.28	43.85	24.05	671.37	21.30	3.17
$MgSO_4$	175.43	41.45	23.19	693.95	23.73	3.40

soybean and tofu 23.19 g/100 g followed by curd coagulated tofu with a yield of 189.37 g/100 g soybean with tofu solids 43.85 g/100 g soybean and tofu 23.19 g/100 g soybean and Mg SO_4 coagulated tofu recorded a yield of 175.43 g/100 g soybean with tofu solids 41.45 g/100 g soybean and tofu 23.19 g/100 g irrespective of variety and bean form used in the study. Similar trends were also observed with respect to whey yield and whey solids. One can derive three important conclusions from this table. First, Bragg variety was most suitable for making tofu, second whole beans gave higher yield of tofu with higher solid content as compared to full fat soyflour. Third, the milk protein coagulating ability of citrus juice was better than curd and $MgSO_4$ as citrus juice produced higher yield of tofu with higher content of solids as compared to other two coagulants. These findings are almost similar to the findings discussed in Table 4.7.

Smith *et al* (1960) reported the yield of tofu from U.S and Japanese soybean varieties to vary from 4.69 kg to 6.97 kg from 1.8 kg of soybean whereas Grover and Tyagi (1989) reported the tofu yield to vary from 54.3 to 70.0 g/100 g flour on dry weight basis and tofu solids to vary from 25.60 to 37.5 per cent in tofu prepared with four different types of coagulants. Lim *et al* (1990) reported comparatively higher yield of tofu varying from 4.45 to 5.11 kg/kg beans among nine varieties of soybean. They also reported the whey volume to vary from 59 to 93 ml/300 ml of soymilk and the whey solids to range from 2.50 to 3.40 per cent. Arora and Mittal (1991) reported the average yield of tofu about 1.66 kg per kg of soybean and the mean total solids contents 25.15 per cent. Jain and Mittal (1992) reported the yield of tofu to range from 119 to 148 g/100 g with a mean value of 133.1 g/100 g of beans with total solids ranging from 26.9 to 31.1 per cent with the mean value of 29.4 per cent. The variations in the tofu yield, tofu solids, whey yield and whey solids obtained in this study and in the studies reported earlier as mentioned above may be attributed to differences in the processing conditions, type of coagulant used, varieties and the physico-chemical constitution of the tofu samples used in various investigations.

4.3.2 Organoleptic evaluation

Data regarding sensory characteristics (colour, texture, flavour, taste and overall acceptability of tofu prepared from whole beans and full fat soyflour of various varieties with the help of various types of coagulants (Plate 2) on a nine point hedonic scale are presented in Table 4.9. The effects of all the treatments on the sensory attributes of tofu were found to be significant and are discussed as under:

i) Colour : The colour scores of all the treatments ranged from 4.50 to 8.00 which were significantly lower than control milk paneer (8.40) used in the comparison. Tofus coagulated from whole beans with the help of citrus juice scored the highest points followed by the tofus coagulated with $MgSO_4$ and by curd for all the varieties. However, the tofu samples coagulated from whole soybean milk from Bragg was rated to be superior to other varieties in term of colour parameter. Almost the same trend was followed for tofu coagulated from the milks obtained from full fat soyflour of different varieties but the tofu samples obtained from full fat soyflour were rated to be inferior to tofus obtained from whole soybeans.

ii) Flavour : The control (milk paneer) was scored best (8.90) among all the treatments, flavour score for rest of the treatments ranged from 4.55 to 8.05 on 9 point hedonic scale. The tofus prepared from whole beans were rated superior to tofus prepared from full fat soyflour for all varieties. Tofu coagulated from citrus juice scored better than other two coagulants (curd

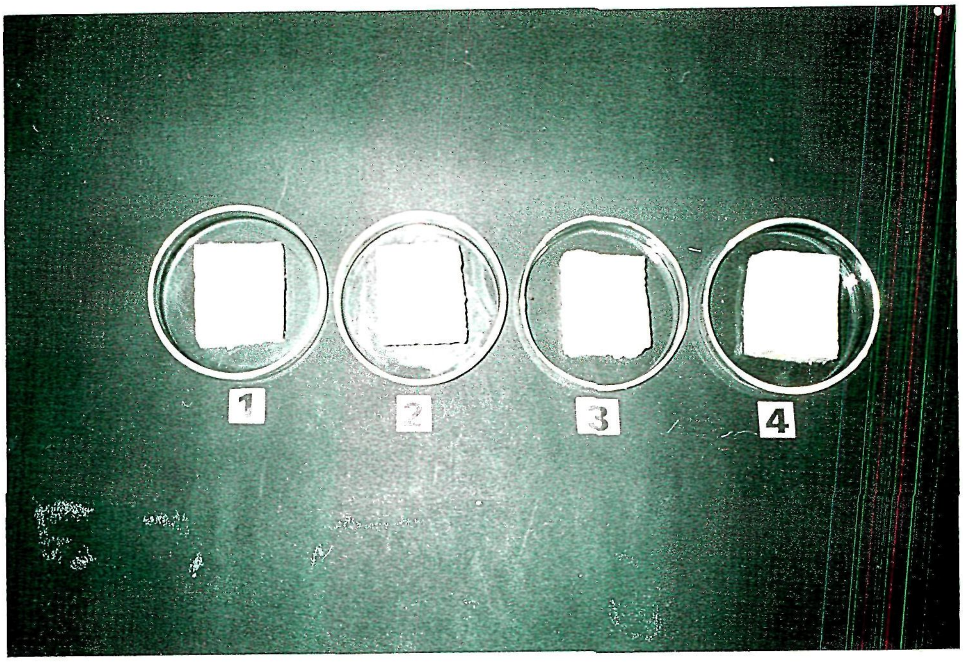


Plate 2. Various types of tofu
1. Curd coagulated 2. Citrus juice coagulated
3. $MgSO_4$ coagulated 4. Control (milk paneer)

Table 4.9 : Effect of varieties, bean forms and coagulants on organoleptic acceptability scores (1-9) of tofu

Variety	Bean form	Coagulant	Colour	Flavour	Texture	Taste	Overall acceptability
Bragg	Whole bean	Curd	7.40	7.88	7.99	7.75	7.75
		Citrus juice	8.00	8.05	8.05	8.67	8.20
		$MgSO_4$	7.75	7.77	7.80	8.65	7.99
	Soyflour	Curd	5.59	4.17	4.88	5.75	5.10
		Citrus juice	6.60	5.06	5.55	6.25	5.86
		$MgSO_4$	5.55	4.55	6.75	6.50	5.83
Shivalik	Whole bean	Curd	6.20	6.25	5.35	6.75	6.14
		Citrus juice	6.75	6.75	6.30	5.00	6.20
		$MgSO_4$	7.77	7.20	6.75	7.00	7.18
	Soyflour	Curd	4.72	4.70	6.65	4.75	5.20
		Citrus juice	5.75	6.76	4.50	6.00	5.75
		$MgSO_4$	4.50	5.25	5.45	5.50	5.17
Lee	Whole bean	Curd	6.00	5.95	6.02	7.00	6.24
		Citrus juice	7.78	6.08	7.55	6.55	6.99
		$MgSO_4$	6.75	7.50	6.57	5.69	6.63
	Soyflour	Curd	5.25	4.57	4.78	6.65	5.31
		Citrus juice	6.20	5.58	6.77	6.66	6.30
		$MgSO_4$	5.55	6.25	5.75	7.65	6.30
PK 416	Whole bean	Curd	6.67	5.83	5.67	5.80	5.87
		Citrus juice	6.83	7.00	7.33	7.50	7.16
		$MgSO_4$	7.17	6.83	6.50	7.00	6.87
	Soyflour	Curd	6.50	5.00	4.17	4.55	5.05
		Citrus juice	6.66	5.33	5.67	6.75	6.10
		$MgSO_4$	5.50	6.33	6.00	4.77	7.11
Control (milk paneer)			8.40	8.90	8.95	9.00	8.81
LSD Varieties			0.17	0.15	0.20	0.15	0.11
LSD Bean forms			0.18	0.16	0.15	0.11	0.17
LSD Coagulant			0.11	0.18	0.09	0.09	0.10

and $MgSO_4$) in terms of flavour parameter. The flavour score of tofu from whole beans of Bragg was rated next to the control.

iii) Texture : As with colour and flavour, the texture score for all the treatments differed significantly from control. The control milk paneer sample scored 8.95 points whereas other samples scored from 4.17 to 8.05 on the 9 point hedonic scale. Citrus juice performed better than $MgSO_4$ and curd in its ability to produce better textured tofu. The milk extracted from whole bean when coagulated with citrus juice also produced better texture as compared to milk extracted from full fat soyflour and coagulated with citrus juice.

iv) Taste : The control milk paneer tasted the best (9.00) among all the treatments. The rest of the treatments were rated inferior to control in terms of taste parameters as the taste scores were lower than the control and ranged from 4.55 to 8.67. The tofu prepared from whole beans with the help of citrus juice was rated superior to tofus prepared from whole beans and the help of $MgSO_4$ and curd. Bragg yielded the best tofu in terms of taste parameters. The tofus obtained from full fat soyflour with the help of different coagulants were rated inferior to the tofus prepared from whole beans in terms of taste.

v) Overall acceptability : The overall acceptability scores were computed from sum total of scores of all the sensory attributes divided by number of attributes. Tofus prepared from different varieties and different bean forms using different coagulants were rated inferior to the control (milk paneer) in terms of overall acceptability. The overall acceptability score of tofus ranged from 5.05 to 8.20 as compared to 8.81 for control sample. The tofus prepared from whole beans were rated superior to the tofus prepared from full fat soyflour. The tofus coagulated with citrus juice were rated superior to tofus coagulated with $MgSO_4$ and the tofus coagulated with curd. Although the soy tofus were rated inferior to the control but they were highly to reasonably acceptable by the consumer. The tofu prepared from whole beans of Bragg was found to be highly acceptable among all the treatments, excluding control.

Nasim *et al* (1986) also reported that an acceptable product resembling milk paneer in appearance, taste and texture can be prepared by organic acids such as citric acid. In this study citrus juice was used as a source of citric acid (4.5%) as citric acid is not available to common man in villages whereas citrus juice can be extracted from the locally grown sour citrus fruits and can be preserved for convenient use in the preparation of tofu. Jain and Mittal (1992) prepared tofu from different varieties of soybean using 2 per cent citric acid and also reported varietal variations in the sensory properties of tofus. They reported that tofu prepared from Punjab-1 variety exhibited greater resemblance to milk paneer in sensory attributes than other varieties tested.

Almost similar sensory and overall acceptability scores for tofu samples prepared from different varieties of soybean were reported by Jain and Mittal (1992).

4.3.3 Proximate composition

Bragg was found to perform better than the other three varieties in relation to tofu making quality as it yielded highest contents of milk solids and gave higher yield of tofu with better sensory properties as compared to other three varieties. The Bragg tofus coagulated with different coagulants were therefore analyzed for various chemical attributes to assess the nutrient composition. The results of some of the proximate constituents of tofu are presented in Table 4.10. The coagulation of milks extracted from whole beans of Bragg, when coagulated with different types of coagulants affected the contents of various proximate constituents of tofu significantly. The tofu coagulated with three different types of coagulants contained significantly higher contents of water (71.11 to 74.74%) and significantly lower contents of dry matter (25.22 to 28.95 %) than the milk paneer control which contained 4.15 per cent moisture and 35.55 per cent dry matter respectively. The citrus juice coagulated tofu contained significantly higher solids (28.85 %) compared to the solids contained in $MgSO_4$ coagulated (25.27 %) and curd coagulated (26.50 %) tofus. The crude protein, crude fat and ash contents of tofus also varied significantly among different treatments. The tofus coagulated with different types of coagulants contained significantly higher contents of protein (54.17 to 55.29 %) compared to protein content of milk paneer (43.73 %), indicating that tofus are richer in protein compared to milk paneer control.

The milk paneer contained almost double the amount of crude fat (39.55%) as compared to the crude fat contents of tofus (20.21%). This is important from nutritional view point as dairy fats are rich in unsaturated fatty acids and cholesterol and contribute to the development of atherosclerosis, hypertension and cardiovascular diseases. As the soy tofus are low in fat and contain no cholestrol,these can replace dairy paneer at a low cost in Indian diets and can reduce the incidence of fat related diseases and the expenditure to be incurred in the management of these diseases. Dairy paneer control also contained lower amount of ash (2.68%) compared to tofu samples (3.54 to 4.02%). The level of mineral ash in tofus can contribute to the mineral nutrition of consuming population significantly.

Table 4.10 : Effect of various coagulants on the proximate composition of tofu prepared from Bragg

Tofu type	Moisture (%)	Dry matter (%)	Crude protein (%)	Crude fat (%)	CP Ash (%)	Other constituents (%)
Curd coagulated	73.41	26.59	54.17	20.12	3.54	22.17
Citrus juice coagulated	71.15	28.85	55.29	20.95	3.62	20.14
$MgSO_4$ coagulated	74.73	25.27	54.86	20.05	4.02	21.07
Control (milk paneer)	64.15	35.85	43.73	39.55	2.68	14.04
LSD	0.02	0.05	0.05	0.02	0.02	0.11
SE.d.	0.01	0.02	0.02	0.01	0.01	0.04

Table 4.11 : Effect of different coagulants on the mineral composition of tofu prepared from Bragg

Tofu type	Ca	P	K	Zn	Cu	Fe	Mn
Curd coagulated	0.35	0.54	0.66	0.73	0.60	5.06	0.70
Citrus juice coagulated	0.34	0.55	0.60	0.66	0.73	5.56	0.33
$MgSO_4$	0.38	0.57	0.64	0.43	0.73	4.96	0.46
Control (milk paneer)	0.68	0.52	0.79	ND	ND	2.10	ND
LSD	0.02	NS	0.05	NS	NS	0.57	0.05
SE.d.	0.01	NS	0.02	NS	NS	0.23	0.02

ND = Not detected

Nasim *et al.* (1986) studied the effect of different coagulants such as lactic acid, citric acid, tartaric acid and gluconic acid. Soy paneer obtained by lactic acid, citric acid, tartaric acid and gluconic acid contained low moisture and high protein than control. Gluconic acid yielded a tofu with higher moisture content and lower protein control. Citric acid also gave tofu with more fat and ash compared to tofu prepared with gluconic acid.

It can be said that soy tofu, being rich in protein, can contribute in the protein nutrition of the people in the State if it becomes a part of regular diet of people.

The coagulation of soymilk with commercial salt such as calcium sulphate gave higher yield of tofu because of high moisture content and protein also contained 7-8 per cent protein on wet basis (Wang *et al.*, 1983, Lim *et al.*, 1990). In contrast to this, acid coagulation of milk with citric acid yielded a product with lower yield, lower moisture content, higher solids and high protein content (Jain and Mittal, 1992). Tofu samples coagulated with $CaCl_2$ solution by Pant *et al.* (1993) were reported to contain high protein, ash, carbohydrates and much lower fat than milk paneer. It was also suggested that tofu can be more suitable than milk paneer for those suffering from cardiac disease.

4.3.4 Mineral composition

The mineral composition of tofu as affected by different soymilk coagulants and compared with control is presented in Table 4.11. The control milk paneer contained higher amount of calcium (0.68%) and potassium (0.79%) than the tofu samples which contained 0.43 to 0.38% calcium and 0.60 to 0.66% potassium. Phosphorus did not differ significantly among different treatments from control. Calcium and potassium contents of tofus prepared with curd, citrus juice and $MgSO_4$ were almost similar. The micro minerals zinc and copper also did not differ significantly among the tofus prepared by three different coagulants. However, iron content was significantly higher in tofu than in dairy paneer, whereas manganese varied from 0.33 to 0.70mg/100 g.

Scrutiny of the data shows that tofu can contribute to the mineral nutrition of the consuming population with respect to Ca, P, K, Zn,Cu and Mn nutrition.

4. 4 *PARANTHAS* SUPPLEMENTED WITH DIFFERENT TYPES OF TOFU

4.4.1 Organoleptic acceptability

The organoleptic acceptability scores of *paranthas* supplemented with different types of tofus prepared with three different coagulants are presented in Table 4.12. The physical appearance of *paranthas* is shown in Plate 3.

The supplementation of *paranthas* with various types of tofus and the control milk paneer did not produce any effect on colour of the *paranthas* whereas texture, flavour and taste scores of all the tofu supplemented *paranthas* were significantly lower than control (milk paneer) *paranthas*. Three types of tofu however, did not differ significantly in their contribution to colour, texture, flavour and taste properties of the supplement *paranthas*. The overall acceptability of different types of tofu *parantha* was found to be lower than control milk paneer but the tofu supplemented *paranthas* were acceptable to the panel of judges.

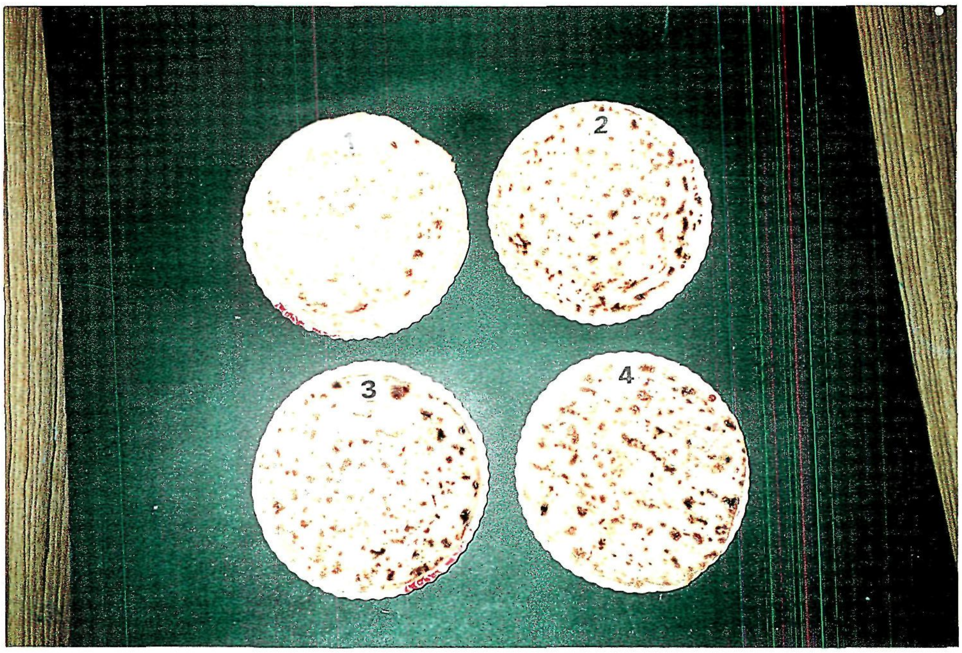


Plate 4. Various types of tofu - supplemented *matar* curry
1. Curd coagulated 2. Citrus juice coagulated
3. $MgSO_4$ coagulated 4. Control (milk paneer)

Table 4.12 : Organoleptic acceptability scores (1-9) of *paranthas* supplemented with different types of tofu

Tofu type	Colour	Texture	Flavour	Taste	Overall acceptability
Curd coagulated	7.40	6.60	6.80	6.20	6.75
Citrus juice coagulated	7.20	6.40	7.40	6.80	6.95
$MgSO_4$ coagulated	7.20	7.20	6.40	6.40	6.80
Control (Milk paneer)	8.20	8.40	8.40	8.40	8.35
Mean	7.50	7.45	7.25	6.95	7.21
LSD	NS	1.35	NS	1.05	1.07
SEd.	NS	0.54	NS	0.42	0.43

Table 4.13 : Proximate composition of *paranthas* supplemented with different types of tofu

Tofu type	Moisture (%)	Dry matter (%)	Crude protein (%)	Crude fat (%)	Ash (%)	Other constituents (%)
Curd coagulated	52.46	47.54	25.58	35.31	2.16	36.95
Citrus juice coagulated	50.19	49.81	26.02	34.69	2.11	37.18
$MgSO_4$ coagulated	52.55	47.45	25.69	34.12	2.32	37.87
Control (milk paneer)	48.55	51.45	24.01	38.27	2.18	35.54
LSD	0.91	0.75	0.05	0.50	NS	NS
S.Ed.	0.36	0.30	.02	0.20	NS	NS

From this part of the experiment, it can be said that tofu prepared from curd, $MgSO_4$ and citrus juice can be used in *paranthas* without having any significant effect on overall acceptability of *paranthas*. *Parantha* is a popular food in many households in the State and can be supplemented with tofu to derive maximum nutritional benefit at a low cost.

4.4.2 Proximate composition

The proximate composition of *paranthas* supplemented with tofus is presented in Table 4.13. Supplementation of *paranthas* with different types of tofu supplements produced significant effects on the contents of various proximate principles. Tofu supplemented *paranthas* contained 50.19 to 52.46 per cent moisture, 47.45 to 48.10 per cent dry matter, 25.58 to 26.02 per cent protein, 34.69 to 35.31 per cent crude fat, 2.11 to 2.30 per cent ash and 36.95 to 37.87 per cent other constituents. As compared to this, milk paneer supplemented *paranthas* contained 48.55 per cent moisture, 51.45 per cent dry matter, 24.01 per cent protein, 38.27 per cent crude fat, 2.18 per cent ash and 35.4 per cent other constituents. Milk paneer supplemented *paranthas* contain slightly lower moisture, higher protein, high crude fat, slightly lower protein and other constituents. Critical appraisal of the data shows that content of different nutrients in tofu supplemented *paranthas*, though statistically different from control *paranthas* had values which are very close to each other. It may be said that the milk supplemented *paranthas* are almost similar to tofu supplemented *paranthas* in terms of nutritional value and their acceptability, though lower, is close to control *paranthas*.

The tofu supplemented *paranthas* may be preferred by consuming population in view of lower cost involved in preparation of tofu from soybean than the milk paneer from dairy milk.

4.5 *PAKORAS* SUPPLEMENTED WITH DIFFERENT TYPES OF TOFUS

4.5.1 Organoleptic acceptability

Sensory characteristics of tofu supplemented *pakoras* have been shown in Table 4.14. The colour and taste scores of *pakoras* were not affected significantly with the types of tofu and were not significantly different from control milk supplemented *pakoras*. However, the texture (6.17 to 7.17) and flavour (6.5 to 8.10) scores of tofu supplemented *pakoras* were slightly but significantly lower than the texture (8.50) and flavour (8.50) scores of the milk paneer supplemented *pakoras*. The overall acceptability scores of tofu supplemented *pakoras* were slightly and significantly lower (7.00 to 7.30) than the control (8.41) on a nine point hedonic scale. The critical evaluation of the sensory data revealed that the overall acceptability of tofu supplemented *pakoras*, though slightly lower than that of the control milk paneer supplemented *pakoras*, was comparable to the overall acceptability of the control (milk paneer supplemented *pakoras* and the products were appreciated for their organoleptic attributes by the judges evaluating the tofu *pakoras*.

The proximate composition of *pakoras* supplemented with different types of tofu according to the recipe given in section 3.2.3 is shown in Table 4.15. All the tofu supplemented *pakoras* contain high moisture (40.19 to 42.55%), low dry matter (57.45 to 59.81 %), higher crude protein (34.21 to 35.10%) and low curde fat (35.27 to 35.61%), as compared to control (milk paneer *pakoras*) which contain 38 per cent moisture, 62 per cent dry matter; 33.45 per cent protein and 38.35 per cent fat. The tofus prepared with three different types of coagulants had almost similar type of chemical constitution with small differences and the values

Table 4.14 : Organoleptic acceptability scores (1-9) of *pakoras* supplemented with different types of tofu

Tofu type	Colour	Texture	Flavour	Taste	Overall acceptability
Curd coagulated	7.17	6.83	6.50	7.50	7.00
Citrus juice coagulated	6.67	6.17	8.16	8.00	7.30
$MgSO_4$ coagulated	6.67	7.17	7.83	7.17	7.21
Control coagulated	8.33	8.50	8.50	8.33	8.41
Mean	7.21	7.17	7.75	7.75	7.48
LSD	NS	1.31	1.09	NS	1.19
SEd.	NS	0.52	0.44	NS	0.48

Table 4.15 : Proximate composition of *pakoras* supplemented with different types of tofu

Tofu type	Moisture (%)	Dry matter (%)	Crude protein (%)	Crude fat (%)	Ash (%)	Other constituents (%)
Curd coagulated	42.46	57.54	35.10	35.27	1.96	27.48
Citrus juice coagulated	40.19	59.81	34.81	35.61	2.07	27.51
$MgSO_4$ coagulated	42.55	57.45	34.21	35.34	2.96	28.79
Control (milk paneer)	38.00	62.00	33.45	38.35	2.09	26.11
LSD	0.02	0.07	0.02	0.03	0.02	0.02
SEd.	0.01	0.03	0.01	0.01	0.01	0.01

were not too different from the control milk paneer supplemented *pakoras*. It can be stated that *pakoras* prepared with milk paneer were almost similar and not much different from *pakoras* prepared with different types of tofus.

4.6 *MATAR* CURRY SUPPLEMENTED WITH DIFFERENT TYPES OF TOFU

4.6.1 Organoleptic acceptability

The sensory characteristics of *matar* curry supplemented with different types of tofu as assessed from colour, texture, flavour taste and organoleptic acceptability of curry samples are presented in Table 4.16 (Plate 4). The *matar* curry supplemented with different types of tofu produces significantly lower colour (7.17 to 7.67), texture (7.0 to 7.83), flavour (7.0 to 7.33), taste (7.50 to 7.33) and overall acceptability (7.3 to 7.45) scores as compared to colour (8.50), texture (8.32), flavour (8.67), taste (8.67) and overall acceptability (8.54) scores of curry supplemented with milk paneer (control). All the tofu samples were almost identical in producing their effects on various sensory attributes. Though the sensory scores of tofu supplemented curry were slightly lower than the milk paneer supplemented curry samples, the tofus from all the treatments were acceptable to the consumer with an overall acceptability score varying from 7.16 to 7.45 on the nine point hedonic scale by a panel of ten judges. It was observed that none of the judges disliked tofu supplemented *matar* curry.

4.6.2 Proximate composition

The data for the proximate composition of tofu supplemented *matar* curry have been presented in Table 4.17. It was found that moisture content and ash content among all the preparations did not differ significantly whereas the crude protein and crude fat differed significantly.

Plate 4. Various types of tofu - supplemented *matar* curry
1. Curd coagulated 2. Citrus juice coagulated
3. $MgSO_4$ coagulated 4. Control (milk paneer)

Table 4.16 : Organoleptic acceptability scores (1-9) of *matar* curry supplemented with different types of tofu

Tofu type	Colour	Texture	Flavour	Taste	Overall acceptability
Curd coagulated	7.17	7.83	7.33	7.50	7.45
Citrus juice coagulated	7.67	6.33	7.00	7.33	7.08
$MgSO_4$ coagulated	7.67	7.00	7.17	6.83	7.16
Control (milk paneer)	8.50	8.32	8.67	8.67	8.54
Mean	7.75	7.37	7.54	7.58	7.56
LSD	0.89	0.82	0.71	0.71	0.70
SEd.	0.36	0.33	0.28	0.28	0.28

Table 4.17 : Proximate composition of *matar* curry supplemented with different types of tofu

Tofu type	Moisture (%)	Dry matter (%)	Crude protein (%)	Crude fat (%)	Ash (%)	Other constituents (%)
Curd coagulated	87.55	12.45	25.68	35.26	1.01	38.05
Citrus juice coagulated	88.05	11.95	27.49	34.16	1.11	37.24
$MgSO_4$ coagulated	88.90	11.10	24.86	35.57	1.75	37.82
Control (milk paneer)	86.60	13.40	20.73	38.88	1.01	39.38
LSD	NS	0.02	0.01	0.55	NS	0.02
SEd	NS	0.01	0.00	0.22	NS	0.01

It was found that citrus juice coagulated tofu *matar* curry had significantly highest crude protein (27.49 %) whereas crude protein of control was found to be significantly lower (20.73 %). The crude fat was found to be significantly higher (38.88%) in case of control when compared to other treatments. Crude fat of curd and $MgSO_4$ coagulated tofu *matar* curry was found to be same whereas it was significantly lower in case of curd coagulated tofu *matar* curry.

4.7 SOYMILK RESIDUE

4.7.1 Proximate composition

Table 4.18 shows the varietal differences in proximate composition of soymilk residue obtained from whole soybeans used for extraction of milk. The whole soybean residue obtained from different varieties did not differ significantly in moisture and dry solids. However, crude protein, crude fat, ash and carbohydrate content differed significantly among residues obtained from different varieties. The mean moisture and dry matter content were found to be 51.95 per cent and 48.04 per cent, respectively. The protein content varied from 20.11 to 25.05 per cent, crude fat from 6.01 to 7.54 per cent, crude fibre from 7.78 to 9.58 per cent, ash from 3.01 to 3.36 per cent and other constituents from 56.51 to 59.32 per cent with mean values of 23.07, 6.89, 8.71, 3.16 and 58.15 per cent respectively. The composition of all the values was comparable, based on proximate principles.

Kulkarni *et al.* (1985) reported similar values for proximate composition of residue. The results of present investigation agree with those reported by Smith *et al.* (1960).

Table 4.18 : Varietal differences in proximate composition of soymilk residue obtained from whole beans

Variety	Moisture (%)	Dry matter (%)	Crude protein (%)	Crude fat (%)	Crude fibre (%)	Ash (%)	Carbohydrates by difference (%)
Bragg	50.26	49.74	20.11	7.63	9.58	3.36	59.32
Shivalik	51.31	48.69	24.03	6.01	8.62	3.01	58.33
Lee	54.28	45.72	25.05	7.54	7.78	3.12	56.51
PK 416	51.98	48.02	23.11	6.41	8.86	3.15	58.47
Mean	51.95	48.04	23.07	6.89	8.71	3.16	58.15
LSD	NS	NS	0.02	0.02	0.01	0.06	0.04
SEd.	NS	NS	0.01	0.01	0.002	0.03	0.02

From the proximate composition, soybean residue appears to be rich in protein, crude fibre, ash and carbohydrates and can be a good nutritional supplement to various traditional foods such as nuggets. Nuggets are a traditional food prepared from black gram dal. Addition of residue to black gram in preparation of nuggets is assumed to enhance the nutritional value of nuggets in term of protein and fibre and at the same lime it may promote a new use for the soymilk residue, which is otherwise a waste product of soymilk extraction process, for the preparation of tofu.

4.7.2 Mineral composition

Mineral composition of soymilk residue is presented in Table 4.19. Calcium in all the varieties was found to vary significantly from 0.13 to 0.17 g/100 g. Phosphorus in Bragg, Shivalik and Lee was found to be similar whereas PK 416 had significantly lower phosphorus content. Potassium was found to vary significantly from 0.31 to 0.60 g/100 g. Iron content was found to be similar in residue of Bragg (3.5 mg/100 g) and PK 416 (3.1 mg/100 g), whereas iron content in residue of Shivalik and Lee (2.8 and 2.5 mg/100 g, respectively) was found to be almost same.

4.8 NUGGETS (*BARI*)

4.8.1 Organoleptic acceptability

The organoleptic acceptability scores of soymilk residue supplemented nuggets as affected by level of residue in nuggets are shown in Table 4.21 (Plate 5). The scores for colour, flavour, texture and taste decreased significantly with increase in the level of residue. The colour score decreased from 7.33 to 5.50 whereas flavour, texture and taste decreased from 7.33 to 5.00, 7.00 to 5.33 and 7.70 to 5.67, respectively.

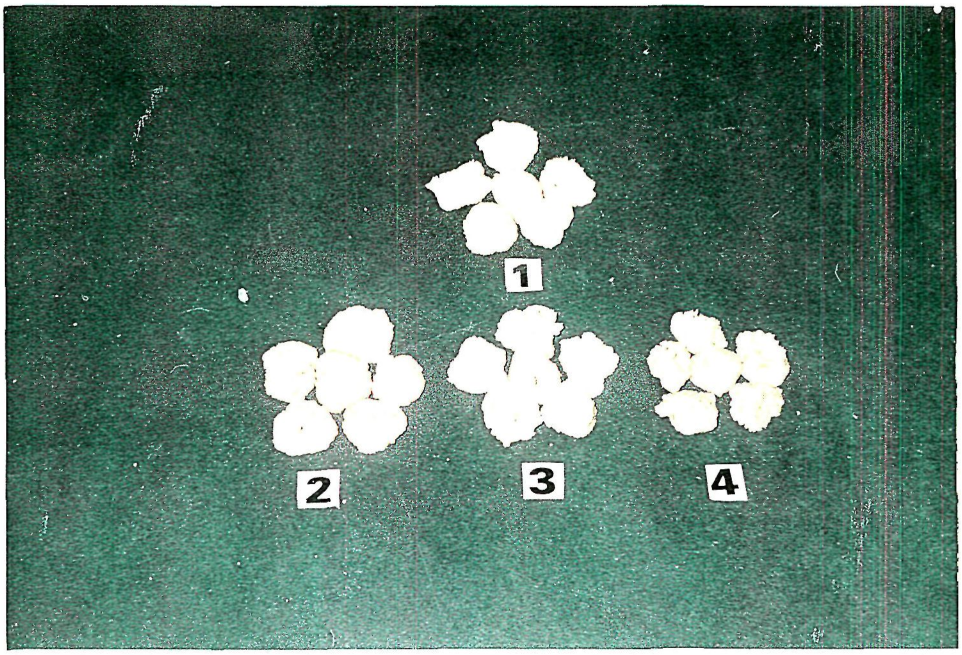


Plate 5. Nuggets (*bari*) supplemented at different levels (%) of soymilk residue
1. Zero 2. Ten 3. Twenty 4. Thirty

Table 4.19 : Varietal differences in mineral composition of soymilk residue obtained from whole milk

Variety	Ca	P	K	Zn	Cu	Fe	Mn
Bragg	0.17	0.32	0.60	2.80	0.70	3.50	2.60
Shivalik	0.16	0.34	0.57	2.40	0.69	2.80	2.00
Lee	0.13	0.33	0.37	2.10	0.91	2.50	2.80
PK 416	0.14	0.41	0.31	2.60	0.80	3.10	2.50
Mean	0.15	0.35	0.46	2.47	0.77	2.97	2.47
LSD	0.01	0.01	0.15	0.30	0.09	0.04	0.05
SEd.	0.002	0.002	0.06	0.12	0.04	0.02	0.02

Table 4.20 : Varietal differences in NDF and ADF of soymilk residue from whole beans

Variety	NDF (%)	ADF (%)
Bragg	27.12	11.00
Shivalik	28.53	12.56
Lee	27.49	11.59
PK 416	29.56	12.30
Mean	28.18	11.86
LSD	0.17	0.15
S.Ed.	0.07	0.06

The overall scores ranged from 5.59 at 30 per cent level of supplementation to 7.34 at 0 per cent level of supplementation. From the overall acceptability view point, it appears that residue present in nuggets used in the preparation of curry was acceptable upto 20 per cent level of supplementation. The *bari* product at 30 per cent level of supplementation was neither liked nor disliked by the judges.

4.8.2 Proximate composition

Proximate composition of nuggets supplemented with different levels of soymilk residue is shown in Table 4.21. The increase in level of soymilk residue from 10 to 30 per cent increased the level of moisture in nuggets and decreased dry matter. This may be due to the fact that more water was retained in nuggets after drying the nuggets. The fat and fibre content of nuggets increased significantly whereas carbohydrate content decreased significantly with the increase in the level of soymilk residue. The protein content was found to remain unchanged (24.70 %). The fat content increased from 5.50 to 7.87 per cent, crude fibre increased from 0.91 to 3.93 per cent and the ash content increased from 3.00 to 3.23 per cent.

It can be concluded that the addition of soymilk residue to nuggets enhances the fibre and mineral value. The importance of fibre in human nutrition is very well recognized (Dreher, 1987). Thus, the soymilk residue, which is otherwise a waste product, can be utilized in nuggets.

4.9 COST AND PROTEIN CONTENT OF TOFU AND MILK PANEER PRODUCTS

The comparative cost and protein content of tofu, milk paneer and their products viz. *parantha, pakora* and *matar* curry are presented in

Table 4.21 : Effect of different levels of soymilk residue on organoleptic acceptability scores (1-9) of nugget (*bari*) curry

Residue (%)	Colour	Flavour	Texture	Taste	Overall acceptability
0	7.33	7.33	7.00	7.70	7.34
10	6.83	6.00	6.50	6.67	6.50
20	6.16	5.67	6.17	5.67	5.59
30	5.11	5.00	5.33	5.50	5.61
Mean	6.35	6.00	6.25	6.93	6.25
LSD	1.31	1.03	NS	0.85	0.66
SEd.	0.52	0.41	NS	0.34	0.26

Table 4.22 : Proximate composition of nuggets supplemented with different levels of soymilk residue

Residue used (%)	Moisture (%)	Dry matter (%)	Crude protein (%)	Crude fat (%)	Crude fibre (%)	Ash (%)	Other constituents (%)
0	10.47	89.53	24.15	5.50	0.91	3.00	66.44
10	10.27	89.73	24.23	6.60	1.80	3.03	64.34
20	11.06	88.94	25.20	7.27	2.83	3.11	61.59
30	11.20	88.80	25.25	7.87	3.93	3.25	59.70
Mean	10.75	89.25	24.70	6.81	2.36	3.09	63.01
LSD	0.11	0.09	NS	0.25	0.95	0.45	1.75
SEd.	0.04	0.04	NS	0.10	0.38	0.18	0.70

Table 4. 23. The average cost of production of tofu was calculated as Rs.10/kg whereas the average cost of paneer was Rs.70/kg which was 7 times more than the cost of tofu. At the same time the mean protein content of tofu was higher (54.77 per cent) than the mean protein content of dairy paneer (43.73 per cent). This shows that consumer has to spend about 7 times more on the purchase of unit amount of dairy paneer compared to the unit amount of tofu with a substantially lower protein content. The costs of tofu supplemented *parantha* (Rs.30/kg), *pakora* (Rs.25/kg) and *matar* curry (Rs.15/kg) were also lower than the milk paneer *parantha* (Rs.45/kg), *pakora* (Rs.42/kg) and *matar* curry (Rs.20/kg). The protein contents and tofu products and paneer products were almost the same. This shows that consumer can derive more benefit in terms of protein value of tofu products at a lower cost compared to the cost of dairy paneer products.

Table 4.23 : Comparative cost of preparation and protein content of tofu and milk panner and their products

Product	Cost (Rs/kg)		Mean protein content (%)	
	Tofu products	Paneer products	Tofu products	Paneer products
Tofu/paneer	10.00	70.00	54.77	43.73
Parantha	30.00	45.00	26.77	24.01
Pakora	25.00	42.00	35.70	33.45
Matar curry	15.00	20.00	26.01	20.73

SUMMARY AND CONCLUSIONS

Chapter 5

SUMMARY AND CONCLUSIONS

This study "Studies on preparation and utilization of soypaneer (tofu)" was undertaken to assess the physico-chemical characteristics of soybean varieties Bragg, Shivalik, Lee and PK 416 grown in Himachal Pradesh in relation to their tofu making quality using various household coagulants (citrus juice and curd) and commercial coagulant ($MgSO_4$). The soymilks extracted from whole beans and full fat soyflour of different varieties were coagulated with different types of coagulants. The tofus were recovered by filtration and pressing and evaluated for their physico-chemical and sensory attributes for screening.

The tofu prepared from whole beans of variety Bragg was assessed to be the best and from this tofu supplemented products (*Parantha, Paneer, matar curry*) were prepared and assessed for their organoleptic acceptability and nutrient composition compared to the milk paneer supplemented food products. The products were also assessed for their cost of production compared to cost of production of dairy paneer and paneer supplemented products.

An attempt was made to use soymilk residue obtained from the extraction of soymilk as a supplement in the preparation of nuggets (*bari*) at different levels of supplementation. The supplemented nuggets were also evaluated for organoleptic acceptability and nutrient composition. The results of this study are summarized and concluded as under:

1. The seeds of Bragg were found to be bolder and heavier than those of other varieties as adjudged from 1,000 kernel weight. This variety was also found to contain the lowest hull content (7.95%) and highest cotyledon

content (92.05%) compared to Shivalik, Lee and PK 416 . The hydration characteristic of Bragg was also found to be superior to other varieties.

2. The proximate analysis of different varieties revealed that significant differences existed between varieties in their crude protein, NSI, crude fat, ash, crude fibre and carbohydrate content. Bragg was found to contain highest protein content (41,96%) compared to other three varieties (35.34 to 40.01%). The protein content and NSI are useful parameters to be considered in determining the suitability of a variety for extraction of milk and for the preparation of tofu.

3. The varieties did not differ significantly in their milk yield. However, the method of processing of beans prior to extraction of milk affected milk yield significantly. Whole beans gave higher yield (802.50 to 815.00 ml/100 g of soybean) than the yield given by full fat soyflour (795.50 to 801.05 ml/100 g soybean). Higher contents of milk solids were extracted from whole soybean (64.96 to 72.65 g/100 g soybean) compared to the solids extracted from full fat soyflour (63.73 to 65.47 g/100 g soybean). Highest solids were extracted from Bragg (72.65 g/100 g soybean) with highest content of milk solids (8.99 g/100 ml milk). The amount of soymilk residue obtained from different varieties and bean forms also varied significantly (78.22 to 85.05 g/100 g soybean). However, whole beans gave lower residue and full fat soyflour gave higher residue. From this part of the experiment it was concluded that whole soybeans were more suitable for extraction of milk than full fat soyflour as whole beans gave higher yield and lower residue.

4. Bragg was found to yield highest amount of tofu (181.15 g/100g soybean) with highest content of tofu solids (46.30 g/100 g soybean and 25.38 g/100g tofu) among different varieties irrespective of the bean form and coagulants

used. Whole beans in general gave higher yield of tofu (181.30 g/100 g soybean) with higher content of tofu solids (45.30 g/100 g soybean and 24.70 g/100 g tofu) than the yield given by full fat soyflour irrespective of variety and coagulant used in the preparation of tofu.

5. Among the three coagulants (curd, citrus juice and $MgSO_4$), the citrus juice produced the best coagulation followed by curd and $MgSO_4$. Tofu coagulated with citrus juice contained the highest content of tofu solids among the three coagulants.

6. The overall acceptability of tofus ranged from 5.05 to 8.20 as compared to 8.81 of control. Tofus from whole beans were rated superior to the tofus prepared from full fat soyflour. Tofus coagulated with citrus juice were found to be more acceptable than tofus coagulated with $MgSO_4$ and curd. Although tofus were rated inferior to milk paneer (control), they were found to be highly to reasonably acceptable to judges. Tofus prepared from whole beans of Bragg were found to be most acceptable among all the treatments, excluding control.

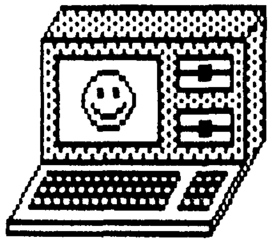
7. Tofus prepared from whole soybean of Bragg were rated superior to other tofus and were analysed for proximate composition and compared with milk paneer (control). Tofus coagulated with different types of coagulants contained significantly higher content of protein (54.17 to 55.29%) compared to milk paneer (43.73%) indicating that tofus are richer in protein compared to milk paneer.

8. Overall acceptability of various tofus supplemented products (*paranthas*, *Pakoda*, and *matar* curry) was found to be lower than control milk paneer but these were found to be acceptable to the judges.

9. *Pakoras* prepared with three types of tofus were found to have similar type of constitution with small differences and the values were not much different from milk paneer supplemented pakoras. Similar observation was made with respect to chemical composition of tofu supplemented *parantha* and *matar* curry.

10. Supplementation of nuggets with soymilk residue from 10 to 30 per cent decreased the overall acceptability of nuggets proportionate to the level of residue in nuggets. However, nuggets upto 20 per cent level of substitution were found to be near to control but nuggets were acceptable to judges.

11. Cost analysis of tofu and tofu products revealed that tofu and tofu supplemented products were much cheaper than milk paneer and milk paneer supplemented products. The cost of tofu was observed to be 7 times lower (Rs.10 /kg) than milk paneer (Rs.70 /kg) with significantly higher protein content (54.77%) than the protein content of milk paneer (43.73%).



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APPENDIX-1

EVALUATION CARD FOR HEDONIC RATING TEST FOR FOOD PRODUCTS

Name____________________ Date____________________

Product__________________

Please evaluate the following food samples and check how much you like or dislike each one. Use the appropriate scale to show your attitude by checking at the point that best describes your feeling about the sample. Please give reasons for this attitude. Remember, you are the only one who can tell what you like. An honest expression of your personal feeling will help us.

Liking	Points
Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like or dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

Sample code, Colour, Taste, Flavour, Texture, Overall acceptability

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Remarks if any, Signature