NUTRITIONAL EVALUATION OF LENTIL *(LENS CULINARIS)* GENOTYPES AND ITS UTILIZATION IN DEVELOPMENT OF VALUE ADDED PRODUCTS

By

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CERTIFICATE – I

This is to certify that this thesis entitled**, "Nutritional evaluation of lentil (*Lens culinaris*) genotypes and its utilization in development of value added products",** submitted for the degree of **Master of Science**, in the subject of **Foods and Nutrition** to the CCS Haryana Agricultural University, is a bonafide research work carried out by **Deepika Ahlawat** under my supervision and that no part of this dissertation has been submitted for any other degree.

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CERTIFICATE – II

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CHAPTER–I

INTRODUCTION

Lentil or *masoor* (*Lens culinaris*) is one of the most important *rabi* crops in the country. It is the oldest food legume that has been known to the mankind. Indian production of this crop hovers around 9-10 lakh meteric tons per year that is cultivated on about 14 lakh hectares of land. In the year 2010, the total production of lentil in India was estimated 14.65 million tones in an area of 23.63 million hectares with average productivity 625 kg/ha. *Masoor* is mainly cultivated in Uttar Pradesh, Madhya Pradesh and Bihar and to a small extent in West Bengal, Rajasthan, Haryana and Punjab (http://www.nationalspotexchange. com, 2010).

On an average, about 70 percent of the world lentil production is consumed in the countries where they are produced. There are mainly three types of lentil grown in the world like red, green and brown lentils. Out of various lentil grown, estimated 70 per cent of world lentil production is the red type, 25 per cent green type and 5 per cent brown and other type. Canada and US are larger producers of the green type whereas rest of the world produces mainly the red type (FAO, 2009).

Lentils contain high levels of proteins, including the essential amino acids like isoleucine and lysine, and are an essential source of inexpensive protein in many parts of the world for those who adhere to a vegetarian diet or cannot afford meat. Lentils are deficient in two essential amino acids, methionine and cystine. However, sprouted lentils contain sufficient levels of all essential amino acids, including methionine and cystine. Apart from a high level of proteins, lentils also contain dietary fiber, folate, vitamin-B and minerals. Lentils are one of the best vegetable sources of iron. This makes them an important part of a vegetarian diet and useful for preventing iron deficiency. Lentils, like other beans are rich in dietary fiber both the soluble and insoluble type. Lentils not only help in lowering the cholesterol but they are of special benefit in managing blood-sugar disorders since their high fiber content prevents blood sugar levels from rising rapidly after a meal (Bejiga, 2006; Raymond, 2006; http://www.agriculture.gov.sk.ca, 2009).

The seeds have a short cooking time (especially for small varieties with the husk removed, such as the common red lentil) and a distinctive earthy flavor. Lentils are used to prepare an inexpensive and nutritious soup all over Europe and North and South America, sometimes combined with some form of chicken or pork. Rice and lentils are also cooked together in *khichadi*, a popular Indian dish. A large percentage of Indians are vegetarian and lentils have long been part of the indigenous diet as a common source of protein. Usually,

lentils are boiled to a stew-like consistency with vegetables and then seasoned with a mixture of spices to make many side dishes such as *sambar, rasam* and *dal*, which are usually served over rice and *roti* (Yadav *et al*., 2007).

Like other legumes, utilization of lentil for human nutrition is constrained by the presence of several inherent antinutritional factors like phytic acid, polyphenols and trypsin inhibitor activity (Gibson *et al.*, 2006; EL-Maki *et al.*, 2007; Kakati *et al.*, 2010). Phytic acid lowers the bioavailability of minerals by forming insoluble complexes with mono, di and trivalent cations (Ali and Harland, 1991) and inhibits the hydrolytic enzymes like proteases and amylase (Deshpande and Cheryan, 1984; Sandberg, 2002). Polyphenols decrease the digestibility of carbohydrates and proteins and the availability of vitamins and minerals (Rao and Deosthale, 1982). Trypsin inhibitor disrupts digestive process and may lead to other undesirable physiological reactions (Doshi and Simlot, 1997).

In India, legume grains are processed and consumed in a variety of forms, depending on cultural and taste preferences. The most common domestic methods for processing the legume seeds include soaking, ordinary cooking, pressure cooking and sprouting which may bring about changes in the levels of antinutrients and influence the digestibility of protein and starch and availability of minerals of the legume grains (Sinha *et al*., 2002; Saharan *et al*., 2002; Grewal and Jood, 2006). Soaking could be one of the processes to remove soluble antinutritional factors, which can be eliminated with the discarded soaking solution. Cooking generally inactivates heat sensitive factors such as trypsin and chymotrypsin inhibitors and volatile compounds. Germination and fermentation has been documented to be effective treatments to remove antinutritional factors like phytic acid, polyphenols, trypsin inhibitors, amylase inhibitors etc. and improve *in vitro* digestibility and availability of nutrients (Huma *et al*., 2008; Wang *et al*., 2008).

To evolve new high yielding varieties is one of the most important objectives of increasing the production of food grains in India. Any alteration in the nutritional quality of these grains, brought introduction of new varieties, would have a significant impact on the nutritional status of the population consuming such diets. The efforts put in by plant breeders in evolving high yielding and nutritionally superior varieties may be of little significance, if it does not fit in the consumer preferences regarding its physical acceptability and cookability. This is therefore desirable to evaluate a newly developed variety for its nutritive value, consumer acceptability and cooking quality. However, the newly released varieties may not only have different grain quality characteristics, but also behave differently from existing cultivars after processing and cooking (Mehla *et al*., 2001).

Various studies have been conducted on different processing and cooking methods and development of value added products but the information is still lacking on effect of processing on nutritional composition, acceptability and shelf life of value added products based on lentil. Keeping in view the importance of lentil in healthy diet, the present investigation was undertaken with the following objectives:

i) To asses the physico-chemical characteristics and nutrient composition of processed and unprocessed lentil genotypes.

ii) To develop value added products from the most acceptable lentil genotype by using various processing techniques and to study their acceptability.

iii) To study the shelf life of selected valued added products.

CHAPTER–II

REVIEW OF LITERATURE

The relevant literature available on physico-chemical and nutritional properties of unprocessed lentil seeds as well as effect of different processing and cooking treatments on nutrient composition of processed lentils and development of value added products has been suitably reviewed under the following heads and sub-heads :

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iii).1 Physico-chemical properties

Physico-chemical properties such as density, hydration capacity, swelling capacity and cooking time etc. of pulses are the important parameters ultimately play an important role in their behaviour for cooking and processing. Williams *et al.* (1982) observed that hydration capacity of chickpea was highly correlated with seed size. Seed volume and swelling capacity per seed were related to cooking time. According to Ahmed and Shehaba (1982), both consumers and processors preferred faba beans that have high hydration and swelling capacities.

Jood *et al.* (1998) observed that Gora Hisari (*Kabuli* type), Haryana *chana* (*desi* type) cultivars of chickpea and among lentil, LH 82-6 cultivar manifested higher values of

seed volume, seed density, hydration capacity, swelling capacity and water absorption capacity which might have contributed less cooking time. Similarly, Saharan *et al.* (2002) reported that hydration index, swelling capacity and swelling index of rice bean were found higher as compared to faba bean which resulted in less cooking time.

Cooking time is defined as the time from commencement of boiling until 90 to 100 per cent seeds were cooked (Jood *et al.,* 1998). Cooking time is an important property as most of the legumes require hours of cooking if not soaked. Williams *et al.* (1982) observed that cooking time was significantly positively correlated with seed weight, seed volume and water absorption was much lower for the cultivar with larger seeds.

Singh (2001) reported that physico-chemical are important parameters for accessing the consumer acceptability and also give information on how a particular ingredient (e.g., protein and carbohydrates) will behave in a food system (Singh, 2001). One of the main drawbacks that limit the utilization of pulses is the long time required for cooking. The adverse effects of hard-to-cook defects are of importance to consumer point of view of convenience and saving of valuable cooking fuel.

Saharan *et al.* (2002) reported that hydration index, swelling capacity and swelling index of rice bean were found greater as compared to faba bean which resulted in less cooking time. Sood *et al.* (2002) reported that 100 seeds weight (g), swelling capacity (ml/seed), hydration capacity (g/seed), hydration index (g/seed) and cooking time (minutes) of chickpea ranged between 11.31 and 22.8, 0.53 and 0.69, 0.43 and 0.48, 1.37 and 1.64 and 46.50 and 62.50, respectively. Agrawal and Singh (2003) reported 100 grains weight 11.4-26.4 g and 100 grains volume 8.5-21.1 ml in eight indigenous chickpea varieties. Agarwal *et al*. (2004) reported the hydration capacity, swelling capacity, seed volume, seed weight and cooking time to be 0.034 g/seed, 0.076 ml/seed, 2.57 ml/100 seeds, 1.73 g/50 seeds and 60 min in mung bean cultivars.

Grewal *et al.* (2006) reported that the seed density, swelling capacity, swelling index, hydration capacity, hydration index and cooking time varied significantly from 1.21 to 1.65g/ml, 0.01 to 0.12ml/seed, 0.99 to 1.15.0.14 to 0.20g/seed, 0.42 to 0.99 and 30 to 38 min, respectively in all the 11 cultivars of green gram. The cultivar MH1K-25 had maximum value of hydration capacity, hydration index, swelling capacity and swelling index, which resulted in less cooking time i.e. 38 min. MHIK-25 cultivar also manifested higher contents of protein and fat, whereas Asha cultivar had maximum sugar contents. Seed weight, seed volume, hydration capacity, swelling capacity and cooking time of *desi* type chickpea varieties, ranged from 0.18 to 0.26 g, 0.15 to 0.20 ml, 0.21 to 0.28 ml, 0.21 to 0.29 ml and 71.7 to 120.7 min, respectively (Bibi *et al.,* 2007).

2.2 Nutritient composition of different unprocessed pulses

Table 2.1: Proximate composition of different pulses

Pluses	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Fibre (%)	References
Fababean	---	---	0.8-4.5	2.5-3.5		Sharma and Sehgal (1991)
Green gram	---	22.42-27.69	1.16-2.16	---		Jood *et al.* (1998)
Chickpea (*Kabuli*)	---	19.94-25.14	6.00-6.33	---		Jood *et al.* (1998)
Chickpea (*Desi*)	---	24.59-27.32	4.16-5.60	---		Jood *et al.* (1998)
Chickpea	---	23.00-31.50	6.10-6.82	3.34-4.44		Sood *et al.* (2002)
Green gram	8.20-8.90	22.10-23.80	2.01-2.40	---		Grewal (2003)
Mungbean	9.75	27.5	1.85	3.76	4.63	Mubarak (2005)
Pigeonpea	---	25.2	---	---	---	Habib *et al.* (2005)
Kidneybean	---	23.0	---	---	---	Habib *et al.* (2005)
Lentil	9.3	26.1	3.2	2.8		Iqbal *et al.* (2006)
Mungbean	9.4	23.7	3.9	6.8	---	Habibullah *et al.* (2007)
Chickpea (*Desi*)	7.07-11.51	16.85-21.13	---	2.61-3.09	---	Bibi *et al.* (2007)
Cowpea	9-12	20-27	0.6-1.0	3-4	---	Henshaw (2008)
Mungbean (cultivated)	7.49-8.45	24.26-28.50	0.57-1.86	3.64-4.24	3.21-4.18	Li *et al.* (2010)
Fieldpea (genotypes)	---	18.20-24.67	1.28-2.17	1.70-2.70	1.23-1.84	Mishra *et al.* (2010)

Table 2.2: Sugar contents of different pulses

Pulses	Total soluble sugars (%)	Reducing Sugars (mg/100g)	Non-reducing sugars (%)	References
Chickpea (*Kabuli*)	8.7-9.3	4.30-5.70	8.1-8.9	Jood *et al.* (1998)
Chickpea (*Desi*)	9.0-9.6	4.30-3.90	8.6-9.2	Jood *et al.* (1998)
Mothbean	6.84-7.70	0.30-0.34	6.53-7.28	Negi *et al.* (2000)
Ricebean	1.24-3.52	---	---	Shrivastav (2001)
Ricebean	5.6	547.3	4.3	Saharan *et al.* (2002)
Fababean	4.9	608.7	4.3	Saharan *et al.* (2002)
Cowpea	8.33-9.46	230-261	8.10-10.48	Sinha *et al.* (2002)
Chickpea	2.26-2.40	0.62-0.72	1.61-1.72	(Agarwal and Singh, 2003)
Mungbean	4.85	---	---	Mubarak (2005)

Table 2.3: *In vitro* digestibility and minerals of different pulses

Pulses	Protein digestibility (%)	Starch digestibility (mg maltose released/g)	Total minerals (mg/100g)				Available minerals (%)			Reference
			Ca	Fe	Zn	Mg	Ca	Fe	Zn	
Green gram	52.5-64.3	17.5-26.3	---	---	---	---	---	---	---	Jood *et al.* (1998)
Green gram	---	---	7.9-13.2	0.11-0.42	0.05-0.28	---	2.9-4.9	2.9-4.6	2.9-5.2	Jood *et al.* (1998)
Chickpea (*Kabuli*)	39-41	52-58	---	---	---	---	---	---	---	Jood *et al.* (1998)
Chickpea (*Desi*)	29-34	49-51	---	---	---	---	---	---	---	Jood *et al.* (1998)
Cowpea	78.30	76.22	---	---	---	---	---	---	---	Komalpreet and Punia (2000)
Fababean	70.8	159	---	---	---	---	---	---	---	Alonso *et al.* (2002)
Cowpea	---	20.03-23.80	---	---	---	---	---	---	---	Sinha *et al.* (2002)
Ricebean	58.4	30.8	---	---	---	---	---	---	---	Saharan *et al.* (2002)
Ricebean	---	---	311	6.6	---	---	59.8	37.9	---	Saharan *et al.* (2002)
Fababean	---	---	201	5.2	---	---	45.1	4.1	---	Saharan *et al.* (2002)
Pigeon pea	---	---	210.06	10.88	---	---	---	---	---	Duhan *et al.* (2002)
Mungbean	80.2	---	203.18-220.59	6.5-8.9	---	---	---	---	---	(Agarwal and Singh, 2003)
Black gram	---	40.4	----	---	---	---	---	---	---	Rehman and Shah (2005)
Lentil	---	---	120	3.1	4.4	4.5	---	---	---	Iqbal *et al.* (2006)
Mung bean	---	---	216	11.34	1.88	4.07	4.51	---	---	Habibullah *et al.* (2007)
Soyabean (9 ciltivars)	---	20.48-25.8	----	---	---	---	---	---	---	Rani and Grewal (2009)

Table 2.4: Antinutrient contents of different pulses

Pulses	Phytic acid (mg/100g)	Polyphenols (mg/100g)	Trypsin inhibitors (TIU/g)	Reference
Green gram	877-1003	365-503	497-869	Jood *et al.* (1998)
Mothbean	818.46-927.85	778.82-809.45	---	Negi *et al.* (1999)
Cowpea	818.4-927.8	778.8-809.4	---	Komalpreet and Punia (2000)
Fababean	21.7	392	---	Alonso *et al.* (2000)
Pigeonpea	886	---	---	Duhan *et al.* (2002)
Fababean	101.2	750	905	Saharan *et al.* (2002)
Ricebean	201.8	169.8	552	Saharan *et al.* (2002)
Red gram	184.15-257.84	---	---	Mulimani *et al.* (2003)
Green gram	610	---	---	Ghavidel and Prakash (2007)
Lentil	190	---	---	Ghavidel and Prakash (2007)
Fieldpea	640-830	---	130-201	Wang *et al.* (2008)
Lentil	---	---	191-277	Wang *et al.* (2008)

2.3 Effect of processing and cooking treatments

2.3.1 Proximate composition

A majority of the Indian population uses legumes as major source of dietary protein not only because of cultural or religious beliefs, but also because of the expensiveness of animal feeds and their unavailability. A wide range of variations were reported for total protein, ether extract, crude fibre, ash and moisture in different pulses and among different varieties of same pulses (Punia and Chauhan, 1998; Jood *et al.,* 1998). Giami (1993) found no effect of cooking on ether extract, total ash and crude fibre but 5 per cent decrease was found in protein content of cooked cowpeas.

Soaking of cowpea varieties for 4 h brought about 5.7 per cent increase in crude protein content while dehulling raised the protein content by 2.7 per cent over the raw values (Akinyele and Akinlosotu, 1991). In different cultivars of chickpea Saxena *et al.* (2003) reported that soaking for 12 h in distilled water decreased the protein content from 22.4 to 20.9 g/100g. Mubarak (2005) reported that ash and fibre was decreased significantly after soaking and dehulling of mung bean. Sinha *et al.* (2007) reported the effect of different processing treatments on proximate composition of cowpea. They reported that soaking of seeds produced a significant decrease in ash content and this loss increased with the increase

in the period of soaking. Wang *et al.* (2008) reported that soaking resulted in 1.0-7.7 per cent reduction of ash content of field pea. Soaking and dehulling resulted in 5.4-10.4 per cent increase in protein.

Rani and Hira (1998) observed that crude protein, crude fibre and total ash content reduced in pressure cooked mash bean. Parihar *et al.* (1999) reported the effect of cooking on the nutritional quality of red gram, bengal gram, lentil and soybean. Losses in carbohydrate, protein and fat contents increased in all the pulses during cooking. Sood *et al.* (2002) also reported that the cooking of chickpea brought about a reducing effect on crude protein, crude fat, crude fibre and total ash contents.

Legume seeds have been reported to undergo pronounced metabolic changes during germination and the structural profile of various components is altered in sprouts. Giami (1993) reported that germination resulted in a decrease in fat (17.65%) and carbohydrate (4.34%) while the crude protein, total ash and crude fibre increased by 3.75, 3.23 and 4.76 per cent, respectively. Germination in pigeonpea and mung beans increased the protein, moisture and crude fibre content while ash, fat and carbohydrate content decreased (Igbedioh *et al*., 1995).

2.3.2 Carbohydrates

Food legumes are good source of dietary carbohydrates. Most legumes contain 50 to 60 per cent carbohydrates.

Kataria *et al*. (1990) reported that soaking of dry seeds of the amphidiploids (green gram x black gram) reduced the level of total soluble sugars, reducing sugars, non-reducing sugars and starch significantly. The extent of reduction increased with increase in period of soaking. Losses of sugars during soaking could be due to simple diffusion of sugar after mobilization. The greater losses of the sugars during the longer periods of soaking may be due to enhanced solubility of sugars (Sinha, 1999; Negi, 2000).

Similarly, Grewal and Jood (2009) reported effect of different treatments on sugar contents of green gram cultivars. Soaking (12h) of seeds significantly reduced the level of total, reducing, and non reducing sugars. Reduction was observed by 18, 21 and 27 per cent, respectively losses of sugars during soaking would be on account of simple diffusion of sugars after being solubilized. When the soaked seeds were cooked the losses in the sugars contents were reversed and consequently there was an increase in these sugars. Pressure cooking had a more prolonged effect than ordinary cooking.

Cooking brought a significant increase in the oligosaccharide contents of all pulses. Jood *et al*. (1986) reported that cooking decreased the concentration of sugars and starch of soaked and cooked seeds of pulses. Contrary to these observation, Kataria *et al*. (1990) and

Youssef and Abdel-Gawad (1992) reported that cooking brought about a significant increase in total soluble sugars, reducing sugars and non-reducing sugars. These differences in the two cases could be explained mainly on the basis of the fact that in later studies, the cooking water was not discarded, whereas in the study of Jood *et al.* (1986), the soaking and cooking water was discarded and seeds alone after drying were analysed for various carbohydrate components. Hydrolysis of starch to oligosaccharides and that of oligosaccharides to monosaccharides during cooking may be responsible for increased concentration of sugars in pulses (Attia *et al.,* 1994; Sood *et al.,* 2002; Sinha *et al.,* 2002).

With the increase in germination period, the total soluble carbohydrates and non-reducing sugars increased in chickpea and green gram (Jaya and Venkataraman, 1980). Germination of amphidiploids (black gram x mung bean) increased the concentration of total soluble sugars, reducing sugars and non-reducing sugars gradually with the increase in germination time (Kataria *et al.,* 1990; Sinha, 1999; Negi, 2000). Germination may be leading to more available non-reducing as well as reducing sugars. Rapid mobilization might yield significant amount of maltose, a reducing sugar. Longer the period of germination, more may be hydrolysis of starch, thereby resulting in more concentration of soluble sugars (Kataria *et al.,* 1990; Murkya *et al.,* 2000).

Saleh *et al.* (2006) reported the effect of microwave cooking on carbohydrate fractions of raw and treated chickpea seeds. Reducing sugars, sucrose, raffinose and stachynose were significantly reduced while verbascose was completely eliminated after cooking treatments. These reduction are presumably due to their diffusion into cooking water.

Kakati *et al.* (2010) reported that the starch, reducing sugars and non-reducing sugar decreased during soaking in black gram. Kaushik *et al.* (2010) reported that total soluble sugars decreased by 17 per cent, reducing sugars by 23 per cent and starch content by 14 per cent in soybean after soaking.

Negi *et al.* (2011) reported that cooking of unsoaked, soaked and soaked-dehulled moth bean cultivars increased the reducing sugars (5 to 32% and 6 to 36%) and non-reducing sugars (4 to 16% and 6 to 18%), while decreasing the starch content (26 to 49%).

2.3.3 Dietry fibre

Lentils are very good source of cholesterol lowering fibre. Not only in lowering cholesterol but also helps in managing blood sugar disorders, since their high fibre content prevents blood sugar levels from rising rapidly after a meal (Raymond, 2006).

Ramulu and Rao (1997) analyzed that dietry fibre contents of cereals and pulses products and found that among the cereals, rice had the lowest TDF (4.1%) and wheat had

the highest (12.5%). TDF content of whole pulses ranged from 15.8 per cent in lentil to 28.3 per cent in chickpea. IDF as per cent of TDF constituted 85 to 89 per cent in whole pulses. Dehusking of pulses into *dal* decreased TDF and IDF contents significantly. Among the *dal*, green gram *dal* had the lowest (8.2%, 6.5%) and chickpea dhal (15.3%, 12.7%) had the highest TDF and IDF contents, respectively. Processing of cereals had no effect on their TDF and IDF contents, with the exception of ragi, where a significant increase in TDF and IDF was observed. Cooking of *dal* brought about a significant increase in their TDF and IDF contents.

Khan *et al.* (2007) reported that soaking (distilled water, 0.1% citric acid (CA) and 0.07 per cent sodium bicarbonate (SB) solutions), and cooking (distilled water) affected dietary fiber components of lentils. A high increase of protopectin, total pectic substances (PS), and dietary fiber (DF) was observed in soaked lentils (dry matter basis). Soaking in CA and in SB solutions led to an appreciable increase of hemicellulose (HMC) and neutral detergent fiber, but not in lentils soaked in water. Cooking the previously soaked lentils, reduced the amount of DF, due to a drastic loss of HMC, although cellulose and lignin increased. PS content of cooked lentils, previously soaked in CA and SB was still higher than in raw lentil.

2.3.4 Minerals

2.3.4.1 Total minerals

Phosphorus, potassium, calcium and magnesium are the major minerals present in common pulses whereas zinc, copper, iron and manganese are the minor ones.

Different processing and cooking methods are known to have a pronounced effect on the mineral content of legumes. Youssef *et al*. (1987) reported that dehulling of faba bean resulted in 68 per cent decrease in calcium, 20.7 per cent in iron and 7.4 per cent increase in zinc content whereas Rani and Hira (1993) observed 11 per cent decrease in calcium, 7.5 per cent in iron and no effect on zinc content of faba bean after dehulling. Calcium, phosphorus and iron content of pigeon pea were reduced significantly upon soaking and dehulling (Duhan *et al.*, 2001).

Similarly, El-Maki *et al.* (2007) reported that iron and calcium content reduced by soaking in white bean. Dave *et al.* (2008) reported that concentration of calcium, magnesium, iron, and zinc increased during soaking in cowpea, horse gram, moth bean and mung bean. Kaushik *et al.* (2010) reported that soaking resulted in a decrease of around 4 per cent in calcium, 5 per cent in magnesium, 7 per cent in phosphorus and 3 per cent in iron in soybean.

Bishnoi and Khetarpaul (1995) reported an enhancement in mineral extractability upon germination of soaked peas. They observed an increase of 82 to 112 per cent in calcium

extractability, 58 to 71 per cent in iron extractability and 102 to 104 per cent in zinc extractability after 48 h of germination.

According to Rani and Hira (1993), pressure cooking and roasting resulted in significant loss of iron and phosphorus contents in faba bean. Reduction in phosphorus content might be due to leaching of minerals in cooking water.

Grewal and Jood (2006) reported that on soaking non-significant reduction was observed in mungbean cultivars. Dehulling of soaked seeds caused significant reduction in total minerals i.e. 10 to 17 per cent in all the cultivars. The loss in minerals on soaking may be attributed to leaching out of total minerals into the soaking water. Minerals present in the hulls might have been lost during dehulling, therefore contributing to the lower minerals contents in soaked and dehulled seeds.

Cooking treatments such as ordinary and pressure cooking caused 6 to 12 per cent reduction in mungbean cultivars (Grewal and Jood, 2006). Similarly, Saleh *et al*. (2006) reported that the minerals leached from the chickpea seeds into water at different rates during cooking treatments. However, microwave cooking resulted in the greatest retention of all minerals, followed by autoclave and boiling. They reported that cooking in boiling water caused great losses of K (24%), Cu (15%) and Fe (8%). Similarly, Wang *et al*. (2008) reported that cooking of lentils in boiling water caused significant reduction in Fe, K, Mg, P and Zn where as significant increase was observed in Ca, Cu and Mn contents of lentil cultivars.

2.3.4.2 Available minerals

The solubility of minerals in foodstuffs subjected to *in vitro* gastric or gastro-intestinal digestion is indication of their bioavailability from these foodstuffs (Rao and Prabhavathi, 1978; Miller *et al*., 1981; Wein and Schwartz, 1985). Prabhavathi *et al.* (1979) studied the effect of simple domestic processing on ionizable iron from cereals and pulses. They reported that soaking in water alone had no influence on available iron in chickpea.

Soaking of rice bean for 12 h caused a significant reduction in extractable calcium content (Kaur, 1986). Bishnoi (1992) reported that extractability of calcium, iron and zinc improved after 12 h soaking by 36 to 56 per cent, 9 per cent and 31 to 44 per cent, respectively. Dehulling of soaked pea seeds further improved the extractability of all the three minerals.

Jood *et al*. (1998) studied the significant increase in *in vitro* availability of calcium, iron and zinc by presoaking (7-20, 7-27 and 5-22%), cooking of unsoaked seeds (46-80, 29-83 and 39-78%) and cooking of presoaked seeds (94-136, 68-172 and 82-167%) among mung bean cultivars. The increase was highest in cooking of presoaked seeds.

An increase in iron availability in legume sprouts has been reported by Giri *et al*. (1981). During germination, translocation of individual mineral elements takes place. The solubilization may influence the bioavilability of minerals.

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

Grewal and Jood (2006) reported that all the treatments including soaking, dehulling, cooking and sprouting enhanced *in vitro* availability of Ca, Fe and Zn of mungbean cultivars. A decrease in the level of phytic acid during soaking and dehulling may partly account for improved availability of these minerals. Both ordinary cooking and pressure coking caused significant improvement in *in vitro* availability of minerals.

Sprouting also improved *in vitro* availability of minerals, which ranged from 21 to 34 per cent, respectively in mungbean cultivars (Grewal and Jood, 2006). Increased minerals availability during germination may be caused by increased phytase activity resulting in decreased phytate content in sprouts (Eskin and Wiebe, 1983). Other antinutrients are also known to hinder the availability of minerals and are catabolized during germination leading to improvement in minerals availability (Grewal and Jood, 2006; Wang *et al*., 2008).

2.3.5 Antinutritional factors

2.3.5.1 Phytic acid

Phytic acid (myo-inositol) 1,2,3,4,5,6-hexakis inositol dihydrogen phosphate) occurs mainly in the seed coat and germ of plant seeds. At acidic pH, phytate forms a binary protein-phytate complex by binding to basic residues of protein. In the presence of cations at alkaline pH, phytic acid forms a tertiary protein-mineral-phytate complex (Cheryan, 1980) which inhibits enzymatic degradation of protein and, therefore, affects the protein digestibility (Serraino, 1985). Phytic acid, a powerful chelating agent for divalent cations interfere with the mineral availability by formation of insoluble phytates (Reddy and Salunkhe, 1981).

The nutritive value of legume seeds could be improved if phytate is reduced or hydrolyzed before consumption. Various domestics processing and cooking methods are known to reduce or eliminate phytic acid content (Yadav, 1992; Bishnoi *et al*., 1994; Rani *et al*., 1996; Sinha, 1999; Negi, 1999; Duhan *et al*., 2002).

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

al., 1998). Soaking of dry beans in water for 12 h at 24°C resulted in slight decrease in phytate (Jood *et al*., 1998b; Sinha, 1999; Negi, 1999; Duhan *et al.*, 2002). Ramkrishna *et al.* (2006) reported that phytic acid content reduced by 18 per cent during soaking for 8 h, however, soaking for 24 h reduced the phytic acid content to 9 per cent in white bean (El-Maki *et al.*, 2007). Similarly (Mubarak, 2005) reported that soaking and dehulling processes decreased phytic acid content by 20.70 and 26.70 per cent in mung bean. Similarly, Tajoddin *et al.* (2001) reported that soaking for 12 h reduced the phytic acid content by 13 to 41 per cent while soaking for 12 h followed by germination for 48 h reduced 60 to 73 per cent of phytic acid in 9 cultivars of mung bean.

Germination caused a significant reduction in phytic acid content of cowpea, mung bean and lima bean (Ologholbo and Fetuga, 1984), chickpea and black gram (Duhan *et al.,* 1989), soybean (Grewal, 1992), moth bean (Negi, 1999) and mungbean (Grewal and Jood, 2006).

Huma *et al*. (2008) reported that soaking and cooking reduced the anti nutrients, phytic acid and tannins significantly. A longer cooking time is required to destroy phytates in dry beans. The ordinary cooking as well as pressure cooking followed by soaking in plain water had a decreasing effect on phytic acid content of mung bean varieties.

2.3.5.2 Polyphenols

Polyphenols, also termed as tannins are mainly present in the seed coat of legumes and interfere with the biological value of grains. Tannin content of dry beans depend upon the bean species and colour of seed coat. Tannins are mainly located in the testa (81-85%) while only 15-18 per cent located in kernel (Barroga *et al*., 1985). Gorski (1985) found that the coloured varieties of faba beans contained more tannins as compared to lighter coloured beans.

The tannin content in different legumes can be reduced by various processing methods e.g. dehulling, soaking, cooking and germination. Rao and Prabhavathi (1982) stated that dehulling was found most practical and efficient way to reduce the total tannin contents as most of the tannins were located in testa. On dehulling, tannin content was reduced by 59 to 68 per cent in peas (Bishnoi *et al*., 1994).

Soaking of beans reduced the polyphenol content. Kaur and Kapoor (1990) reported that the soaking of rice bean, green gram and black gram for 12 h brought about 35.0 to 46 per cent, 23 per cent and 26 per cent decrease in polyphenol content, respectively. The polyphenol content of peas declined by 44 to 53 per cent after 12 h of soaking (Bishnoi *et al*., 1994). Whereas soaking of mung bean varieties for 12 h reduced the tannin content by 5 to 9 per cent, respectively (Jood *et al.*, 1998).

Germination has also been reported to reduce the level of polyphenol in various legumes like chickpea, pigeonpea and green gram (Jood *et al*., 1987; Duhan, 1992; Grewal and Jood, 2006). More than 50 per cent tannins are lost in chickpea, black gram and green gram after overnight soaking in water followed by germination for 40 h (Reddy *et al*., 1985; Jood *et al*., 1987). The loss of polyphenols in legumes during germination may be attributed to the presence of polyphenol oxidase and enzymatic hydrolysis (Rao and Deosthale, 1982; Jood *et al.*, 1987; Saharan *et al*., 2002).

2.3.5.3 Trypsin inhibitor activity

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

Trypsin inhibitor activity in raw and processed seeds of peas, mesh bean, lentils and chickpea was investigated by various workers (Bishnoi, 1991; Rani and Hira, 1993; Jood *et al.,* 1998). Shinde *et al.* (1991) and Saharan (1994) observed a slight increase in the trypsin inhibitor activity after dehulling treatment as trypsin inhibitors were mostly concentrated in the cotyledons of cowpea and faba bean seeds.

Chimmad *et al.* (2005) found 8.46 per cent decrease in trypsin inhibitor activity (TIA) in black bean after soaking. Trypsin inhibitor activity was 7.59 and 15.85 per cent decreased by soaking and dehulling after soaking processes in mung bean (Mubarak 2005). Soaking resulted in an increase in trypsin inhibitor activity from 3.2 to 19.3 per cent and soaking and dehulling resulted in 5.3-13.1 per cent reduction of trypsin inhibitor activity in field pea (Wang *et al.*, 2008). Similarly reduction in trypsin inhibitor activity was found by soaking black gram (Kakati *et al.*, 2010).

Jood *et al*. (1998) reported reduction in trypsin inhibitor activity was 19 to 30 per cent in cooking of unsoaked and 42 to 65 per cent in cooking of soaked seeds of mung bean varieties. Similarly, Grewal and Jood (2006) reported significant reduction in trypsin inhibitors activity of mungbean cultivars on pressure cooking.

2.3.6 *In vitro* digestibility

2.3.6.1 *In vitro* protein digestibility

Although the pulses contain fairly high content of protein, its digestibility is low, the reasons being either resistance of globulins, the major problem in pulse seed to the proteolytic enzyme (Walker and Kochar, 1982) or presence of antinutritional factors such as

protease inhibitors (Liener and Kakade, 1980), phytate (Oberleas, 1983) and polyphenols (Elias *et al.,* 1979).

Kaur and Kapoor (1990) also reported that *in vitro* digestibility improved by 8 to 23 per cent when the rice beans were soaked for 6 to 18 h. Bishnoi and Khetarpaul (1994) observed 6 to 8 per cent increase in protein digestibility in soaked peas. Various processing techniques have been reported to significantly improve the protein digestibility of several legumes including blackgram (Khan and Gafoor, 1978), cowpeas (Chavan *et al.,* 1989), field and vegetables peas (Bishnoi and Khetarpaul, 1994), pigeonpea (Duhan, 1992; Rani *et al*., 1996).

Similarly, Alonso *et al.* (2002) reported that on soaking and dehulling after soaking, the protein digestibility (*in vitro*) of faba bean improved 28.0 and 53.3 per cent, respectively. Mubarak (2005) reported *in vitro* protein digestibility increase significantly after soaking and dehulling in mung bean. Shimelis and Rakshit (2007) reported that the *in vitro* protein digestibility in kidney bean was increased by 5 per cent during soaking. Increased protein digestibility due to soaking is attributed to leaching out of phytates, trypsin inhibitors, polyphenols and other factors affecting the protein content in seed (Reddy *et al*., 1982).

Grewal and Jood (2006) reported that ordinary cooking and pressure cooking of soaked seeds of moong bean cultivars increased their protein digestibility significantly. Pressure cooking had pronounced effect on protein digestibility. The increase was found 30 to 35 per cent, respectively. Heat processing increase the protein digestibility of legume grains most likely by destroying the heat labile proteases inhibitors and also by denaturing globulins, highly resistant proteases in the native state (Walker and Kochhar, 1982).

Saleh *et al*. (2006) also reported that *in vitro* digestibility of chickpea soaked seeds was improved by cooking treatments. The improvement in digestibility may be attributed to denaturation of protein, destruction of trypsin inhibitors or reduction of tannins and phytic acid.

Beneficial effect of germination has been reported to improve *in vitro* protein digestibility of various legumes viz., pea (Bishnoi and Khtarpaul, 1994), cowpea (Sinha, 1999), mothbean (Negi.1999), pigeonpea (Rani *et al*., 1996), chickpea (Garg, 2001). It has reported that seed proteins are mobilized and antinutrients are catabolized during germination (Jood *et al*., 1989; Kataria *et al*., 1989; Saleh *et al.*, 2006) which leads to better protein digestibility of legume sprouts.

2.3.6.2 *In vitro* starch digestibility

Among the legume carbohydrates, starch is the major constituent which possesses low digestibility. The starch digestibility in food legumes is limited by the cell wall

structural features (Tovar *et al.,* 1991) and antinutrients such as phytic acid, polyphenols (Thompson and Yoon, 1984), amylase inhibitors (Singh *et al.,* 1982) and chain length (Srinivasa, 1976).

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

Sharma and Sehgal (1991) reported that soaking improved the starch digestibility in faba bean by 10 to 26 per cent, dehulling of soaked seeds further enhanced digestibility by 21 to 42 per cent. Duhan (1992) and Rani *et al.* (1996) showed that soaking (12 h) improved the starch digestibility from 22.0 to 31.0 per cent in different pigeonpea cultivars.

Soaking resulted in significant increase in *in vitro* starch digestibility by 19.25 per cent in four different varieties of moth bean and soaking and dehulling resulted in significant improvement in starch digestibility by 30-36 per cent (Negi *et al*., 2001). Grewal and Jood (2009) found that soaking improved *in vitro* starch digestibility in mung bean. They also observed that soaking and dehulling further improved starch digestibility.

Kataria *et al.* (1990) reported an increase of 35 to 48 per cent in starch digestibility of amphidiploids (black gram x mung bean) when the seeds were cooked for 18 h. Jood *et al.* (1998) also reported a significant improvement (38 to 48%) in starch digestibility of various cooked mung bean varieties.

Grewal and Jood (2006) reported that pressure cooking caused maximum enhancement in starch digestibility i.e. 44 to 49 per cent, respectively. Enhancement of starch digestibility in cooked legumes may be attributed to swelling and rupturing of starch granules, which facilitates more randomized configuration for α–amylase to affect hydrolysis (Jood *et al*., 1998).

Similarly, Negi *et al*. (2011) also reported that pressure cooking of unsoaked seeds increased starch digestibility by 74 to 78 per cent as compared to unprocessed moth bean seeds. They also reported that starch digestibility increased markedly in all the moth bean cultivars after microwave cooking.

Germination has been reported to increase the digestibility significantly in pea, mung bean, rice bean, faba bean and moth bean (Bishnoi, 1992; Kataria *et al.*, 1992; Saharan, 1994; Negi, 1999; Grewal and Jood, 2009).

Grewal and Jood (2009) reported that there was an 47 to 49 per cent increase in mung bean cultivars after 24 h germination. This may be because of the pre digestion of starch molecules by amylolytic enzymes. Amylase and phosphorylase may become active during germination process. The resulting enhanced concentration of oligosaccharides in the sprouts may contribute to better starch digestibility (Jood *et al*., 1998; Negi *et al*., 2011).

iii).4 Development of value added products and their organoleptic evaluation

Singh (2003) developed products include bread, cake, biscuit, *nankhatai*, *namkeen sev*, *ladoo* mix, *matar* and popped pearl millet *ladoo*. All the developed products were organoleptically acceptable by the judges.

Several *papads* have been prepared using blends of different pulses and it was found that bengal gram *dhal* flour may be incorporated upto 30 per cent level in the black gram *dhal* flour for making acceptable quality *papads* (Saxena *et al.,*1989). Sangwan (2002) prepared composite flour biscuits (wheat-soya-sorghum flour) which were acceptable in terms of colour, texture and taste.

Grewal (2003) used various domestic processing and cooking methods viz., boiling, fermentation, sprouting, frying, baking and roasting for preparation of different types of products from green gram, viz., *dal, khichari, chat, tikki, dhokla, wadi, halwa, bhujia, papad*, cake, biscuit, bread and roasted *dhal* etc. All the products were found to be organoleptically acceptable.

Singh (2003) developed bread, cake, biscuit, *nan khatai, namkeen, sev, ladoo* mix, *matar* and popped pearl millet *laddoo*. Products prepared from 50 per cent processed pearl millet and 50 per cent chickpea / soybean flour were found best on the basis of organoleptic evaluation.

Garg and Dahiya (2003) prepared *papad* of mung flour supplemented with wheat flour, chickpea and pea flour in different proportions (10, 20 and 30%). They also prepared *papads* from black gram incorporating *jowar* millet flour in amount of 5, 10, 15, 20 per cent.

Lentils are used to prepare an inexpensive and nutritious soup all over Europe and North and South America, sometimes combined with some form of chicken or pork. Rice and lentils are also cooked together in *khichadi*, a popular Indian dish. A large percentage of Indians are vegetarian and lentils have long been part of the indigenous diet as a common source of protein. Usually, lentils are boiled to a stew-like consistency with vegetables and then seasoned with a mixture of spices to make many side dishes such as *sambar*, *rasam* and *dal*, which are usually served over rice and *roti* (Yadav *et al*., 2007).

Grewal *et al*. (2007) prepared various products like *chat*, *tikki*, *dhokla*, *papad* and biscuits from MH1K-25 mungbean cultivar using different processing methods. All the products were found organoleptically in terms of colour, appearance, aroma, texture and taste were found in the category of ‘liked very much’ to ‘liked moderately’.

Grewal *et al*., (2007) prepared *wadi* from mungbean and found organoleptically acceptable. Khatoon and Prakash (2006) prepared four types of *dhals* from bengal gram, green gram, lentils and red gram using microwave and pressure cooking were found

organoleptically acceptable. Microwave cooking required more time with a higher water uptake.

Raghuvanshi *et al*. (2011) formulated *mung* bean based products namely, whole fried *namkeen*, dehusked fried *namkeen*, roasted *namkeen* by using three different cultivars of mungbean. All the products were found to be acceptable by the panel, from which the over all acceptability of whole fried *namkeen*, dehusked fried *namkeen*, and roasted *namkeen* were 7.61, 7.80 and 7.02 respectively out of 9.

iii).4.1 Shelf life

2.5.1 Sensory evaluation

Gursu *et al.* (1997) studied the effect of the addition of soy flour on quality and shelf-life of biscuit. Wheat flour samples were fortified with 2, 4, 6 and 10 per cent full fat or defatted soy flour heated at 110^0C for 2 hr., these fortified flour samples were used for manufacture of biscuits. The best quality and shelf-life of the biscuits were achieved with flour containing 2 per cent full fat or 2 or 4 per cent defatted soy flour. Sinha (1999) prepared *ladoo, burfi,* fried *dhal*, roasted *dhal*, *kadhi, chat,* cutlet, cake, biscuit, *pakora, sev, mathi* etc. from unprocessed and processed cowpea and its flour was organoleptically acceptable and comparable to their respective control.

Dhaka (2001) reported overall acceptability scores of *sev* prepared from chickpea flour was in 'liked moderately' category at 30^{th} day of storage. Hooda (2002) concluded that supplemented biscuits and control biscuits could be stored safely in polythene bags without any adverse changes in the organoleptic traits upto 60 days at room temperature.

Hooda and Jood (2005) reported that control and supplemented biscuits can be stored safely in polyethylene bags at room temperature for 30 days without any adverse changes in the organoleptic traits.

2.5.2 Chemical analysis

Increase in fat acidity could be attributed to the hydrolysis of triglycerides resulting in formation of free fatty acids which increase the fat acidity (Kapoor and Kapoor, 1990). Dahiya and Kapoor (1994) studied the storability of roasted and malted supplements for a period of 30 days and reported that malted mixtures had significantly higher levels of moisture, peroxide value, fat acidity and alcoholic acidity than the roasted one. Supraja (2001) reported a significant ($P<0.05$) increase in peroxide value, fat acidity and free fatty acids in nutritious *ladoo* and besan *burfi* on storage for 45 days. Hooda (2002) reported that the peroxide value of whole, supplemented and control biscuits was not detected upto 60 days of storage period at room temperature and these results indicated the effectiveness of baking process in reducing the lipolytic activity in the biscuits.

Kumari (2002) analyzed fat acidity and free fatty acids of three types of instant porridge mixes and the values were 12.60 to 12.83 mg KOH/100g sample and 32.8 to 40 mg/100g fat, respectively on 0 day. All these parameters increased significantly ($P<0.05$) with progression of storage period, increase was 29.8 to 30.7 and 86.5 to 114.3 per cent, respectively for fat acidity and free fatty acid after 60 days.

CHAPTER-III

MATERIAL AND METHODS

The present investigation entitled, "Nutritional evaluation of lentil (*Lens culinaris*) genotypes and its utilization in development of value added products" was carried out in the Department of Foods and Nutrition, College of Home Science, Chaudhary Charan Singh, Haryana Agricultural University, Hisar.

This chapter contains relevant information pertaining to the research designs and methodological steps used for carrying out the present investigation. The research procedures to achieve the foregoing objectives have been distinctly described under the following heads and sub-heads:

3.1 Materials

3.2 Physico-chemical properties of unprocessed lentil genotypes

3.3 Processing of seed samples of lentil genotypes

3.4 Nutritional evaluation of raw and processed seed samples

- 3.4.1 Proximate composition
  - 3.4.1.1 Moisture
  - 3.4.1.2 Crude protein
  - 3.4.1.3 Crude fat
  - 3.4.1.4 Crude fibre
  - 3.4.1.5 Ash
- 3.4.2 Carbohydrates
  - 3.4.2.1 Total soluble sugars
  - 3.4.2.2 Reducing sugars
  - 3.4.2.3 Non-reducing sugars
  - 3.4.2.4 Starch
- 3.4.3 Dietary fibre
  - 3.4.3.1 Total dietary fibre
  - 3.4.3.2 Soluble dietary fibre
  - 3.4.3.3 Insoluble dietary fibre
- 3.4.4 Minerals
  - 3.4.4.1 Total minerals
  - 3.4.4.2 Available minerals
- 3.4.5 *In vitro* digestibility
  - 3.4.5.1 Protein digestibility

3.4.5.2 Starch digestibility

3.4.6 Antinutritional factors

3.4.6.1 Phytic acid

3.4.6.2 Polyphenols

3.4.6.3 Trypsin inhibitors

3.5 Development of value added products

3.5.1 Boiled products: Soup and *dal*

3.5.2 Fermented products: *Dhokla* and *bhalle*

3.5.3 Sprouted products: *Chat* and cutlet

3.5.4 Fried products: *Papad* and *sev*

3.5.5 Baked products: Biscuits and bread

3.5.6 Roasted product: Roasted *dal*

3.6 Organoleptic evaluation of value added products

3.7 Shelf life

3.8 Statistical analysis

3.1 MATERIALS

Six lentil genotypes namely Garima, Sapna, LH7-12, LH-13, LH-26, MH-1 were procured in single lot from the Department of Genetics and Plant Breeding, College of Agriculture, CCS Haryana Agricultural University, Hisar. The seeds were cleaned and made free of dust, dirt and foreign materials prior to nutritional analysis, processing and product development.

3.2 PHYSICO-CHEMICAL PROPERTIES

Raw seeds of lentil genotypes were analyzed for the following physico-chemical properties (Williams *et al*., 1983).

3.2.1 Seed weight

One hundred seeds were counted thrice and weighed in grams for calculating seed weight by using the following formula:

$$\text{Seed weight} = \frac{\text{Weight of 100 seeds (g)}}{\text{No. of seeds}}$$

3.2.2 Seed volume

Seed volume was determined by using the water displacement method. Hundred seeds were immersed in a cylinder containing water and the amount of water displaced was recorded as volume of seeds in ml.

$$\text{Seed volume} = \frac{\text{Volume of 100 seeds (ml)}}{\text{No. of seeds}}$$

3.2.3 Seed density

Seeds (50 g) were weighed accurately and transferred to a measuring cylinder. Then 50 ml distilled water was added to it. Seed volume was recorded by subtracting 50 ml from the total volume (ml). Density was recorded as g/ml.

3.2.4 Swelling capacity

Fifty gram seeds were soaked overnight in a measuring cylinder. The volume of the soaked seeds was noted to calculate swelling capacity per seed. Swelling capacity per seed was determined by using the following formula:

$$\text{Swelling capacity (per seed)} = \frac{\text{Volume after soaking (ml)} - \text{Volume before soaking (ml)}}{\text{No. of seeds}}$$

3.2.5 Swelling index

Swelling index was calculated using the following formula:

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

3.2.6 Hydration capacity

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

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

3.2.7 Hydration index

Hydration index was calculated by using this formula:

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

3.2.8 Cooking time

Seeds weighing 100 g were taken in tall beakers containing distilled water (1:3) and heated at 70°C on heating plates. Beakers were connected with condenser to avoid evaporation of water during boiling. Samples were stirred for every 2 min. After 30 min few seeds were taken out and pressed between fingers to test the degree of cooking. When the seeds were not soft heating was continued for another 10 min or until the seeds were soft and then the cooking time was noted.

3.3 PROCESSING OF SEEDS SAMPLES OF LENTIL GENOTYPES

All the lentil genotypes were subjected to various processing methods including soaking, dehulling, roasting, germination, pressure cooking and microwave cooking as per method given below:

3.3.1 Soaking

The seeds were soaked in distilled water (1:4 w/v) for 12 h at room temperature. The unimbibed water was discarded. The soaked seeds were rinsed in distilled water and then dried in hot air oven maintained at 55°C (except those used for further treatments).

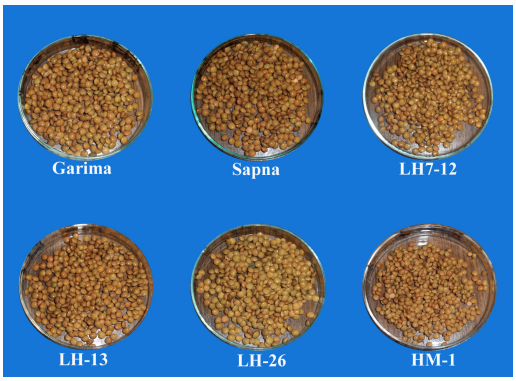

Plate 1 : Soaked lentil genotypes

3.3.2 Germination

To obtain the sprouts, the soaked seeds were kept in petri dishes lined with wet filter paper for 24 h germination in an incubator at 30°C. The sprouts measured 1.5-2.00 cm. The sprouts were rinsed in distilled water and dried at 55°C.

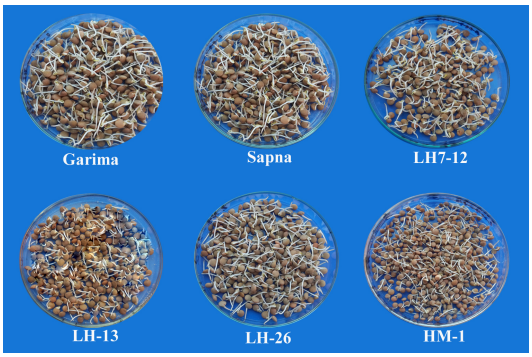

Plate 2 : Germinated lentil genotypes

3.3.3 Dehulling

The soaked seeds (12 h) were dehulled manually. The dehulled seeds were dried at 55°C in hot air oven.

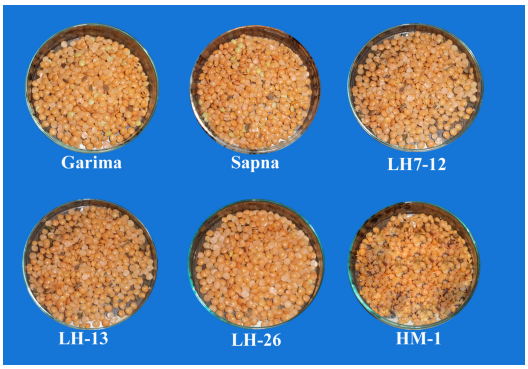

Plate 3 : Dehulled lentil genotypes

3.3.4 Pressure cooking

The presoaked seeds were cooked (seed to water ratio 1:2 w/v) in pressure cooker for 15 min. The pressure cooked seeds were mashed and dried at 55°C.

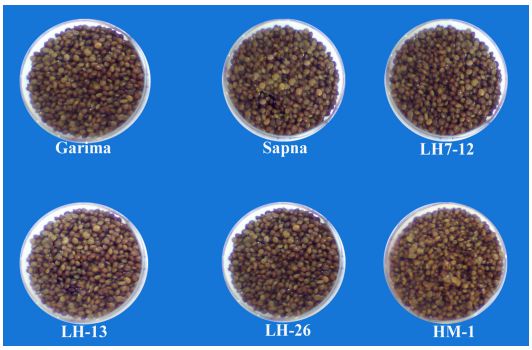

Plate 4 : Pressure cooked lentil genotypes

3.3.5 Microwave cooking

The soaked seeds were placed in a microwave glass container (seed to water ratio 1:5 w/v), then cooked in microwave oven till the seeds were soft when felt between the fingers .The cooked seeds were mashed and dried at 55°C.

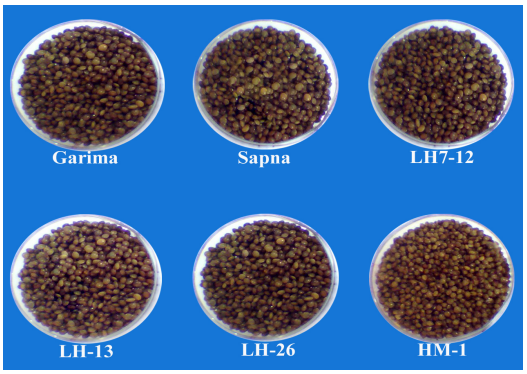

Plate 5 : Microwave cooked lentil genotypes

3.3.6 Roasting

Seeds soaked for 4 h, sun dried and then roasted in an open pan at 120°C.

All the treatments were carried out in duplicate. Raw and processed samples (one portion of the processed samples used for product development) were ground in an electric mill and stored in plastic container for further analysis.

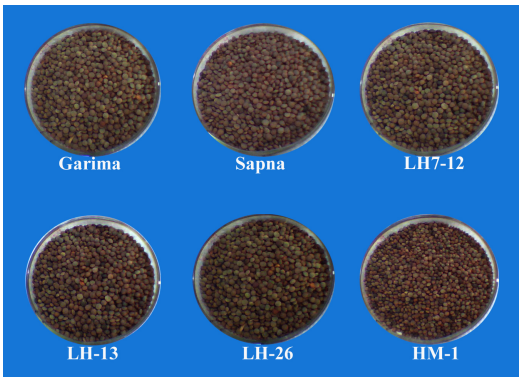

Plate 6 : Roasted lentil genotypes

3.4 NUTRITIONAL EVALUATION OF RAW AND PROCESSED SEEDS

3.4.1 Proximate analysis

3.4.1.1 Moisture

Moisture in the samples was calculated by employing the standard methods of analysis (AOAC, 2000).

Procedure

Five gram sample was weighed in a petri dish and dried in an oven at 60°C temperature for 6 h or till a constant weight was obtained. The sample was weighed after cooling it in a desiccator.

$$\text{Moisture (\%)} = \frac{\text{Loss in weight}}{\text{Weight (g) of sample}} \times 100$$

3.4.1.2 Crude protein

Crude protein in the samples was estimated employing the standard methods of analysis (AOAC, 2000).

Reagents

i) **N/100 HCl**

ii) **Boric acid (4%)**

iii) **Mixed indicator solution**: Bromocresol green 0.5 g and 0.1 g methyl red was taken and dissolved in 100 ml 95% ethanol.

iv) **NaOH (40%)**

v) **Digestion mixture**: Ten g potassium sulphate (K2SO4), 0.5 g copper sulphate (CuSO4.5H2O) and 2 g ferrous sulphate (FeSO4) were mixed together.

Procedure

One g sample was taken and digested with 25 ml concentrated sulfuric acid and a pinch of digestion mixture. The nitrogen, as ammonical salt, was distilled with 40 per cent NaOH in a Microkjeldahl apparatus. The ammonia thus liberated was absorbed in 10 ml of boric acid solution containing a few drops of mixed indicator and titrated against standard N/100 HCl. The end point was indicated by change of colour. A factor of 6.25 was applied to convert the amount of nitrogen to crude protein. The crude protein was calculated by using the following formula:

$$\text{Crude protein (\%)} = \frac{0.00014 \times V \times (S-B) \times 100}{V1 \times W} \times F$$

Where,

W = Weight (g) of sample taken

V = Volume (ml) made

V1 = Volume (ml) of aliquot taken for distillation

S = Volume (ml) of HCl (N/100) used in titration for blank

B = Volume (ml) of HCl (N/100) used in titration for blank

F = Factor for converting N to protein

0.00014 = 10 ml of 0.1 N HCl neutralize 0.00014 g of nitrogen

3.4.1.3 Crude fat

Crude fat was estimated by standard method of analysis (AOAC, 2000) using Automatic Socs Plus apparatus.

Procedure

A weighed amount (2 g) of dry sample was transferred to an ready made extraction thimble dried overnight at 60°C temperature. The thimble was placed in a Socs beaker fitted with a condensor containing sufficient petroleum ether (BP 60-80°C). After 2 h extraction, thimble was removed from the extraction apparatus (Automatic Socs Plus) and dried in the hot air oven to a constant weight, cooled in a desicator to room temperature and weighed. Loss of weight of thimble indicated the amount of fat in the sample

$$\text{Fat (\%)} = \frac{\text{Loss of weight (g)}}{\text{Sample weight (g)}} \times 100$$

3.4.14 Crude fibre

Crude fibre was estimated by the standard method of analysis (AOAC, 2000).

Reagents

i) **Hydrochloric acid (%) v/v**.

ii) **Sulphuric acid stock solution (10%, w/v):** Fifty five ml concentrated sulphuric acid was diluted and made to one litre.

iii) **Sulphuric acid working solution (1.25%):** One twenty five ml of sulphuric acid stock solution was diluted and made to one litre.

iv) **Sodium hydroxide stock solution (10%, w/v):** One hundred gram sodium hydroxide was dissolved in water and diluted to one litre.

v) **Sodium hydroxide working solution (1.25%):** One twenty five ml of sodium hydroxide stock solution was diluted and made to one litre.

vi) **Alcohol**

vii) **Acetone**

viii) **Antifoam**: 2% silicon antifoam in CCl4

Procedure

After weighing one g of fat free dried sample in one litre tall beaker, 200 ml of 1.25% H_2SO_4 was added. The solution was kept boiling for 30 min. under bulb condensors. Beaker was rotated occasionally to mix the content and removed the particles from the sides. The content of the beaker was filtered through funnel. The sample was washed back into the tall beaker with 200 ml 1.25 per cent sodium hydroxide, brought to boiling point and boiled exactly for 30 min. All insoluble matter was transferred to the sintered crucible by means of boiling water until it became acid free, washed twice with alcohol, three times with acetone, dried at 100°C to constant weight, reweighed and ashed in a muffle furnace at 550°C for 1 h.

The crucible was cooled in a desiccator, reweighed and the percentage of crude fibre in the samples was calculated by using the formula:

$$\text{Crude fibre (\%)} = \frac{W2 - W3}{W1} \times 100$$

Where,

W1 = Weight (g) of sample

W2 = Weight (g) of insoluble matter (weight of crucible + insoluble matter – weight of crucible)

W3 = Weight (g) of ash (crucible + ash – wt. of crucible)

3.4.1.5 Ash

Ash in the sample was estimated by employing the standard method of analysis (AOAC, 2000).

Procedure

Five gram of dried sample was taken in a weighed crucible and ignited until no charred particles remained in the crucible and then the crucible was put in muffle furnace (550°C) for 6 h or until a white ash was obtained. Thereafter, the crucible was cooled in a desiccator and reweighed.

$$\text{Ash (\%)} = \frac{\text{Weight (g) of ash}}{\text{Weight (g) of sample}} \times 100$$

3.4.2 Carbohydrates

3.4.2.1 Total soluble sugars

Extraction

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

Twenty five ml ethanol (80%) was added to 0.5 g sample in a round bottom flask connected to a condensor and kept on a heating mantle for 30 min. with occasional stirring. The extract was cooled, centrifuged at 8000 rpm for 15 min. and supernatant was collected. The above procedure was repeated thrice, each time extracting the residue in 25 ml of 80 percent ethanol. The extract in beaker was evaporated to dryness on a boiling water bath. The residue was dissolved in distilled water and volume was made to 50 ml.

Estimation

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

Reagents

i) **Standard sugar solution**: Twenty five mg glucose was dissolved in water and volume was made to 100 ml. This solution contained 250 µg glucose per ml. For obtaining a standard curve, different concentrations of this solution were used.

ii) **Anthrone reagent (0.2% anthrone in 70% H_2SO_4)**: The reagent was allowed to stand for 30-40 min. with occasional shaking until it was perfectly clear. The reagent was freshly prepared each day and used within 12 h.

iii) Ten ml freshly prepared anthrone reagent was pipetted in test tube (150x25 mm) and chilled in ice cold water. One ml sugar extract was taken and layered on the acidic anthrone reagent. After cooling for further five min., the contents were thoroughly mixed while still immersed in ice cold water. The contents in the tube were heated vigorously in a boiling water bath for 10 min. and then, immediately cooled in cold water. The absorbance was then read at 625 nm in UV-VIS spectrophotometer against a suitable blank.

The amount of sugars was then determined by referring to a standard curve previously prepared with glucose.

3.4.2.2 Reducing sugars

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

Reagents

i) **Copper reagent A:** Twenty five gram anhydrous sodium carbonate, 25 g potassium sodium tartarate, 20 g sodium bicarbonate and 200 g anhydrous sodium sulphate was dissolved in about 800 ml distilled water and diluted to one litre.

ii) **Copper regent B:** Fifteen gram copper sulphate was dissolved in 100 ml distilled water containing two drops of HCl.

iii) **Arsenomolybdate reagent (Nelson's reagent):** Twenty five gram ammonium molybdate was dissolved in 450 ml distilled water by warming and 21 ml concentrated sulphuric acid. Three g sodium hydrogen arsenate was dissolved in 25 ml distilled water with stirring and added to the above solution. The reagent was stored in a glass stoppered brown bottle and kept in an incubator at 37°C for 24 h before use.

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

v) **Standard sugar solution:** Twenty five mg glucose was dissolved and made to 100 ml with water. This contained 250 µg glucose per ml.

Procedure

One ml test extract was taken in blood sugar tube graduated at 25 ml. One ml mixed copper reagent (iv) was added, and then, heated for 20 min. in a boiling water bath. To this, one ml of arseno-molybdate reagent was added, mixed thoroughly, and the contents were diluted to 25 ml. A stable blue colour appeared quickly, which was read at 520 nm against

suitable blank. The amount of reducing sugars was then determined by referring to the glucose standard curve.

3.4.2.3 Non-reducing sugars

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

3.4.2.4 Starch

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

Procedure

Five ml water was added to aforesaid residue of test material, and while stirring, 6.5 ml of 52 percent perchloric acid was added. The contents were stirred with a glass rod continuously for five min., and then, occasionally for the next 15 min. To this, 20 ml of water was added and centrifuged at 8000 rpm for 15 min. The supernatant was settled in a 100 ml volumetric flask. Five ml of distilled water was added to the residue and extraction was repeated with 52 percent perchloric acid, stirring occasionally for the next 30 min. The contents of the tube were washed into the flask containing first extract. The combined extracts were diluted to 100 ml with distilled water and filtered, discarding the first five ml of the filtrate. 0.1 ml extract was used for glucose estimation, using anthrone reagent by the method of Yemm and Willis (1954). Starch was calculated by using the following formula:

Starch = Glucose × 0.9

3.4.3.1 Dietry fiber

Total, soluble and insoluble dietry fiber constituent were determined by enzymatic method given by Furda (1981)

Reagents

i) **0.005 NHCl**

ii) **Phosphate buffer (pH 10)**

iii) **EDTA**

iv) **Enzyme-** Alpha amylase and protease enzyme were obtained from Sigma chemical company, USA.

v) **Ethnaol** (75% and absolute)

vi) **Acetone**

Procedure

i) **Sample preparation**: 5g or less than 1mm particle size food material was defined on a Soxhlet or Goldfish apparatus.

ii) **Extraction of water soluble material**: The prepared sample weighing about 2.0 g was dispersed in 200 ml of 0.005N HCL and boiled for 20 min. EDTA was added

and then adjusted to pH 5.0-6.5 with 12 ml of phosphate buffer pH 10. The extraction was continued for an additional 40 min at 60°C to ensure the extraction of pectins with minimal degradation.

iii) **Starch and protein hydrolysis:** Adjust the pH 6.0-6.5 to bring the solution closer to pH optimum amylase and proteases. Cooled the suspension to 20-30°C before incubation overnight with 10 mg of bacterial alpha-amylase and 10 mg of bacterial protease. The incubation was accompanied by slow stirring with a magnetic bar.

iv) **Isolation of insoluble dietery fibre (IDF):** The suspension was filtered through a coarse –tared Gooch filtering crucible containing glass wool and the insoluble residue was washed with a small amount of water. The filtrate was saved for the next step. The insoluble residue was then washed with water, alcohol and acetone before being dried at 70°C in a vacuum oven overnight. The residue was weighed in the crucible to give the soluble dietry fibre (SDF) content of the original material. The SDF fraction was corrected for ash and for co- precipitated protein.

vi) **Total dietry fibre (TDF):** The sum of insoluble dietry fibre and soluble fibre content were calculated.

(TDF = IDF + SDF)

3.4.4 Minerals

3.4.4.1 Total minerals

Acid digestion

To one gram ground sample in a 150 ml conical flask, 25-30 ml of diacid mixture (HNO3 : HClO4 :: 5:1, v/v) was added and kept overnight. The contents were digested by heating until clear white precipitates settled down at the bottom. The volume is made to 50 ml with double distilled water. The crystals were filtered through Whatman No. 42 filter paper and used for the determination of total iron, zinc, calcium and magnesium.

Estimation of calcium, iron, magnesium and zinc

Calcium, iron, magnesium and zinc in acid digested samples were determined by Atomic Absorption Spectrophotometer according to the method of Lindsey and Norwell (1969).

$$\text{Minerals (mg/100g)} = \frac{\text{Reading (conc. µg/ml)} \times \text{volume made}}{\text{Weight of sample (g)} \times 1000} \times 100$$

3.4.4.2 Available minerals

3.4.4.2.1 Calcium and Zinc availability (*in vitro*)

Available calcium and zinc were extracted by method of Kim and Zemel (1986)

Reagents

i) 0.1% pepsin in 0.1 N HCl.

ii) HCl

i) $NaHCO_3$

ii) 0.5% pancreatin in 5% bile

Procedure

Two g finely ground sample was taken in a conical flask and 3 ml distilled water was added to rehydrate it. To this, 20 ml of pepsin solution (0.1% pepsin in 0.1 N HCl) was added. The pH was adjusted to 1.5 with dilute HCl. The contents were incubated at 37°C in a shaker cum water bath for an h. Therefore, the pH of the contents was raised to 6.8 with sodium bicarbonate solution. Then 2.5 ml of suspension containing 0.5% pancreatin in 5% bile were added and the contents were incubated at 37°C for an hour. Then the content were taken out and total volume was made to 50 ml with distilled water. Contents were then immediately centrifuged at 50,000 rpm for 45 min at 5°C. Supernatant were collected and recentrifuged at 25,000 rpm for 45 min at 5°C. The supernatant was collected, oven dried, digested in the diacid mixture and proceeded for the estimation of calcium and zinc by atomic absorption spectrophotometer method.

3.4.4.2.2 Iron availability (*in vitro*)

Extraction

Ionizable iron in the samples was extracted according to the procedure of Rao and Prabhavati (1978). Two g sample was mixed with 25 ml pepsin HCl (0.5% pepsin in 0.1 N HCl) in a conical flask. The pH of the mixture was adjusted to 1.35 with HCl and incubated at 37°C for 90 min in an environmental shaker. After incubation, pH was adjusted to 7.5 with NaOH and again incubated at 37°C in an environmental shaker for 90 min. Contents of the flask were centrifuged at 900 rpm for 30 min and the supernatant was filtered through Whatman No. 42 filter paper. The filtrate was used for determination of ionizable iron.

Ionizable iron

Free form of iron in the filtrate reacts with α', α'-dipyridyl was determined as described by AOAC (2000).

Reagents

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

ii) **Hydroxylamine hydrochloric acid (10%)**

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

iv) **HCl**

v) **Iron standard solution (0.01 mg irom/ml):** Dissolved 3.512 g Fe (NH4) $2H_2SO_4$, $6H_2O$ in water, added two drops of HCl and made to 500 ml with water. Ten ml of the

solution was further diluted with water and made to 500 ml. This solution contained 0.01 mg iron per ml.

Procedure

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

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

3.4.5 *In vitro* digestibility

3.4.5.1 *In vitro* protein digestibility

In vitro protein digestibility was carried out by using the modified method of Mertz *et al.* (1983).

Reagents

i) **Pepsin reagen**t: [0.1 M potassium phosphate (pH 2.0) containing 0.2 per cent pepsin]: 13.6 g potassium phosphate (KH_2PO_4) was dissolved in 1 litre of water, and pH of the solution was adjusted to 2.0, and then, 2 g pepsin was dissolved (Sigma) in the buffer.

ii) **TCA (50%):** Fifty gram trichloroacetic acid was dissolved in water and made up volume to 100 ml.

Procedure

Two hundred and fifty mg of sample was weighed and transferred to a centrifuge tube. To it, 20 ml of pepsin reagent was added. The tube was stoppered and arranged in a shaker-incubator maintaining the temperature at 37°C for 3 h. Then, the centrifuge tube was removed and cooled. Five ml of 50 per cent TCA was added and centrifuged the contents at 10,000 rpm for 10 min. at room temperature and filtered. Ten ml of aliquot was taken and dried in hot air oven. Dried aliquot was digested for nitrogen determination by using Microkjeldahl method (AOAC, 2000). Digested protein of sample was determined. Protein digestibility was calculated by following formula given as under:

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

3.4.5.2 *In vitro* starch digestibility

In vitro starch digestibility was assessed by following the method of Singh *et al.* (1982).

Reagents

i) **0.2 M Phosphate buffer (pH 6.9) :** Fifty ml of 0.2 M (27.28 g/litre) potassium dihydrogen phosphate was added to 46.8 ml of 0.2 M (35.59 g/litre) disodium hydrogen phosphate and made to 200 ml with water.

ii) **Pancreatic amylase**: Twenty mg pancreatic amylase was dissolved in 50 ml of 0.2 M phosphate buffer (pH 6.9).

iii) **Dinitrosalicylic reagent**: Ten gram of 3,5 dinitrosalicylic acid, 300 g sodium-potassium tartarate and 16 g NaOH was dissolved in carbon dioxide free water and made to 1000 ml. The reagent was stored in brown bottle and protected from carbon dioxide.

iv) **Standard maltose solution**: Hundred mg maltose monohydrate was dissolved in water and made to 100 ml.

Procedure

Fifty mg of defatted sample was dispersed in one ml of 0.2 M phosphate buffer (pH 6.9). 0.5 ml of pancreatic amylase was added to sample suspension and incubated in water bath at 37°C temperature for 2 h. After the incubation period, 2 ml of dinitrosalicylic acid reagent was quickly added, and the mixture was heated in a boiling water bath for 5 min. After cooling, the solution was made to 25 ml with distilled water and filtered prior to measurement of absorbance at 550 nm.

A blank was run simultaneously while incubating the sample. In blank, the dinitrosalicylic acid reagent was added before addition of enzyme solution. Maltose was used as standard and the values were expressed as mg maltose released per gram defatted sample. Standard curve was prepared by taking 0.8 to 8 mg maltose from a standard maltose solution.

3.4.6 Antinutrients

3.4.6.1 Phytic acid

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

Reagents

i) **0.5 M HNO_3**: 15.96 ml of 69.5% HNO_3 was diluted to 500 ml with water.

ii) **Ferric ammonium sulphate**: 2.5 mg ferric ammonium sulphate was dissolved in water, added a few drops of HCl and made volume to 500 ml with water.

iii) **Ammonium thiocyanate**: Ten gram of ammonium thiocyanate was dissolved in water and made to 100 ml.

iv) **Iso-amyl alcohol**

v) **Sodium phytate**: 30.54 mg sodium phytate was dissolved (5.5% H2O, 97% purity and containing 12 Na/mole) in 100 ml 0.5 M HNO_3 which gave a solution containing 20 mg phytic acid in 100 ml or 200 mg phytic acid/ml.

Extraction

Five hundred mg sample was extracted with 20 ml 0.5M HNO_3 for 3 h and continuous shaking on a shaker at room temperature. After proper shaking, it was filtered through Whatman filter paper No. 1. Filtrate was used for the estimation of phytic acid.

Procedure

One ml HNO_3 extract was taken in a stoppered test tube and made a final volume of 1.4 ml with water. One ml ferric ammonium sulphate solution was added. The content was mixed in the tubes thoroughly and placed in a boiling water bath for 20 min. Tubes were cooled down to room temperature under running tap water. Five ml iso-amyle alcohol was added, mixed the contents vigorously and added 0.1 ml ammonium thiocyanate solution. The tubes were shaken well and centrifuged at 3000 rpm for 10 min. Colour intensity in the alcohol was read at 465 nm against iso-amyl alcohol blank exactly after 15 min. of addition of ammonium thiocyanate.

For plotting standard curve, 0.4-1.0 ml standard phytate solution containing 80-200 mg phytic acid was taken and made to 1.4 ml with water.

3.4.6.2 Polyphenols

Total polyphenols were extracted by the method of Singh and Jambunathan (1981).

Extraction

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

Reagents

i) **Folin-Denis reagent:** Added 100 g sodium tungstate, 20 g phosphomolybdic acid, 50 ml phosphoric acid to 750 ml distilled water and refluxed for 2 h, cooled and diluted it to one litre.

ii) **Tannic acid solution:** Dissolved 100 mg tannic acid in distilled water and made upto one litre. Twenty ml of this stock solution was further diluted to 25 ml with water to give working standard solution containing 20 mg tannic acid per ml.

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

Procedure

The extract, 1.5 ml was diluted with water to 8.5 ml in a graduated test tube. After thorough mixing, added 0.5 ml Folin-Denis reagent and the tubes were well shaken. Exactly after 3 min., one ml of saturated sodium carbonate solution was added and the tubes were thoroughly shaken again. After an hour, the absorbance was read at 725 nm using a suitable blank. If the solution was cloudy or precipitates appeared, it was centrifuged before readings were taken.

A standard curve was plotted by taking 0.5 ml to 4.0 ml working tannic acid standard solution containing 10 mg to 80 mg tannic acid. 0.200 O.D. corresponded to 35 mg tannic acid.

3.4.6.3 Trypsin inhibitor activity

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

Reagents

i) **0.1M phosphate buffer (pH 7.6):** Sixteen ml NaH2PO4 (0.2M) and 84 ml Na2HPO4 (0.2M) were diluted to 200 ml with distilled water and the pH was adjusted to 7.6

ii) **0.05M phosphate buffer (pH 7.0):** 50 ml 0.1M phosphate buffer was diluted to 100 ml with water, and the pH was adjusted to 7.0.

iii) **Casein solution (2%):** A suspension of 2 g casein was prepared with phosphate buffer (0.1M, pH 7.6) and dissolved by warming and shaking in a steam water bath for about 10 min. The solution was cooled and made to 100 ml with phosphate buffer and stored in the refrigerator.

iv) **Trypsin solution (5 mg/ml)**: Trypsin (125 mg, 20000units/g) was dissolved in 25 ml phosphate buffer (0.1M, pH 7.6).

v) **0.001N HCl:** 8.88 ml concentrated was added HCl to distilled water and made the volume to one litre with distilled water. Ten ml of this 0.1N HCl was pipetted and it was made to one litre with water to give 0.001N HCl.

vi) **Trichloroacetic acid (5%):** Trichloroacetic acid (5 g) was dissolved in distilled water, and the volume was made to 100 ml.

Procedure

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

	Test	**Control**	**Blank**
Phosphate buffer (0.1M, pH 7.6)	1.0 ml	1.1 ml	1.0 ml
Trypsin solution (5 mg/ml)	0.5 ml	0.5 ml	0.5 ml
HCl (0.001 N)	0.4 ml	0.4 ml	0.4 ml
TCA (5%)	-	-	6.0 ml
Casein (2%)	2.0 ml	2.0 ml	2.0 ml
Extract	0.1 ml	-	0.1 ml
	Incubated at 37°C for 20 min.		
TCA (5%)	6.0 ml	6.0 ml	-

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

Reagents

i) **2% Na_2CO_3 in 0.1N NaOH**

ii) **0.5% $CuSO_4.5H_2O$ in 1% sodium citrate**

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

iv) **1N Folin:** Ciocalteau phenol reagent

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

Estimation

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

For preparing standard curve, 0.1 ml to 0.5 ml of the working standard casein solution was taken.

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

3.5 DEVELOPMENT OF VALUE ADDED PRODUCTS

On the basis of physico-chemical characteristics and nutritional parameters of all the six lentil genotypes, Garima genotypes was found superior. Hence, Garima was selected for the development of products by using various domestic processing and cooking methods viz., soaking, cooking, dehulling, sprouting, fermentation, frying, baking, roasting etc.

3.5.1 Boiled products

3.5.1.1 Lentil soup

Ingredients

Soaked lentil seeds	:	100 g
French beans	:	15 g
Carrot	:	15 g
Butter	:	½ tsp
Corn flour	:	1 tsp
Salt and black pepper	:	to taste
Spring onion	:	to garnish

Method:

- Boiled soaked lentil seeds and ground to a fine paste.

- Boiled half of total vegetables and strained to get stock.
- Added lentil paste to the vegetable stock and boiled for 5 min.
- Blanched the chopped french beans, carrot and rest kept aside.
- Made a paste of corn flour with water, added to the soup and boiled for 5 min.
- Added salt and pepper in the soup and boiled on slow flame for 2 min.
- While serving, added butter and finely cut and blanched French beans and carrot.

Plate 7

3.5.1.2 *Dal*

Ingredients

Whole lentil	:	100 g
Water	:	350 ml
Onions	:	20 g
Tomato	:	20 g
Hydrogenated oil	:	5 ml
Salt	:	3 g
Red chilli powder	:	1 g
Turmeric powder	:	2 g

Method

- Added soaked *dal,* salt, turmeric powder and water in a pressure cooker.
- Pressure cooked the *dal* for 25 min.
- Chopped the onions, tomatoes and fried them till light brown.
- Added spices to it.
- Added boiled *dal* to the above mixture and cooked for another 3 min.

3.5.2 Fermented products

Two types of products viz., *dhokla* and *bhalle* were prepared. *Dhokla* (control) prepared from dehulled bengal gram flour where as *bhalle* (control) were prepared from dehulled black gram flour.

3.5.2.1 *Dhokla*

Ingredients	**Control**	**Type-I**	**Type-II**	**Type-III**
Dehulled bengal gram (*besan)*	100 g	60 g	50 g	40 g
Dehulled lentil flour	--	40 g	50 g	60 g
Salt	1 g	1 g	1 g	1 g
Fine ginger and chilly paste	2 g	2 g	2 g	2 g
Turmeric powder	1 g	1 g	1 g	1 g
Lemon juice	5 ml	5 ml	5 ml	5 ml
Mustard seeds	5 g	5 g	5 g	5 g
Green chilies	4 No.	4 No.	4 No.	4 No.
Eno	5 g	5 g	5 g	5 g
Water	200 ml	200 ml	200 ml	200 ml
Vegetable oil	5 ml	5 ml	5 ml	5 ml
Curry leaves	6-7 leaves	6-7 leaves	6-7 leaves	6-7 leaves

Method

- Sieved the flour and added salt and turmeric in it.
- Put the sieved flour in empty bowl and added ginger and chilly paste, two cups of water and one tea spoon of oil in it.
- Added one teaspoon of lemon juice and stirred the whole batter.
- Greased microwave bowl, poured whole batter in it and then added one whole teaspoon of eno in it and immediately kept that bowl in microwave at micro mode for 8 min.

***Dhokla* seasoning**

- Took oil in frying pan. Added mustard seeds to it and allowed to crackle.
- Then added green chilies and curry leaves.
- Added water and lemon juice to it.
- Cooked on slow flame, till the *dhokla* was ready.
- Transferred *dhokla* from microwave to a plate and sprinkled *dhokla* seasoning over it into pieces and served.

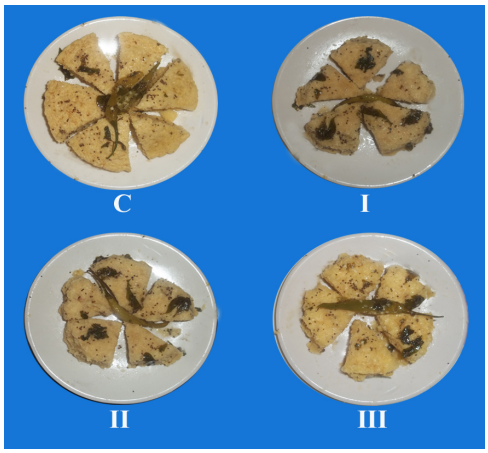

Plate 8 : *Dhokla*

C = Control (Dehulled bengal flour 100%)
Type-I = Dehulled bengal flour + Dehulled lentil flour (60:40)
Type-II = Dehulled bengal flour + Dehulled lentil flour (50:50)
Type-III = Dehulled bengal flour + Dehulled lentil flour (40:60)

3.5.2.2 *Bhalle*

Ingredients	Control	Type-I	Type-II	Type-III
Dehulled black gram flour	100 g	60 g	50 g	40 g
Dehulled lentil flour	--	40 g	50 g	60 g
Baking soda	2 g	2 g	2 g	2 g
Oil for frying	250 ml	250 ml	250 ml	250 ml
Salt	5 g	5 g	5 g	5 g
Curd	300 g	300 g	300 g	300 g
Roasted cumin seed powder	5 g	5 g	5 g	5 g
Red chilli powder	2.5 g	2.5 g	2.5 g	2.5 g
Tamarind chutney	50 ml	50 ml	50 ml	50 ml

Method

- *Dal* was soaked in 300 ml of water at room temperature overnight.
- Soaked water was discarded, hulls were removed manually, and dehulled *dal* was ground in an electric grinder.
- It was kept at room temperature for an hour.
- Soda and salt was added.
- A spoon of this paste was taken and put in to oil.
- It was fried until golden brown.
- It was put in to the water and squeeze out.
- Curd and tamarind chutney was poured.
- Salt, red chilli powder and cumin seed powder were sprinkled.

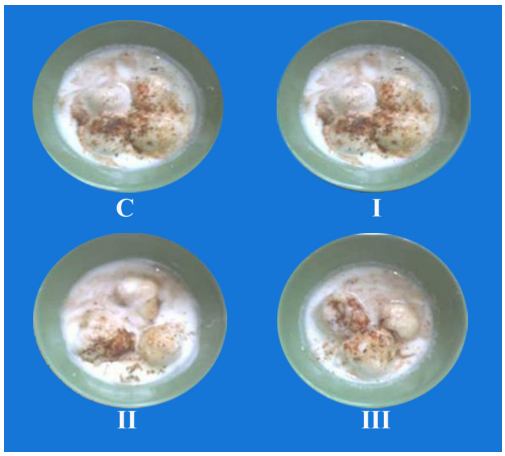

Plate 9 : *Bhalle*

C = Control (Dehulled black gram flour 100%)
Type-I = Dehulled black gram flour + Dehulled lentil flour (60:40)
Type-II = Dehulled black gram flour + Dehulled lentil flour (50:50)
Type-III = Dehulled black gram flour + Dehulled lentil flour (40:60)

v).42 Sprouted products

3.5.3.1 *Chat*

Ingredients	Control	Type-I
Sprouted green gram	100 g	--
Sprouted lentil	--	100 g
Potatoes (boiled)	50 g	50 g
Salt	2 g	2 g
Red chilli powder	1 g	1 g
Coriander leaves	1 g	1 g
Mango powder	0.5 g	0.5 g

Method

- Boiled potatoes were cut into small pieces.
- Then steamed sprouted *dal*, soaked *dal* and potatoes were slightly cooked on slow fire for 3 min.
- Added salt, red chilli powder, mango powder and coriander leaves.

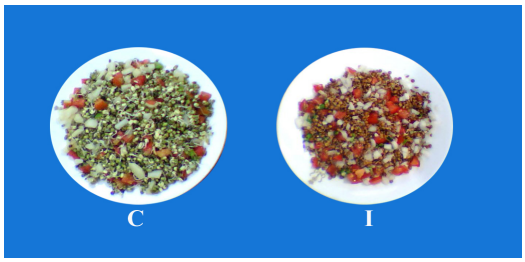

Plate 10 : Sprouted *chat*

C = Control (Sprouted green gram)
Type-I = Sprouted lentil

3.5.3.2 Cutlets

Sprouted green gram served as control.

Ingredients	Control	Type-I
Sprouted green gram	100 g	--
Sprouted lentil	--	100 g
Spinach	50 g	50 g
Salt	3 g	3 g
Red chilli powder	1 g	1 g
Mango powder	1 g	1 g
Oil	For frying	For frying

Method:

- Washed spinach in luke warm water and chopped it.
- Ground the sprouted *dal* coarsely.
- Mixed all the ingredients.
- Took small portion from this mixture and shaped it in the form of cutlet
- Heated oil and deep fried it.
- Rotated the sides to protect over browning.

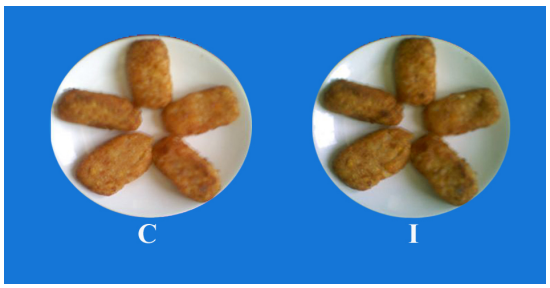

Plate 11 : Sprouted cutlets

C = Control (Sprouted green gram + spinach + potato)
Type-I = Sprouted lentil + spinach + potato

3.5.4 Fried products

Two type of products viz., *sev* and p*apad* were prepared. Dehulled bengal gram flour (*besan*) is used as control in *sev*, and dehulled black gram flour is used as control in *papad.*

3.5.4.1 *Sev*

Ingredients	Control	Type-I	Type-II	Type-III
Dehulled bengal gram flour	100 g	60 g	50 g	--
Dehulled lentil flour	--	40 g	50 g	100 g
Salt	2 g	2 g	2 g	2 g
Ajwain	1 g	1 g	1 g	1 g
Baking powder	0.25 g	0.25 g	0.25 g	0.25 g
Oil	For frying			

Method:

- Added salt and *ajwain* to the flour.
- Prepared the dough.
- Kept it in machine.
- Took oil in *karahi*, fried the *bhujia*.

Plate 12 : *Sev*

C = Control (Dehulled bengal gram flour 100%)
Type-I = Dehulled bengal gram flour + Dehulled lentil flour (60:40)
Type-II = Dehulled bengal gram flour + Dehulled lentil flour (50:50)
Type-III = Dehulled bengal gram flour + Dehulled lentil flour (00:100)

3.4.4.2 *Papad*

Ingredients	Control	Type-I	Type-II	Type-III
Dehulled black gram flour	100 g	60 g	50 g	--
Dehulled lentil flour	--	40 g	50 g	100 g
Black pepper (coarsely ground)	5 g	5 g	5 g	5 g
Sodium bicarbonate	6 g	6 g	6 g	6 g
Cumin seeds	3.5 g	3.5 g	3.5 g	3.5 g
Salt	8 g	8 g	8 g	8 g
Mustard oil	5 g	5 g	5 g	5 g
Water	30 ml	30 ml	30 ml	30 ml

Method :

- Mixed all the ingredients to the flour.
- Then kneaded a hard dough using lukewarm water.
- Mustard oil was used while kneading so that dough did not stick to the hands.
- Kept the dough for half and hour.
- Dough was divided into small balls of 25-30 g and rolled on circular plate having smooth surface with a wooden pin (roller) to give disc of about 0.6 to 0.8 mm thickness and 150-200 cm diameter.
- Dried the papads under sun.
- On drying fried papads and served.

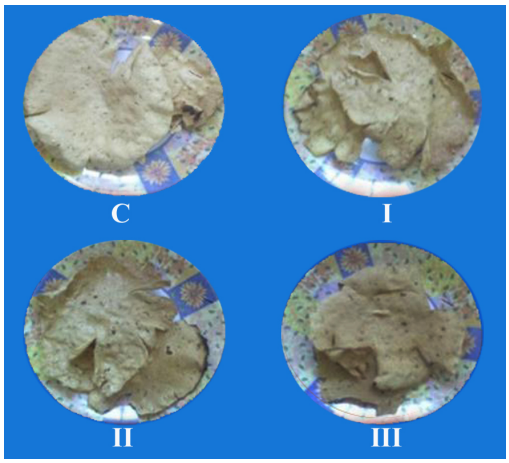

Plate 13 : *Papad*

C = Control (Dehulled black gram flour 100%)
Type-I = Dehulled black gram flour + Dehulled lentil flour (60:40)
Type-II = Dehulled black gram flour + Dehulled lentil flour (50:50)
Type-III = Dehulled black gram flour + Dehulled lentil flour (00:100)

3.5.5. Baked products

Two types of products viz., biscuits and bread were prepared, in which whole wheat flour for biscuits and refined wheat flour for bread were taken as control.

3.5.5.1 *Atta* biscuits

Ingredients	Control	Type-I	Type-II
Whole wheat flour	100 g	60 g	50 g
Dehulled lentil flour	--	40 g	50 g
Sodium bicarbonate	0.25 g	0.25 g	0.25 g
Milk	30 ml	30 ml	30 ml
Ghee	57.5 g	57.5 g	57.5 g
Sugar	50 g	50 g	50 g
Ammonia	0.25 g	0.25 g	0.25 g

Method:

- Sieved flour along with soda and baking powder twice.
- Creamed ghee and sugar until light.
- Mixed refined wheat flour with cream mix.
- Add milk and kneed , make soft dough and pas it from biscuits cutter machine.
- Cut even with cutter and place them in trays.
- Baked at 160°C for 15 to 20 min.

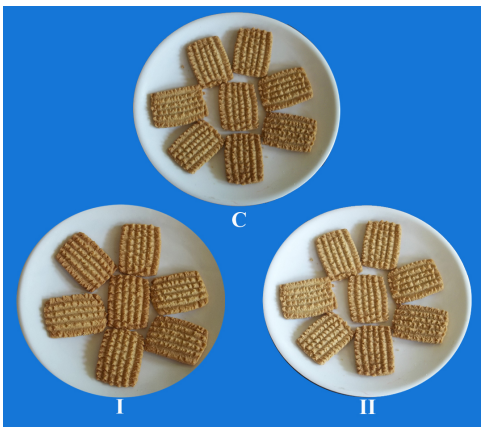

Plate 14 : Biscuits

C = Control (Whole wheat flour 100%)
Type-I = Whole wheat flour + Dehulled lentil flour (60:40)
Type-II = Whole wheat flour + Dehulled lentil flour (50:50)

3.5.5.2 Bread

Ingredients	Control	Type-I	Type-II
Refined wheat flour (*maida*)	100 g	70 g	60 g
Dehulled lentil flour	--	30 g	40 g
Sugar	50 g	50 g	50 g
Salt	2 g	2 g	2 g
Compressed yeast	3 g	3 g	3 g

Water	60 ml	60 ml	60 ml

Method

- Added 30 ml of water, yeast and sugar.
- Took 30 ml water and added the lentil flour and *maida*, then added the above mixture.
- Kneaded it into dough with some oil on the flour.
- Put this flour in incubator at 30°C for 2 h.
- Moulded and kept it for proofing in incubator at 32°C for 55 min.
- Put the dough in the container.
- Baked it for 15 min. at 200-225°C.

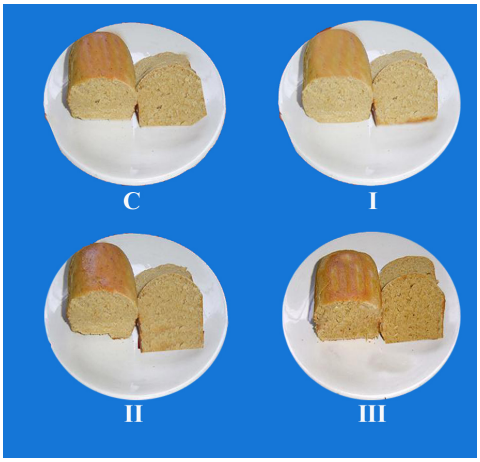

Plate 15 : Bread

C = Control (Refined wheat flour 100%)
Type-I = Refined wheat flour + Dehulled lentil flour (70:30)
Type-II = Refined wheat flour + Dehulled lentil flour (60:40)

Plate 16

3.5.6. Roasted product

3.5.6.1 Roasted *dal*

- Lentil seeds were soaked in water for 4 h.
- Soaked seeds were rinsed (with fresh water) and the seeds were sun dried.
- Dried seeds were roasted in sand in an iron pan at about 250°C for approximately 2 min.

All the products were developed in duplicate.

3.6 ORGANOLEPTIC EVALUATION OF VALUE ADDED PRODUCTS

All the developed products were organoleptically evaluated using 9-point hedonic scale by ten judges.The judges were selected from the Department of Foods and Nutrition, College of Home Science, CCS Haryana Agricultural University, Hisar.

v)5 SHELF LIFE

3.7.1 Sensory evaluation

The storable products like *papad*, biscuits, *sev* and roasted *dal* were packed in air-tight polythene bags at room temperature (29-30°C) for three months. At every 15 days interval, these were evaluated for their sensory attributes.

3.7.2 Fat acidity

The fat acidity was determined by the standard method of analysis (AOAC, 2000).

Reagents

(i) **Benzene-alcohol-phenolpthalein solution (0.02%)**: To one litre benzene, one litre alcohol and 0.4g phenolphthalein was added and mixed.

(ii) **Potassium hydroxide solution (0.0178 N)**.

Procedure

Ten gram sample was extracted with petroleum ether on Soxhelet apparatus. The solvent of the extract was completely evaporated on steam bath. The residue was dissolved in extraction flask with 50ml benzene-alcohol-phenolpthalein solution and titrated with standard potassium hydroxide (1g/lt) to orange pink colour. Blank titration was made on 50ml benzene-alcohol-phenolpthalein and this value was substracted from titration value of the sample. Fat acidity was calculated as mg of potassium hydroxide required to neutralize free fatty acids from 100g

$$\text{Fat acidity} = 10 \times (T-B)$$

Where,

T = ml of KOH required to titrate sample extract

B = ml KOH required to titrate blank

3.7.3 Peroxide value

Peroxide value was determined by the method of AOAC (2000).

Reagents

(i) **Acetic acid: chloroform solution (3:2,v/v)**

(ii) **Saturated potassium iodide solution**

(iii) **0.01 N sodium thiosulphate solution**

(iv) **Starch solution**: One gram soluble starch was dissolved in cold distilled water to make thin paste. Then boiled distilled water was added and boiled for one minute while stirring. When completely dissolved, the volume was made to 100ml.

(v) Potassium hydroxide solution (0.0178 N)

Five gram sample was taken in conical flask. Thirty ml acetic acid-chloroform mixture was added to the flask and swirled to dissolve. Then 0.5 ml saturated potassium iodide solution was added, kept for one minute with occasional shaking and 30 ml distilled water was added. This was slowly titrated against 0.01 N sodium thiosulphate with vigorus shaking until yellow colour almost disappeared. Then 0.05 ml starch solution was added and titration continued with shaking vigorously to release all iodine from chloroform layer until blue colour just disappeared. The blank was run in the similar way. Peroxide value was calculated as:

$$\text{Peroxide value (meq peroxide/1000g)} = \frac{(S-B) \times N \times 1000}{\text{Weight of sample}}$$

Where,

B = Volume (ml) of $Na_2S_2O_3$ used for titration of blank

S = Volume (ml) of $Na_2S_2O_3$ used for titration of sample

N = Normality of $Na_2S_2O_3$ solution

3.8 Statistical analysis

Statistical methods were used for interpretation of data like standard error and analysis of variance (Panse and Sukhatme, 1961).

CHAPTER-IV

RESULTS

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

(ii).6 Physico-chemical characteristics of unprocessed lentil genotypes

(ii).7 Nutritional evaluation of raw and processed lentil seeds

(ii).8 Organoleptic evaluation of developed value added products

(ii).9 Shelf-life

4.1 Physico-chemical characteristics

Physico-chemical properties such as seed weight, seed volume, seed density, hydration capacity, hydration index, swelling capacity, swelling index etc are important parameters need to be studied as they play an important role in cookability of food legumes. The results of physico-chemical characteristics of selected lentil genotypes are presented in Table 4.1. Seed weight of selected six lentil genotypes varied from 1.60 to 2.90 g, respectively. Among the genotypes, Garima and LH7-12 had highest 2.90 g whereas HM-I had lowest 1.60 g seed weight. The values differed non-significantly. Seed volume and seed density of lentil genotypes varied from 0.019 to 0.024 g/ml and 0.79 to 1.15 g/ml, respectively. Swelling capacity and swelling index of all the six varieties varied from 0.017 to 0.024 ml/seed, respectively. Among the lentil genotypes, Garima showed maximum values of swelling capacity (0.024 ml/seed) and swelling index (1.133) whereas HM-I showed minimum values of swelling capacity (0.017 ml/seed) and swelling index (0.937) but other lentil genotypes like Sapna, LH7-12 and LH-26 also had at par values of swelling capacity and swelling index as compared to Garima genotype. Similar trend was also observed in case of hydration capacity and hydration index.

Table 4.1: Physico-chemical properties of lentil genotypes

Genotypes	Seed weight (g/100 seeds)	Seed volume (ml/seed)	Seed Density (g/ml)	Swelling Capacity (ml/seed)	Swelling index	Hydration Capacity (g/seed)	Hydration index	Cooking Time (min)
Garima	2.90±0.00	0.024±0.00	1.150±0.00	0.024±0.00	1.133±0.01	0.026±0.00	0.950±0.01	36±0.33
Sapna	2.80±0.00	0.022±0.00	0.980±0.00	0.022±0.00	1.084±0.00	0.025±0.00	0.931±0.00	39±0.33
LH7-12	2.90±0.00	0.021±0.00	0.881±0.00	0.022±0.00	1.033±0.01	0.025±0.00	0.872±0.00	39±0.00
LH-13	2.80±0.00	0.023±0.00	0.870±0.00	0.023±0.00	1.063±0.01	0.025±0.00	0.870±0.00	40±0.33
LH-26	2.70±0.00	0.022±0.00	0.900±0.01	0.023±0.00	1.109±0.00	0.025±0.00	0.871±0.002	39±0.35

HM-1	1.60±0.00	0.019±0.00	0.790±0.00	0.017±0.00	0.937±0.00	0.014±0.00	0.863±0.00	43±0.00
CD (P≤0.05)	NS	NS	0.09	NS	0.09	0.01	NS	2.04

Values are mean ± SD of three independent determinations
CD (Critical difference). Differences of two means between the varieties / treatments exceeding this value are significant.
NS-Non-significant

The values ranged from 0.014 to 0.026 g/seed and 0.863 to 0.950, respectively. Cooking time of six lentil genotypes varied from 36 to 43 min., respectively. Lowest cooking time (36 min.) was observed in Garima genotype and highest (43 min.) in HM-I. Sapna, LH7-12 and LH-26 genotype took around 39 min. for cooking. It could be attributed to affinity and permeability of cell wall, composition of seed coat, endosperm material and starch gelatinization.

4.2 Nutritional evaluation of raw seeds and processed lentil seeds

4.2.1 Proximate composition

Proximate composition of raw and treated lentil genotypes are presented in Table 4.2. Moisture contents of raw seeds of lentil genotypes varied significantly from 6.87 to 8.19 per cent, respectively. Highest (8.19%) in Garima genotype and lowest (6.87%) in HM-I genotype. Non-significant increase was observed in moisture contents of all the six lentil genotypes when subjected to various treatments like soaking, dehulling, germination, pressure cooking, and microwave cooking as compared to raw seeds. Whereas, non-significant decrease was observed in moisture contents of all the lentil genotypes when subjected to roasting treatment.

After soaking and dehulling of soaked seeds, the moisture content of all genotypes ranging from 7.12 to 8.52 and 6.98 to 8.26 per cent, respectively. After roasting treatment, moisture content reduced which ranged from 6.00 to 7.77 per cent, respectively. After germination, moisture content ranging from 7.02 to 8.20 per cent, respectively. Similarly cooking treatments like pressure cooking and microwave cooking caused non-significant increase in moisture contents as compared to raw values. The contents ranged from 7.22 to 8.4 and 7.18 to 8.23 per cent, respectively.

Crude protein contents of all the six lentil genotypes varied significantly from 21.37 to 27.49 per cent, respectively. Highest (27.49%) in Garima and lowest (21.37%) in HM-I genotype. LH7-12 and LH-13 genotypes were also at par in protein content as Garima genotype. When all the genotypes were subjected to soaking, it caused non-significant decrease in protein contents. The contents ranged from 20.97 to 27.18 per cent, respectively. Dehulling of seeds non-significantly increased the protein content of all the six lentil genotypes. Removal of hulls, which contain relatively less amount of protein might have accounted for higher expressed value of protein. Germination increased protein contents ranging from 21.90 to 27.95 per cent, respectively might be due to utilization of non-protein

moieties and rapid protein synthesis. Whereas heat treatments like roasting, pressure cooking and microwave cooking caused significant ($P \leq 0.05$) decrease in protein contents of all the genotypes. Cultivar differences were also observed. The values ranged from 20.87 to 26.94, 20.30 to 26.54 and 19.11 to 26.08 per cent, respectively after roasting, pressure cooking and microwave cooking. All the treatments caused almost similar reduction in protein contents as compared to control.

Table 4.2: Effect of processing and cooking treatments on proximate composition of lentil genotypes (g/100 g, on dry weight basis)

Proximate composition	Treatments	Garima	Sapna	LH7-12	LH-13	LH-26	HM-1	Mean
Moisture	Raw	8.19±0.17	7.04±0.33	7.46±0.21	7.26±0.12	8.00±0.17	6.87±0.27	7.47
	Soaking(12h)	8.52±0.17	7.22±0.23	7.90±0.19	7.72±0.30	8.07±0.27	7.12±0.11	7.75
	Dehulling (soaked)	8.26±0.21	7.18±0.19	8.03±0.18	7.55±0.29	8.15±0.18	6.98±0.13	7.59
	Roasting	7.77±0.32	7.09±0.26	7.20±0.13	7.16±0.25	7.76±0.12	6.00±0.13	7.51
	Germination (24h)	8.20±0.10	7.24±0.22	7.47±0.10	7.54±0.18	8.11±0.11	7.02±0.12	7.53
	Pressure cooking	8.43±0.18	7.40±0.13	8.45±0.15	7.52±0.10	8.63±0.13	7.22±0.17	7.94
	Microwave cooking	8.23±0.13	7.23±0.15	8.33±0.13	7.50±0.18	8.42±0.19	7.18±0.25	7.78
	Mean	8.20	7.20	7.81	7.46	8.01	6.85	
	CD (P<0.05)	Variety: 0.47		Treatment: 0.51		Interaction (Variety X Treatment): 0.34		
Protein	Raw	27.49±0.19	24.53±0.14	26.53±0.14	26.53±0.15	23.53±0.24	21.37±0.19	24.82
	Soaking (12h)	27.18±0.15	24.26±0.17	26.15±0.18	26.25±0.18	23.39±0.25	20.97±0.16	24.46
	Dehulling (soaked)	27.83±0.29	24.89±0.22	26.94±0.22	26.71±0.27	23.74±0.22	21.45±0.27	24.40
	Roasting	26.94±0.15	23.75±0.15	25.85±0.17	26.43±0.17	23.25±0.15	20.87±0.15	24.12
	Germination (24h)	27.95±0.21	24.88±0.26	26.98±0.12	26.92±0.15	24.48±0.16	21.90±0.12	24.42
	Pressure cooking	26.54±0.13	23.58±0.13	24.94±0.29	25.69±0.22	22.31±0.23	20.30±0.20	23.08
	Microwave cooking	26.08±0.19	22.19±0.16	24.73±0.19	25.02±0.13	22.19±0.13	19.11±0.16	23.03
	Mean	26.25	22.98	25.67	25.93	22.98	22.12	
	CD (P<0.05)	Variety: 0.43		Treatment: 0.46		Interaction (Variety X Treatment): 1.05		
Fat	Raw	1.82±0.01	1.83±0.02	1.58±0.03	1.86±0.01	1.95±0.01	1.36±0.01	1.73
	Soaking(12h)	1.79±0.01	1.80±0.01	1.55±0.02	1.82±0.10	1.85±0.01	1.34±0.01	1.69
	Dehulling (soaked)	1.56±0.03	1.56±0.03	1.28±0.03	1.59±0.02	1.52±0.01	1.22±0.10	1.45
	Roasting	1.64±0.02	1.54±0.01	1.36±0.12	1.55±0.02	1.55±0.02	1.25±0.03	1.41
	Germination(24h)	1.64±0.02	1.75±0.02	1.49±0.06	1.87±0.03	1.60±0.02	1.57±0.11	1.65
	Pressure cooking	1.62±0.01	1.52±0.10	1.32±0.03	1.73±0.03	1.36±0.02	1.54±0.03	1.50
	Microwave cooking	1.59±0.01	1.42±0.01	1.28±0.03	1.70±0.06	1.30±0.03	1.51±0.04	1.46
	Mean	1.67	1.63	1.41	1.73	1.59	1.39	
	CD (P≤0.05)	Variety: 0.06		Treatment: 0.07		Interaction (Variety X Treatment): 0.24		
Crude Fibre	Raw	2.99±0.06	2.39±0.15	2.60±0.12	2.42±0.03	2.46±0.01	1.74±0.09	2.42
	Soaking (12h)	2.92±0.09	2.21±0.07	2.56±0.02	2.37±0.09	2.41±0.07	1.65±0.07	2.35
	Dehulling (soaked)	0.97±0.03	0.91±0.06	0.93±0.13	0.95±0.03	0.85±0.06	0.92±0.00	0.94
	Roasting	2.39±0.13	2.25±0.07	2.26±0.04	2.23±0.15	2.29±0.07	1.64±0.19	2.19
	Germination (24h)	2.28±0.09	2.12±0.06	2.18±0.01	2.20±0.12	2.18±0.06	1.35±0.09	2.39
	Pressure cooking	2.80±0.01	2.20±0.03	2.42±0.03	2.24±0.07	2.33±0.03	1.70±0.06	2.28
	Microwave cooking	2.24±0.02	2.21±0.06	2.25±0.04	2.28±0.09	2.33±0.06	1.58±0.15	2.14
	Mean	2.37	2.04	2.17	2.09	2.12	1.51	
	CD (P≤0.05)	Variety : 0.13		Treatment: 0.15		Interaction (Variety X Treatment): 0.21		
Ash	Raw	3.82±0.03	3.62±0.02	3.76±0.09	3.53±0.03	3.86±0.04	2.51±0.02	3.51
	Soaking (12h)	3.73±0.03	3.49±0.03	3.66±0.03	3.41±0.13	3.78±0.07	2.37±0.06	3.40
	Dehulling (soaked)	2.73±0.00	2.47±0.03	2.63±0.06	2.43±0.03	2.74±0.00	1.35±0.17	3.39
	Roasting	3.78±0.03	3.45±0.02	3.70±0.03	3.49±0.03	3.81±0.07	2.46±0.03	3.44
	Germination (24h)	3.80±0.07	3.56±0.06	3.71±0.07	3.51±0.03	3.82±0.03	2.49±0.01	3.48

	Pressure cooking	3.66±0.13	3.40±0.03	3.60±0.03	3.40±0.07	3.71±0.07	2.29±0.07	3.34
	Microwave cooking	3.70±0.03	3.49±0.03	3.63±0.00	3.46±0.11	3.75±0.05	2.33±0.03	3.41
	Mean	3.60	3.35	3.52	3.31	3.63	2.25	
CD (P≤0.05)	Variety: NS			Treatment: 0.08		Interaction (Variety X Treatment): 0.19		

Values are mean ± SE of three independent determinations
CD (Critical difference). Differences of two means between the varieties / treatments exceeding this value are significant.

Fat content of six lentil genotypes ranged from 1.36 to 1.82 per cent, respectively. Among the genotypes, significant difference was observed in fat contents. Soaking for 12 h did not cause any significant change in fat content of all genotypes as compared to raw values. Whereas dehulling of soaked seeds caused significant (P≤0.05) reduction in fat content of all genotypes. The values ranged from 1.22 to 1.59 per cent, respectively. Germination for 24 h also caused significant change in fat contents ranging from 1.49 to 1.87 per cent, respectively. Among the heat treatments, microwave cooking caused significantly higher reduction in fat contents of all genotypes as compared to raw. The values ranged from 1.25 to 1.64 per cent by roasting, 1.32 to 1.73 per cent by pressure cooking and 1.28 to 1.70 per cent, respectively by microwave cooking. Varietal differences were observed among the genotypes after processing and cooking methods.

Crude fibre contents of unprocessed six lentil genotypes varied significantly from 1.74 to 2.99 per cent, respectively. Highest content was observed in Garima genotype and lowest in HM-I genotype. Soaking treatment caused non-significant change in crude fibre contents of all genotypes. Whereas dehulling of soaked seeds caused significant (P≤0.05) reduction in crude fibre contents of all genotypes. The values ranged from 0.85 to 0.97 per cent, respectively. Almost 50 per cent reduction was observed in crude fibre content of all genotypes on dehulling. As dehulling resulted in significant reduction in fibre content and this may be due to the fact that most of the fibre is found in testa, which was removed during the process of dehulling. Germination for 24 h caused significant change in crude fibre contents of all lentil genotypes. Crude fibre contents ranged from 1.35 to 2.28 per cent, respectively after 24 h germination in all the six genotypes.

Heat treatments like roasting, pressure cooking and microwave cooking showed significant decrease in crude fibre contents of all genotypes. The values ranged from 1.64 to 2.39, 1.70 to 2.80 and 1.58 to 2.24 per cent, respectively after roasting, pressure cooking and microwave cooking. Varietal differences were observed among genotypes after processing and cooking treatments.

Ash content of all genotypes varied significantly from 2.51 to 3.82 per cent, respectively. Highest (3.82%) in Garima and lowest (2.51%) in HM-I genotype. Soaking of seeds did not have significant effect on ash contents of lentil genotypes whereas dehulling of soaked seeds had significant effect on ash contents which ranged from 1.35 (HM-I) and 2.73 (Garima) per cent, respectively. This decrease could have been due to removal of hulls. Other

treatments like roasting, germination, pressure cooking and microwave cooking did not have significant effect on ash contents of all the six genotypes.

4.2.2 Available carbohydrates

The results regarding total, reducing and non-reducing sugar and starch contents are presented in Table 4.3 and 4.4.

4.2.2.1 Sugars

Total sugar contents of six lentil genotypes varied significantly from 8.61 to 9.39 per cent respectively. The highest (9.39%) and lowest (8.61%) amount of total sugars were present in Garima and HM-I genotypes. Similarly, reducing and non-reducing sugars of lentil genotypes varied significantly. These ranged from 1.25 to 1.72 and 7.20 to 8.14 per cent, respectively. Soaking for 12 hrs of seeds significantly reduced the level of total soluble sugars, reducing sugars and non-reducing sugars. Total, reducing and non-reducing sugars decreases ranged from 4 to 8, 5 to 12 and 4 to 9 per cent, respectively in all the lentil genotypes. Losses of sugars during soaking would be on account of simple diffusion of sugars after being solubilized. The extent of diffusion of sugars from seed to soaking medium may be function of structure of seed coat. Dehulling of soaked seeds resulted in significant loss of all the sugar contents as compared to raw lentil genotypes. The reduction was observed by 15 to 21, 6 to 12 and 16 to 25 per cent, respectively. Varietal differences were observed in sugar contents of processed lentil genotypes.

Dry heating like roasting also caused significant ($P \leq 0.05$) increase in sugar contents. In case of total sugars, the extent of increase was found highest (13%) in LH-26 genotype and lowest (6%) in Garima genotype. Similarly, in case of reducing and non-reducing sugars, the extent of increase was ranged from 5 to 10 and 9 to 25 per cent, respectively. The highest increase was observed in Garima genotype. The increase in sugar contents on dry heating may be due to hydrolysis of starch. Germination for 24 h also caused significant improvement in total, reducing and non-reducing sugars. In case of total sugars, the extent of increase ranged from 20 to 28 per cent, respectively. The greater extent of increase was found in LH-13 genotype. Similarly, the increase was ranged from 20 to 26 per cent in reducing sugars and 20 to 29 per cent in non-reducing sugars. The increase in sugar contents of soaked seeds during germination may be because of mobilization and hydrolysis of seed polysaccharides, leading to more available sugars.

Pressure cooking of soaked seeds also increased the total, reducing wand non-reducing sugars of all the lentil genotypes over the control. The increase was 24 to 36 per cent in total sugars, 20 to 29 per cent in reducing sugars and 23 to 34 per cent in non-reducing sugars of pressure cooked seeds of all lentil genotypes. Among the various

treatments, pressure cooking had pronounced effect on sugar contents. Cooking may cause reputing of starch granules followed by hydrolysis of starch to oligosaccharides and then to monosaccharides. Microwave cooking of soaked seeds increased significantly the content of total sugars over the control (unprocessed sample). Maximum increase was in Sapna genotype (19%) followed by LH-13 (17%), HM-I (14%), LH7-12 (13%), Garima (12%) and LH-26 (9%), respectively. The reducing sugar content of raw (unprocessed seeds) of all genotypes varied from 1.39 to 1.85 per cent, respectively.

Table 4.3 : Effect of processing and cooking treatments on sugar content (g/100 g) of lentil genotypes (on dry weight basis)

Available carbohydrates	Treatments	Garima	Sapna	LH7-12	LH-13	LH-26	HM-1	Mean
Total soluble sugars	Raw	9.39±0.03	9.35±0.13	9.13±0.13	9.33±0.09	9.26±0.17	8.61±0.07	9.19
	Soaking (12h)	8.78±0.12 (-6)	8.92±0.23 (-5)	8.62±0.05 (-5)	8.71±0.03 (-6)	8.90±0.36 (-4)	7.92±0.12 (-8)	8.64
	Dehulling (soaked)	7.85±0.07 (-16)	7.79±0.03 (-20)	7.75±0.21 (-15)	7.81±0.17 (-16)	7.41±0.03 (-20)	6.70±0.10 (-21)	7.37
	Roasting	10.01±0.17 (+6)	10.25±0.07 (+9)	10.45±0.31 (+12)	10.05±0.27 (+8)	10.50±0.23 (+13)	9.40±0.18 (+9)	10.11
	Germination (24h)	11.75±0.09 (+25)	11.55±0.15 (+24)	11.05±0.15 (+21)	11.98±0.15 (+28)	11.50±0.18 (+24)	10.35±0.26 (+20)	11.36
	Pressure cooking	12.15±0.32 (+29)	11.56±0.18 (+24)	12.10±0.23 (+32)	12.12±0.23 (+30)	11.96±0.27 (+29)	11.78±0.03 (+36)	11.95
	Microwave cooking	10.50±0.32 (+12)	11.15±0.18 (+19)	10.35±0.23 (+13)	10.90±0.23 (+17)	10.10±0.27 (+9)	9.85±0.03 (+14)	10.48
	Mean	9.50	9.71	9.44	9.66	9.52	8.69	
	CD (P≤0.05)	Variety: 0.08		Treatment: 0.05	Interaction (Variety X Treatment): 0.16			
Reducing sugars	Raw	1.25±0.06	1.33±0.19	1.67±0.09	1.27±0.09	1.72±0.07	1.41±0.09	1.44
	Soaking (12h)	1.19±0.09 (-5)	1.25±0.17 (-6)	1.54±0.03 (-8)	1.12±0.01 (-12)	1.58±0.13 (-9)	1.27±0.03 (-10)	1.32
	Dehulling (soaked)	1.12±0.03 (-12)	1.21±0.10 (-7)	1.51±0.01 (-10)	1.19±0.04 (-6)	1.61±0.09 (-6)	1.30±0.01 (-8)	1.32
	Roasting	1.38±0.05 (+10)	1.43±0.09 (+8)	1.77±0.13 (+6)	1.36±0.03 (+7)	1.81±0.23 (+5)	1.53±0.06 (+9)	1.54
	Germination (24h)	1.56±0.13 (+25)	1.68±0.03 (+26)	1.98±0.23 (+19)	1.60±0.02 (+25)	2.13±0.15 (+24)	1.70±0.07 (+20)	1.80
	Pressure cooking	1.61±0.17 (+29)	1.69±0.06 (+27)	2.08±0.17 (+25)	1.53±0.09 (+20)	2.21±0.06 (+28)	1.85±0.22 (+29)	1.82
	Microwave cooking	1.39±0.09 (+11)	1.50±0.01 (+13)	1.82±0.18 (+9)	1.44±0.07 (+13)	1.85±0.03 (+8)	1.60±0.03 (+13)	1.60
	Mean	1.34	1.42	1.77	1.37	1.83	1.52	
	CD (P≤0.05)	Variety :NS		Treatment: 0.12	Interaction (Variety X Treatment): 0.23			

Non-reducing sugars	Raw	8.14±0.13	8.02±0.06	7.46±0.03	8.06±0.03	7.54±0.13	7.20±0.09	7.89
	Soaking (12h)	7.59±0.13 (-7)	7.67±0.16 (-4)	7.08±0.23 (-5)	7.50±0.13 (-6)	7.21±0.14 (-4)	6.57±0.06 (-9)	7.26
	Dehulling (soaked)	6.73±0.19 (-17)	6.58±0.19 (-18)	6.24±0.07 (-16)	6.62±0.20 (-18)	5.87±0.07 (-22)	5.40±0.10 (-25)	6.24
	Roasting	8.63±0.16 (+25)	8.82±0.18 (+10)	8.68±0.17 (+16)	8.69±0.08 (+18)	8.69±0.06 (+24)	7.87±0.17 (+9)	8.56
	Germination (24h)	10.19±0.23 (+25)	9.87±0.23 (+23)	9.07±0.05 (+22)	10.38±0.13 (+29)	9.90±0.03 (+22)	8.62±0.21 (+20)	9.67
	Pressure cooking	10.54±0.18 (+29)	9.88±0.17 (+23)	10.02±0.13 (+34)	10.59±0.17 (+31)	9.75±0.24 (+29)	9.93±0.23 (+25)	10.18
	Microwave cooking	9.11±0.16 (+12)	9.05±0.09 (+20)	8.53±0.17 (+14)	9.46±0.26 (+17)	8.25±0.16 (+9)	6.38±0.31 (+5)	8.98
	Mean	9.16	9.60	8.15	8.75	8.83	8.50	
	CD (P≤0.05)	Variety:0.05		Treatment:0.12		Interaction (Variety X Treatment): 0.60		

Values are mean ± SE of three independent determinations
Figures in parentheses indicate per cent increase (+) and decrease (-) over the control values
CD (Critical difference). Differences of two means between the varieties / treatments exceeding this value are significant.

On microwave cooking of soaked seeds, reducing sugar contents rose to 8 to 13 per cent, respectively. Higher rise (13%) was observed in Sapna, LH-13 and HM-I and lowest (8%) in LH-26. Similarly trend was also observed in non-reducing sugar contents of all genotypes on microwave cooking. The increase was ranged from 5 to 20 per cent, respectively. Highest increase (20%) was observed in Sapna genotype followed by 17 per cent in LH-13, 14 per cent in LH7-12, 12 per cent in Garima, 9 per cent in LH-26 and 5 per cent in HM-I genotype.

4.2.2.2 Starch

Starch content of unprocessed seeds of all lentil genotypes varied significantly from 46.90 to 61.72 per cent, respectively (Table 4.4). Maximum was found in Garima and minimum in HM-I. Starch content decreased significantly (P≤0.05) on all processing and cooking methods. Soaking for 12 h, caused reduction in starch contents than the unprocessed controls. Dehulling of soaked seeds also resulted in the reduction of starch contents in all the six lentil genotypes. The extent of decreased ranged from 21 to 27 per cent, respectively. Higher reduction was observed in HM-I (27%) followed by Sapna (26%), LH-26 (24%), Garima (22%) and LH7-12 and LH-26 (21%). Heat treatments like roasting, pressure cooking and microwave cooking further increased the loss of starch. The extent of decrease was observed 15 to 19 per cent on roasting, 43 to 48 per cent on pressure cooking and 18 to 23 per cent on microwave cooking in all lentil genotypes. Pressure cooking had a more pronounced effect than roasting and microwave cooking.

Table 4.4 : Effect of processing and cooking treatments on starch content (g/100 g) of lentil genotypes (on dry weight basis)

Treatments	Garima	Sapna	LH7-12	LH-13	LH-26	HM-1	Mean

Raw	61.72±0.18	52.02±0.16	55.21±0.19	57.32±0.02	47.36±0.32	46.90±0.29	53.92
Soaking (12h)	55.71±0.15 (-16)	46.63±0.18 (-14)	50.30±0.26 (-19)	52.23±0.31 (-19)	40.13±0.26 (-15)	39.88±0.32 (-14)	50.31
Dehulling (soaked)	49.62±0.19 (-22)	38.33±0.19 (-26)	43.83±0.13 (-21)	45.53±0.29 (-21)	36.14±0.17 (-24)	35.72±0.25 (-27)	46.86
Roasting	55.43±0.13 (-17)	46.19±1.36 (-15)	48.72±0.26 (-17)	48.52±0.26 (-15)	40.89±0.34 (-16)	39.63.16 (-19)	46.76
Germination (24h)	45.16±0.09 (-29)	39.53±0.29 (-24)	42.52±0.19 (-24)	43.27±0.17 (-25)	33.72±0.16 (-29)	31.15±0.21 (-27)	42.72
Pressure cooking	39.56±0.13 (-47)	37.47±0.32 (-44)	31.24±0.15 (-43)	31.27±0.19 (-45)	25.25±0.23 (-47)	21.37±0.15 (-48)	48.36
Microwave cooking	49.25±0.33 (-23)	43.74±0.12 (-18)	44.75±0.12 (-22)	41.37±0.12 (-23)	38.12±0.19 (-20)	39.23±0.12 (-18)	41.24
Mean	56.24	47.27	46.22	48.36	40.84	41.70	
CD (P≤0.05) Variety: 0.28 Treatment: 0.30 Interaction (Variety X Treatment): 0.73							

Values are mean ± SE of three independent determinations
Figures in parentheses indicate per cent increase (+) and decrease (-) over the control values
CD (Critical difference). Differences of two means between the varieties / treatments exceeding this value are significant.

Sprouting also caused significant (P≤0.05) reduction in starch content. The extent of decrease was ranged from 24 to 29 per cent, respectively. Highest reduction was observed in Garima (29%) and LH-26 (29%) and lowest reduction in Sapna and LH7-12 genotypes over control values.

Leaching out of soluble portion of starch from seed to soaking medium may, perhaps, explain the loss of starch during soaking. Heat treatments like roasting, pressure-cooking and microwave cooking may be responsible for increased concentration of sugars in pulses. Significant decrease in starch content of seeds as a result of cooking treatments may result from amylolysis and it may also explain the observed increase in the concentration of sugars during cooking. Cooking may cause rupturing of starch granules followed by hydrolysis the starch which might be contributed to decrease starch content after cooking process starch may also be hydrolyzed to oligosaccharides and ultimately to monosaccharides during germination.

4.2.3 Dietary fibre

Raw seeds of lentil genotypes contained 2.93 to 3.87 per cent soluble, 13.54 to 14.67 per cent insoluble and 16.92 to 17.97 per cent total dietary fibre contents (Table 4.5). When raw seeds were soaked for 12 h caused non-significant decrease in soluble, insoluble and total dietary fibre constituents. The extent of reduction was ranged from 1 to 3 per cent (soluble), 0.1 to 2 per cent (insoluble) and 0.3 to 2 per cent (total), respectively in all the six lentil genotypes. On the other hand dehulling of soaked seeds caused significant (P≤0.05) reduction in all the three dietary fibre constituents. The extent of reduction was ranged from 25 to 38 per cent in soluble, 45 to 64 per cent in insoluble and 40 to 58 per cent in total dietary fibre contents of all the six lentil genotypes. It might be due to removal of fibre which contributed to great reduction in dietary fibre contents.

Similarly, germination for 24 h also caused significant reduction in all the dietary fibre constituents. The reduction was ranged from 30 to 42 per cent in soluble, 29 to 39 per cent in insoluble and 29 to 39 per cent in total dietary fibre contents of all the six lentil genotypes. Almost similar reduction was observed in all the dietary fibre constituents.

When the soaked seeds of all the six lentil genotypes were subjected to heat treatments like roasting, pressure cooking and microwave cooking caused significant reduction in total and insoluble dietary fibre contents whereas soluble fraction was increased. The extent of decrease in insoluble and total dietary fibre contents ranged from 7 to 12 and 2 to 7 per cent on roasting, 35 to 43 and 23 to 28 per cent on pressure cooking and 13 to 19 and 6 to 11 per cent on microwave cooking, respectively. Whereas soluble fraction was increased by about 5 to 9 per cent on roasting, 27 to 42 per cent on pressure cooking and 10 to 18 per

cent on microwave cooking, respectively in all the lentil genotypes. Among the heat treatments, pressure cooking caused significantly higher reduction in insoluble and total dietary fibre and significant increase in soluble fraction. It might be due to the fact that heat treatments caused redistribution of the insoluble non-starch polysaccharides to soluble fraction, although the total non-starch polysaccharides were not affected.

Table 4.5: Effect of processing and cooking treatments on dietary fibre constituents (g/100g) of lentil genotypes (on dry weight basis)

Dietry fibres	Treatments	Garima	Sapna	LH7-12	LH-13	LH-26	MH-1	Mean
Soluble	Raw	3.87±0.09	3.00±0.03	2.94±0.01	2.93±0.03	3.72±0.06	3.38±0.07	3.30
	Soaking (12h)	3.77±0.02 (-3)	2.98±0.07 (-1)	2.90±0.03 (-1)	2.90±0.02 (-1)	3.65±0.03 (-2)	3.32±0.03 (-2)	3.25
	Dehulling (soaked)	2.89±0.03 (-25)	2.23±0.09 (-26)	2.14±0.02 (-27)	2.03±0.01 (-31)	2.82±0.05 (-32)	2.09±0.01 (-38)	2.36
	Roasting	4.00±0.05 (+9)	3.22±0.01 (+8)	3.24±0.03 (+10)	3.14±0.06 (+7)	3.89±0.03 (+5)	3.62±0.08 (+8)	3.56
	Germination (24h)	2.74±0.01 (-30)	1.97±0.06 (-32)	1.80±0.06 (-39)	1.89±0.05 (-35)	2.22±0.02 (-40)	1.97±0.02 (-42)	2.09
	Pressure cooking	5.50±0.02 (+42)	4.09±0.07 (+36)	3.94±0.05 (+34)	3.84±0.03 (+31)	4.72±0.04 (+28)	4.29±0.01 (+27)	4.39
	Microwave cooking	4.32±0.07 (+12)	3.39±0.02 (+13)	3.35±0.09 (+14)	3.22±0.07 (+10)	4.32±0.01 (+16)	3.99±0.09 (+18)	3.60
	Mean	3.90	2.98	2.90	2.89	3.62	2.93	
Insoluble	CD (P≤0.05)	Variety: 0.38		Treatment: 0.29		Interaction (Variety X Treatment): 0.25		
	Raw	14.10±0.05	14.63±0.06	14.50±0.03	14.35±0.02	14.11±0.15	13.54±0.02	14.29
	Soaking (12h)	14.07±0.02 (-0.2)	14.60±0.01 (-0.2)	14.31±0.06 (-1)	14.19±0.06 (-1)	14.10±0.09 (-0.1)	13.24±0.06 (-2)	14.09
	Dehulling (soaked)	5.93±0.04 (-58)	8.09±0.03 (-45)	6.05±0.07 (-58)	5.22±0.05 (-64)	7.21±0.07 (-49)	6.14±0.00 (-55)	6.44
	Roasting	13.94±0.06 (-10)	13.12±0.06 (-10)	13.81±0.13 (-12)	13.02±0.06 (-9)	13.12±0.03 (-7)	12.54±0.03 (-8)	13.25
	Germination (24h)	10.00±0.09 (-29)	9.52±0.02 (-35)	10.14±0.01 (-30)	8.75±0.03 (-39)	9.14±0.10 (-35)	08.75±0.05 (-38)	9.05
	Pressure cooking	8.00±0.11 (-43)	9.10±1.05 (-37)	9.45±0.02 (-35)	9.18±0.01 (-36)	8.26±0.01 (-41)	7.83±0.07 (-42)	8.63
	Microwave cooking	12.25±0.00 (-13)	12.43±0.10 (-15)	23.16±0.03 (-16)	12.95±0.09 (-10)	11.75±0.06 (-17)	11.00±0.01 (-19)	12.09
	Mean	11.18	11.64	13.06	11.09	11.09	10.43	
	CD (P≤0.05)	Variety : 0.23		Treatment: 0.25		Interaction (Variety X Treatment): 0.60		
Total	Raw	17.97±0.07	17.63±0.07	17.44±0.09	17.28±0.03	17.83±0.10	16.92±0.07	17.51
	Soaking (12h)	17.84±0.12 (-2)	17.58±0.00 (-0.3)	17.21±0.07 (-1)	17.09±0.00 (-1)	17.75±0.00 (-0.4)	16.56±0.03 (-2)	17.33
	Dehulling (soaked)	8.82±0.03 (-51)	10.32±0.03 (-40)	8.19±0.12 (-53)	7.25±0.02 (-58)	10.03±0.07 (-44)	8.02±0.04 (-51)	08.77
	Roasting	17.19±0.01 (-2)	16.34±0.05 (-7)	17.05±0.33 (-2)	16.16±0.09 (-6)	17.00±0.06 (-5)	16.16±0.07 (-4)	16.81
	Germination (24h)	12.74±0.07 (-29)	11.49±0.01 (-35)	11.94±0.09 (-32)	10.04±0.03 (-39)	11.36±0.03 (-36)	10.72±0.05 (-37)	11.38

	Pressure cooking	13.50±0.01 (-25)	13.19±1.13 (-25)	13.39±0.15 (-23)	13.02±0.05 (-25)	12.98±0.02 (-27)	12.12±0.01 (-28)	13.03
	Microwave cooking	16.67±0.02 (-7)	15.82±0.10 (-10)	15.50±0.19 (-11)	16.17±0.03 (-6)	16.07±0.08 (-6)	14.99±0.06 (-11)	15.87
	Mean	15.10	14.62	14.31	13.85	14.72	13.64	
	CD (P≤0.05)	Variety: 0.22		Treatment: 0.24		Interaction (Variety X Treatment): 0.60		

Values are mean ± SD of three independent determinations

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

CD (Critical difference). Differences of two means between the varieties / treatments exceeding this value are significant.

4.2.4 Antinutrients

The antinutritional factors of raw and treated lentil genotype seeds are shown in Table 4.6, 4.7 and 4.8.

4.2.4.1 Phytic acid : Phytic acid is known to be the major storage form of phosphorus in legumes. Phytic acid content of unprocessed lentil genotypes varied significantly from 820.33 to 996.68 mg/100g, respectively (Table 4.6). HM-I had significantly highest (996.68 mg/100g) and Garima had lowest phytic acid contents. Soaking and dehulling of soaked seeds significantly reduced the phytic acid content of all the six genotypes. Soaking for 12 h brought about 2 to 6 per cent, respectively reduction in the content of phytic acid. Dehulling further decreased the phytic acid contents by about 16 per cent in LH-26 followed by 15 per cent in Garima, 13 per cent in Sapna, 12 per cent in LH-13, 11 per cent in LH7-12 and 5 per cent in HM-I genotype. On dehulling, the losses may be because of the removal of husk.

Phytic acid content was also significantly decreased by sprouting for 24 h. The extent of reduction was ranged from 32 to 44 per cent, respectively. The highest (44%) reduction was observed in Garima and lowest (30%) in LH-26 as compared to control (raw). The loss of phytic acid during germination may be caused by hydrolytic activity of the enzyme phytase.

Dry and moist heat treatments like roasting, pressure cooking and microwave cooking also caused significant reduction in phytic acid content of all the six lentil genotypes. The highest reduction was noted after pressure cooking (32 to 46%) followed by microwave cooking (30 to 40%) and roasting (15 to 27%). The reduction observed in phytic acid content of all lentil genotype seeds was possibly through its destruction by heat treatment.

Table 4.6 : Effect of processing and cooking treatments on phytic acid content (mg/100g) of lentil genotypes (on dry matter basis)

Treatments	Garima	Sapna	LH7-12	LH-13	LH-26	HM-1	Mean
Raw	820.33±2.34	938.37±1.37	951.00±1.58	859.00±2.61	957.34±1.28	996.68±1.68	920.45
Soaking (12h)	780.68±1.18 (-5)	900.69±2.69 (-4)	915.69±1.38 (- 4)	810.00±1.38 (-6)	910.49±2.39 (-4)	980.66±1.66 (-2)	747.96
Dehulling (soaked)	705.35±1.32 (-15)	820.00±1.25 (-13)	847.67±2.33 (-11)	745.67±0.33 (-12)	800.33±2.33 (-16)	820.33±1.83 (-5)	789.89
Roasting	680.35±1.48 (-17)	800.00±1.46 (-15)	758.00±1.20 (-20)	645.56±1.56 (-26)	751.68±1.47 (-22	731.37±2.43 (-27)	727.83
Germination (24h)	460.38±2.08 (-44)	642.67±2.20 (-32)	610.67±1.37 (-36)	568.67±0.79 (-35)	670.33±1.53 (-30)	610.33±1.13 (-39)	524.89
Pressure cooking	440.35±1.05 (-46)	534.00±1.96 (-43)	571.33±1.99 (-40)	581.37±1.11 (-32)	534.67±1.67 (-45)	618.33±2.33 (-38)	546.68
Microwave cooking	492.67±2.33 (-40)	570.33±1.73 (-39)	619.68±1.43 (-35)	600.33±2.37 (-30)	591.67±2.13 (-38)	608.00±1.12 (-39)	580.45
Mean	625.73	743.00	751.01	687.22	665.69	775.37	

CD (P≤0.05)	Variety: 9.25	Treatment: 9.34	Interaction (Variety X Treatment): 8.3

Values are mean ± SD of three independent determinations
Figures in parentheses indicate per cent decrease (-) over the control values
CD (Critical difference). Differences of two means between the varieties / treatments exceeding this value are significant

4.2.4.2 Polyphenols : Polyphenol content of raw (unprocessed) whole seeds of six lentil genotypes varied significantly from 478.33 to 540.68 mg/100g, respectively (Table 4.7). Higher (540.68 mg/100g) was observed in Sapna genotype followed by 520.33 mg/100g in HM-I, 503.33 mg/100g in LH-13, 502.00 mg/100g in LH7-12, 483.33 mg/100g in LH-26 and 478.33 mg/100g in Garima genotype. Soaking the seeds for 12 h reduced the polyphenol contents of all the six lentil genotypes. The extent of reduction ranged from 4 to 9 per cent, respectively. Higher (9%) reduction was observed in LH-26 and lowest (4%) in LH7-12 genotype. When the soaked seeds were dehulled, there was a significant decline in the level of polyphenols of all six lentil genotypes. The extent of reduction was observed from 21 to 28 per cent, respectively. Among the six lentil genotypes, maximum reduction was observed in Sapna and minimum in LH-13 and HM-I genotypes over their control values. Polyphenols were reported to be concentrated in the husk and the removal of testa significantly reduced the polyphenol content.

Table 4.7 : Effect of processing and cooking treatments on polyphenol content (mg/100g) of lentil genotypes (on dry matter basis)

Treatments	Garima	Sapna	LH7-12	LH-13	LH-26	HM-1	Mean
Raw	478.33±1.51	540.68±1.33	502.00±2.05	503.33±1.67	483.33±1.88	520.33±1.41	504.66
Soaking (12h)	445.00±1.00 (-7)	512.00±1.17 (-5)	480.33±1.53 (-4)	469.38±1.43 (-7)	438.35±1.37 (-9)	478.00±1.20 (-8)	470.51
Dehulling (soaked)	370.33±2.13 (-23)	390.68±1.62 (-28)	390.33±2.03 (-22)	400.00±1.58 (-21)	462.68±1.33 (-25)	410.68±1.13 (-21)	404.11
Roasting	346.33±1.88 (-28)	400.00±1.07 (-26)	351.68±2.42 (-30)	346.56±2.11 (-31)	343.68±1.68 (-29)	395.68±1.37 (-24)	363.98
Germination (24h)	372.68±1.62 (-22)	418.00±1.96 (-23)	372.23±1.28 (-26)	406.69±1.67 (-21)	339.33±2.13 (-30)	362.45±2.47 (-28)	378.56
Pressure cooking	395.68±1.65 (-38)	318.00±1.72 (-41)	332.00±1.19 (-34)	270.36±2.37 (-46)	289.00±1.58 (-40)	375.68±2.59 (-42)	346.78
Microwave cooking	356.68±1.65 (-25)	451.00±1.72 (-20)	383.00±1.19 (-24)	386.33±2.37 (-23)	372.56±1.58 (-30)	405.68±2.59 (-22)	392.54
Mean	395.00	432.91	357.93	397.51	389.84	421.21	
CD (P≤0.05)	Variety: 12.80		Treatment: 9.86		Interaction (Variety X Treatment): 8.12		

Values are mean ± SD of three independent determinations
Figures in parentheses indicate per cent decrease (-) over the control values
CD (Critical difference). Differences of two means between the varieties / treatments exceeding this value are significant

Sprouting (24 h) was also considerably effective in decreasing the polyphenol content of all the six lentil genotypes which ranged from 21 to 30 per cent, respectively over

the control values. Maximum (30%) reduction was observed in LH-26 and minimum (21%) in LH-13 whereas other genotypes were also found at par in reduction of polyphenol contents.

Heat treatments like roasting, pressure cooking and microwave cooking also caused significant reduction in polyphenol contents. The extent of reduction was 24 to 39 per cent by roasting, 34 to 46 per cent by pressure cooking and 20 to 30 per cent by microwave cooking. Among the heat treatments, pressure cooking had a greater effect in the reduction of polyphenol contents.

4.2.4.3 Trypsin inhibitor : Trypsin inhibitors are present in considerable amount in legumes and are known to affect the digestibility of proteins. Unprocessed seeds of all the six lentil genotypes contained 490.48, 642.76, 582.68, 683.33, 630.58 and 537.33 TIA/g, respectively (Table 4.8). Highest trypsin inhibitor content was observed in Sapna and lowest in Garima genotype. Soaking (12 h) reduced the TIA by about 2 to 7 per cent, respectively in all the six lentil genotypes. A further reduction was found by dehulling process. The extent of reduction ranged from 5 to 9 per cent, respectively in all the lentil genotypes. Dehulling caused comparatively lower reduction in trypsin inhibitor activity as compared to phytic acid and polyphenol content. Sprouting for 24 h also had great effect on the reduction of TIA of all the lentil genotypes. It was ranged from 33 to 42 per cent, respectively in all the lentil genotypes. Among the genotypes, maximum decrease was observed in Garima and LH7-12 genotypes and minimum in LH-26 genotype.

Table 4.8 : Effect of processing and cooking treatments on trypsin inhibitor activity (TIA/g) of lentil genotypes (on dry matter basis)

Treatments	Garima	Sapna	LH7-12	LH-13	LH-26	HM-1	Mean
Raw	490.48±1.57	642.76±1.33	582.68±1.33	683.33±1.33	630.58±1.43	537.33±1.38	594.52
Soaking (12h)	465.00±1.09 (-5)	619.33±1.63 (-4)	549.68±1.68 (-6)	643.68±2.42 (-7)	600.33±1.33 (-5)	525.68±1.69 (-2)	567.27
Dehulling (soaked)	459.14±1.16 (-6)	605.66±1.28 (-6)	550.00±1.36 (-6)	623.66±2.68 (-9)	585.00±1.18 (-7)	509.33±1.33 (-5)	555.41
Roasting	329.18±1.21 (-39)	405.68±1.66 (-37)	414.21±1.25 (-30)	458.68±1.83 (-33)	406.68±1.49 (-36)	580.68±1.72 (-29)	432.51
Germination (24h)	289.21±1.54 (-42)	395.00±1.47 (-39)	338.35±1.63 (-42)	445.32±1.88 (-35)	422.68±1.37 (-33)	333.66±1.67 (-38)	370.70
Pressure cooking	268.26±2.12 (-45)	336.68±1.53 (-48)	285.30±1.58 (-51)	265.00±1.51 (-61)	255.66±1.65 (-59)	268.61±1.73 (-50)	279.91
Microwave cooking	315.74±1.33 (-36)	371.28±1.05 (-42)	358.68±1.67 (-39)	375.67±1.33 (-45)	383.33±1.23 (-39)	312.37±1.31 (-42)	352.84
Mean	373.85	482.34	439.85	485.90	469.18	438.23	
CD (P≤0.05)	Variety: 5.51		Treatment: 6.58			Interaction (Variety X Treatment): 5.18	

Values are mean ± SD of three independent determinations

Figures in parentheses indicate per cent decrease (-) over the control values
CD (Critical difference). Differences of two means between the varieties / treatments exceeding this value are significant.

Similarly, heat treatments like roasting, pressure cooking and microwave cooking also caused pronounced effect in TIA content of lentil genotypes. The extent of reduction was ranged from 29 to 37 per cent by roasting, 45 to 59 pe rcent by pressure cooking and 36 to 45 per cent by microwave cooking. Among the heat treatments, pressure cooking (moist heat) caused significantly higher reduction in all the three antinutrient content of lentil genotypes.

4.2.5 *In vitro* protein digestibility

In vitro protein digestibility was found 49.61 (Garima), 42.26 (Sapna), 47.72 (LH7-12), 48.83 (LH-13), 42.63 (LH-26) and 40.62 (HM-I) per cent, respectively in unprocessed (raw) lentil genotypes (Table 4.9). A significant (P≤0.05) enhancement in protein digestibility occurred when the seeds were soaked in water for 12 h compared to unprocessed seeds. Leaching out of antinutrients such as protease inhibitors, phytic acid and polyphenols during soaking may account for improved digestibility of the soaked legumes. Upon dehulling, the protein digestibility of all lentil cultivars further improved from 11 to 17 per cent, respectively over the control values. Improvement in protein digestibility as a results of dehulling and soaking may be attributed to loss or leaching out of antinutrients.

Table 4.9 : Effect of processing and cooking treatments on *in vitro* protein digestibility (%) of lentil genotypes (on dry weight basis)

Treatments	Garima	Sapna	LH7-12	LH-13	LH-26	HM-1	Mean
Raw	49.61±0.07	42.26±0.37	47.72±0.15	48.83±0.17	42.63±0.42	40.62±0.03	45.27
Soaking (12h)	52.21±0.13 (+5)	45.17±0.12 (+7)	50.73±0.33 (+6)	51.25±0.26 (+5)	44.91±0.27 (+5)	43.14±0.10 (+6)	47.90
Dehulling (soaked)	55.89±0.23 (+13)	49.64±0.29 (+17)	53.28±0.08 (+12)	54.25±0.22 (+11)	47.54±0.32 (+12)	46.94±0.16 (+16)	51.64
Roasting	60.55±0.15 (+22)	50.72±0.32 (+20)	54.42±0.11 (+14)	52.94±0.12 (+18)	50.41±0.13 (+18)	44.15±0.21 (+19)	52.20
Germination (24h)	65.25±0.19 (+32)	56.93±0.06 (+34)	59.15±0.06 (+24)	61.14±.05 (+25)	55.84±0.29 (+31)	52.25±0.03 (+29)	58.42
Pressure cooking	64.55±0.25 (+42)	59.41±2.35 (+40)	61.93±0.18 (+30)	67.47±.33 (+38)	60.53±0.12 (+41)	56.08±0.15 (+38)	61.66
Microwave cooking	62.53±0.32 (+26)	51.82±0.17 (+22)	59.44±0.15 (+24)	59.09±0.13 (+21)	53.14±0.12 (+25)	50.35±0.13 (+24)	56.06
Mean	58.65	50.85	55.23	56.42	50.71	47.64	
CD (P≤0.05)	Variety : 1.55	Treatment: 1.60		Interaction (Variety X Treatment): 1.46			

Values are mean ± SD of three independent determinations
Figures in parentheses indicate per cent increase (+) over the control values
CD (Critical difference). Differences of two means between the varieties / treatments exceeding this value are significant.

Protein digestibility also increased significantly when the soaked seeds were sprouted for 24 h as compared to unprocessed seeds. The extent of increment was ranged from 24 to 34 per cent, respectively in lentil genotypes. Heat processing also significantly increased protein digestibility of all lentil genotypes might be by destroying heat labile protease inhibitors and also by denaturing globulins, highly resistant to proteases in the native state. Among the heat treatments, pressure cooking gave the highest protein digestibility (30 to 42%) followed by microwave cooking (21 to 26%) and roasting (14 to 22%).

4.2.6 *In vitro* starch digestibility

Starch digestibility (*in vitro*) expressed as mg maltose released/g flour, was ranged from 22.94 to 31.17 in raw (unprocessed) seeds of lentil cultivars (Table 4.10). Starch digestibility increased markedly on all processing and cooking methods. Soaking of seeds improved the starch digestibility by about 4 to 11 per cent, respectively in all genotypes over the control values. Dehulling of soaked seeds further improved the starch digestibility possibly due to reduction in antinutrients as these contributed lower starch digestibility. The extent of decrease was ranged from 13 to 21 per cent, respectively in all genotypes. Similarly, sprouting also caused significant improvement in *in vitro* starch digestibility of lentil genotypes. The increment in starch digestibility of all lentil genotypes ranged from 25 to 34 per cent, respectively over the control values. Increased starch digestibility after germination in expected because of the pre-digestion of starch molecules by amylolytic enzymes.

Table 4.10 : Effect of processing and cooking treatments on *in vitro* starch digestibility (mg maltose released/g flour) of lentil genotypes (on dry weight basis)

Treatments	Garima	Sapna	LH7-12	LH-13	LH-26	HM-1	Mean
Raw	32.17±0.09	25.63±0.12	30.14±0.15	29.94±0.13	23.64±0.10	22.94±0.10	27.41
Soaking (12h)	33.55±0.15 (+4)	27.73±3.16 (+8)	32.16±0.37 (+7)	31.54±0.12 (+5)	26.34±0.13 (+11)	25.55±0.13 (+11)	29.48
Dehulling (soaked)	36.24±0.10 (+13)	29.96±0.23 (+17)	34.94±0.10 (+16)	33.74±0.12 (+13)	28.16±0.07 (+19)	27.73±0.27 (+21)	31.46
Roasting	36.03±0.22 (+13)	28.51±0.33 (+11)	33.76±0.23 (+12)	34.96±0.05 (+16)	27.93±0.23 (+18)	26.78±0.16 (+17)	31.32
Germination (24h)	43.26±0.19 (+34)	32.09±0.29 (+25)	39.00±0.09 (+29)	39.04±0.10 (+30)	30.53±0.26 (+29)	29.91±0.18 (+30)	35.63
Pressure cooking	43.85±0.12 (+36)	35.93±0.13 (+40)	39.24±0.17 (+30)	40.24±0.15 (+37)	32.23±0.21 (+36)	30.62±0.26 (+33)	37.02
Microwave cooking	36.96±0.17 (+15)	33.57±0.15 (+13)	35.46±0.15 (+18)	35.77±0.27 (+19)	26.67±0.12 (+13)	28.63±0.13 (+15)	31.48
Mean	37.43	30.28	34.95	35.03	27.92	27.45	
CD (P≤0.05) Variety : 1.52 Treatment: 1.49 Interaction (Variety X Treatment): 2.32							

Values are mean ± SD of three independent determinations
Figures in parentheses indicate per cent increase (+) over the control values
CD (Critical difference). Differences of two means between the varieties / treatments exceeding this value are significant.

Heat treatments like roasting, pressure cooking and microwave cooking significantly (P≤0.05) increased the starch digestibility of lentil genotypes. Roasting caused enhancement by about 11 to 18 per cent, respectively over unprocessed seeds. Whereas pressure cooking was more effective in improving the starch digestibility which ranged from 30 to 40 per cent, respectively. Similarly, increment in starch digestibility was also observed on microwave cooking. The values ranged from 13 to 19 per cent, respectively in all genotypes. Among all the treatments, pressure cooking caused maximum enhancement in starch digestibility of cooked legumes.

4.2.7 Total and available minerals

Total and *in vitro* availability of iron, calcium, zinc and magnesium of raw and processed lentil genotypes are presented in Table 4.11 to 4.14.

4.2.7.1 Iron

Total iron content of six lentil genotypes ranged from 4.00 to 6.21 mg/100g, respectively (Table 4.11). Maximum iron content (6.21 mg/100g) was found in Garima and lowest 4.00 mg/100g was in HM-I genotype. On soaking, iron content was reduced by 2 to 6 per cent, respectively might be due to leaching out of minerals in soaking water. However, dehulling further caused significant reduction in iron content. The values ranged from 10 to 15 per cent, respectively in all the genotypes. As minerals mainly present in hulls might have been lost during dehulling. Whereas other treatments like sprouting, roasting, pressure cooking and microwave cooking caused non-significant change in total iron content.

In vitro availability of iron from unprocessed seeds of six lentil genotypes was 27.83, 25.77, 26.53, 24.41, 26.87 and 19.76 per cent, respectively. All the treatments including soaking, dehulling, sprouting and heat treatments enhanced *in vitro* availability of iron. Soaking (12 h) of seeds enhanced the availability of iron which ranged from 20 to 29 per cent, respectively over the control values. Dehulling of soaked seeds further increased *in vitro* availability of iron from 37 to 43 per cent, respectively in all the six lentil genotypes. Higher improvement was seen in Garima and lowest in HM-I genotype. Other genotypes were also found at par in improvement of *in vitro* availability of iron. This might be due to decrease in antinutrient contents mainly phytic acid and polyphenols during soaking and dehulling may partly account for improved availability of iron.

Sprouting also improved *in vitro* availability of iron, which ranged from 37 to 45 per cent, respectively. Maximum improvement was seen in Garima (45%) followed by Sapna (39%), LH7-12 (37%), LH-13 (42%), LH-26 (40%) and HM-I (44%), respectably. It might be due to catabolizaiton of antinutrients on germination leading to improvement in mineral availability.

All the three heat treatments like roasting, pressure cooking and microwave cooking caused significant ($P \leq 0.05$) improvement in *in vitro* availability of iron. There was significant increase in *in vitro* availability of iron by roasting (20 to 27%), pressure cooking (52 to 69%) and by microwave cooking (33 to 39%) in all the lentil genotypes. Pressure cooking found more effective in improving the *in vitro* availability of iron as moist heating improved the availability of iron of lentil genotypes to a greater extent than other treatments. This increment in iron availability might be due to destruction of antinutrients on heat treatment.

4.2.7.2 Calcium

Total and *in vitro* availability of Ca from unprocessed and processed seeds of six lentil genotypes are presented in Table 4.12. Total Ca content of raw seeds ranged from 50.29 to 74.22 mg/100g, respectively. Raw seeds were processed by employing various treatments

including soaking, dehulling, germination, roasting, pressure cooking and microwave

Table 4.11 : Effect of processing and cooking treatments on total (mg/100 g) and *in vitro* availability (%) of iron of lentil genotypes (on dry weight basis)

Treatments	Total Iron							Available iron						
	Garima	Sapna	LH7-12	LH-13	LH-26	HM-1	Mean	Garima	Sapna	LH7-12	LH-13	LH-26	HM-1	Mean
Raw	6.21±0.03	5.19±0.03	5.12±0.05	4.89±0.09	5.73±0.15	4.00±0.01	5.19	27.83±0.15	25.77±0.10	26.53±0.10	24.41±0.20	26.87±0.19	19.76±0.12	28.52
Soaking (12h)	6.00±0.13 (-3)	5.07±0.05 (-2)	5.09±0.03 (-6)	4.62±0.15 (-6)	5.60±0.03 (-2)	3.85±0.05 (-4)	5.03	33.34±0.14 (+20)	32.44±0.17 (+26)	31.44±0.17 (+29)	30.24±0.19 (+24)	33.54±0.12 (+25)	26.28±0.10 (+28)	32.74
Dehulling (soaked)	5.45±0.04 (-12)	4.52±0.10 (-13)	4.40±0.04 (-14)	4.16±0.05 (-15)	5.15±0.01 (-10)	3.47±0.07 (-13)	4.52	39.73±0.26 (+43)	35.53±0.21 (+38)	36.63±0.21 (+38)	31.33±0.24 (+35)	35.66±0.16 (+39)	27.14±0.13 (+37)	35.76
Roasting	6.20±0.00 (-0.16)	5.12±0.07 (-1)	5.11±0.03 (-0.19)	4.81±0.07 (-2)	5.70±0.03 (-1)	4.00±0.00 (-0)	5.15	32.46±0.15 (+27)	32.49±0.19 (+26)	30.46±0.19 (+25)	29.41±0.19 (+22)	32.75±0.15 (+23)	30.25±0.05 (+20)	30.56
Germination (24h)	6.14±0.01 (-1)	5.10±0.03 (-2)	5.09±0.09 (-1)	4.73±0.03 (-3)	5.63±0.06 (-2)	3.90±0.13 (-0.3)	5.09	38.38±0.05 (+45)	35.88±0.00 (+39)	36.38±0.00 (+37)	35.34±0.10 (+42)	37.68±0.20 (+40)	32.45±0.13 (+44)	36.00
Pressure cooking	6.14±0.07 (-0.32)	5.16±0.05 (-1)	5.00±0.01 (-2)	4.80±0.03 (-3)	5.67±0.07 (-1)	3.89±0.03 (-3)	5.11	45.47±0.20 (+63)	42.51±0.24 (+65)	41.30±0.24 (+66)	38.30±0.14 (+69)	40.73±0.24 (+52)	37.78±0.09 (+60)	42.52
Microwave cooking	6.20±0.15 (-0.16)	5.16±0.00 (-1)	5.06±0.07 (-1)	4.79±0.00 (-2)	5.70±0.05 (-1)	3.97±0.04 (-1)	5.80	38.24±0.15 (+39)	36.74±0.17 (+37)	35.34±0.17 (+33)	34.64±0.11 (+35)	36.54±0.11 (+34)	33.64±0.07 (+35)	38.78
Mean	6.04	5.05	4.98	4.68	5.59	3.34	4.94	38.20	34.75	33.88	35.37	37.30	27.53	
	CD (P≤0.05)	Variety: 0.24	Treatment: 0.32	Interaction (Variety X Treatment): 0.43				CD (P≤0.05)	Variety: 0.54	Treatment: 0.35	Interaction (Variety X Treatment): 0.20			

Values are mean ± SE of three independent determinations

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

CD (Critical difference). Differences of two means between the varieties / treatments exceeding this value are significant

Table 4.12 : Effect of processing and cooking treatments on total (mg/100 g) and *in vitro* availability (%) of calcium of lentil genotypes (on dry weight basis)

Treatments	Total calcium							Available calcium						
	Garima	**Sapna**	**LH7-12**	**LH-13**	**LH-26**	**HM-1**	**Mean**	**Garima**	**Sapna**	**LH7-12**	**LH-13**	**LH-26**	**HM-1**	**Mean**
Raw	74.22±0.13	71.33±0.18	51.34±0.10	53.47±0.26	53.22±0.19	50.29±0.17	69.98	30.42±0.16	26.83±0.12	29.73±0.28	28.37±0.17	27.74±0.16	24.82±0.17	26.88
Soaking (12h)	70.20±0.33 (-5)	67.19±0.27 (-6)	48.32±0.20 (-6)	50.86±0.20 (-5)	49.15±0.17 (-8)	46.20±0.20 (-8)	67.65	34.54±0.27 (+14)	29.46±0.23 (+13)	31.75±0.17 (+17)	33.35±0.17 (+18)	30.62±0.27 (+12)	27.93±0.23 (+13)	31.24
Dehulling (soaked)	66.17±0.27 (-18)	59.03±0.26 (-17)	40.60±0.20 (-21)	42.90±0.10 (-19)	41.04±0.23 (-22)	40.13±0.25 (-20)	66.62	37.21±0.36 (+22)	33.73±0.13 (+24)	36.63±0.26 (+23)	35.68±0.28 (+23)	33.55±0.12 (+21)	29.64±0.13 (+19)	35.49
Roasting	74.20±0.23 (-0.02)	71.07±0.13 (-0.04)	51.30±0.27 (-0.07)	53.00±0.23 (-0.87)	53.07±0.27 (-0.28)	50.10±0.37 (-0.37)	58.79	33.47±0.19 (+12)	30.92±0.25 (+15)	32.44±0.17 (+19)	34.74±0.19 (+12)	31.32±0.17 (+12)	26.37±0.29 (+16)	30.90
Germination (24h)	74.00±0.10 (-0.29)	71.00±0.15 (-0.46)	50.38±0.30 (-2.61)	52.90±0.13 (-0.87)	53.17±0.19 (-0.09)	50.00±0.23 (-0.57)	58.57	37.51±0.17 (+28)	33.57±0.28 (+26)	38.38±0.13 (+29)	37.28±0.23 (+31)	34.96±0.29 (+26)	31.55±0.17 (+27)	44.23
Pressure cooking	74.10±0.20 (-0.16)	70.94±0.12 (-0.54)	50.03±0.25 (-0.60)	53.27±0.17 (-0.37)	52.90±0.16 (-0.60)	49.26±0.27 (-2)	58.41	41.32±0.31 (+41)	37.68±0.17 (+40)	40.62±0.10 (+37)	39.32±0.20 (+39)	36.76±0.22 (+35)	34.81±0.30 (+40)	32.85
Microwave cooking	74.12±0.27 (-0.13)	70.99±1.20 (-0.47)	50.22±0.23 (-2)	52.82±0.20 (-1)	53.12±0.21 (-0.57)	50.00±0.13 (-0.57)	58.54	34.22±0.15 (+29)	34.62±0.22 (+29)	35.72±0.13 (+26)	35.52±0.13 (+25)	35.15±0.12 (+28)	28.21±0.15 (+24)	30.69
Mean	72.43	68.79	48.89	51.31	50.81	47.99		37.75	33.35	31.74	35.03	34.01	28.85	
	CD (P≤0.05)	Variety: 2.16	Treatment: 2.18	Interaction (Variety X Treatment): 2.43				CD (P≤0.05)	Variety: 0.16	Treatment: 0.18	Interaction (Variety X Treatment): 0.23			

Values are mean ± SE of three independent determinations

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

CD (Critical difference). Differences of two means between the varieties / treatments exceeding this value are significant

Table 4.13 : Effect of processing and cooking treatments on total (mg/100 g) and *in vitro* availability (%) of zinc of lentil genotypes (on dry weight basis)

Treatments	Total zinc							Available zinc						
	Garima	Sapna	LH7-12	LH-13	LH-26	HM-1	Mean	Garima	Sapna	LH7-12	LH-13	LH-26	HM-1	Mean
Raw	5.12±0.01	4.72±0.06	4.73±0.07	4.68±0.02	3.87±0.09	2.33±0.13	4.66	27.14±0.37	25.59±0.33	22.23±0.12	24.14±0.21	25.14±0.23	17.53±0.06	22.11
Soaking (12h)	4.65±0.03 (-9)	4.47±0.08 (-5)	4.51±0.03 (-5)	4.48±0.06 (-4)	3.71±0.10 (-5)	2.11±0.00 (-9)	3.98	30.26±0.20 (+16)	28.52±0.25 (+11)	25.16±0.01 (+15)	27.63±0.53 (+14)	27.63±0.43 (+10)	19.56±0.02 (+10)	24.24
Dehulling (soaked)	4.52±0.05 (-12)	4.27±0.07 (-10)	4.21±0.00 (-11)	4.08±0.07 (-13)	3.41±0.03 (-12)	2.05±0.03 (-12)	3.75	32.58±0.43 (+23)	30.43±0.48 (+19)	28.65±0.08 (+23)	29.17±0.41 (+21)	28.17±0.21 (+22)	21.49±0.03 (+20)	27.22
Roasting	5.06±0.09 (-1)	4.68±0.08 (-1)	4.69±0.13 (-1)	4.66±0.05 (-3)	3.85±0.02 (-2)	2.31±0.07 (-1)	4.21	29.32±0.30 (+28)	27.29±0.33 (+29)	27.17±0.09 (+27)	28.42±0.30 (+20)	29.42±0.10 (+23)	22.47±0.07 (+24)	27.34
Germination (24h)	5.09±0.09 (-1)	4.65±0.01 (-1)	4.70±0.05 (-0.63)	4.62±0.11 (-1)	3.85±0.07 (-2)	2.30±0.00 (-1)	4.20	35.16±0.35 (+38)	32.95±0.32 (+29)	29.79±0.05 (+33)	31.58±0.23 (+31)	33.15±0.13 (+36)	24.15±0.01 (+30)	31.13
Pressure cooking	5.08±0.00 (-1)	4.60±0.03 (-2)	4.67±0.09 (-1)	4.60±0.09 (-2)	3.84±0.03 (-2)	2.30±0.10 (-1)	4.18	40.97±0.21 (+51)	38.37±0.24 (+50)	34.93±0.09 (+46)	33.14±0.17 (+47)	37.14±0.27 (+48)	29.54±0.01 (+49)	32.29
Microwave cooking	5.08±0.05 (-1)	4.69±0.11 (-0.89)	4.70±0.01 (-0.63)	4.61±0.07 (-1)	3.87±0.00 (-2)	2.29±0.00 (-2)	4.21	33.54±0.42 (+25)	29.74±0.45 (+19)	31.17±0.07 (+23)	31.17±0.37 (+25)	29.17±0.31 (+24)	22.00±0.03 (+25)	28.42

Mean	4.94	4.58	4.60	4.53	3.22	2.24		32.71	30.41	24.00	29.32	29.97	25.88	
CD (P≤0.05) Variety: 0.39 Treatment: 0.08 Interaction (Variety X Treatment): 0.64								CD (P≤0.05) Variety: 0.29 Treatment: 0.70 Interaction (Variety X Treatment): 0.24						

Values are mean ± SE of three independent determinations

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

CD (Critical difference). Differences of two means between the varieties / treatments exceeding this value are significant

cooking. Among the various treatments, only soaking and dehulling caused significant change in total Ca content. Soaking caused reduction by about 5 to 8 per cent, respectively whereas dehulling further caused reduction in total Ca by about 17 to 20 per cent, respectively in all genotypes. Other treatments caused negligible reduction in Ca content of all genotypes.

In vitro availability of Ca ranged from 24.82 to 30.42 per cent, respectively in unprocessed seeds of lentil genotypes. As in case of iron availability, Ca availability was also enhanced on all processing and cooking treatments. The extent of enhancement in Ca availability ranged from 12 to 18 per cent (soaking), 19 to 24 per cent (dehulling), 26 to 31 per cent (sprouting), 12 to 19 per cent (roasting), 35 to 41 per cent (pressure cooking) and 24 to 29 per cent (microwave cooking), respectively in all the lentil genotypes. Among the treatments, pressure cooking caused maximum enhancement in Ca availability.

4.2.7.3 Zinc

Total and *in vitro* availability of Zn of unprocessed seeds of lentil genotypes are given in Table 4.13. Unprocessed (raw) seeds of six lentil genotypes contained total Zn in the range of 2.33 to 5.12 mg/100g, respectively. Garima genotype was found to be superior than other genotypes. It had maximum total Zn (5.12 mg/100g) content followed by Sapna (4.72 mg/100g), LH7-12 (4.73 mg/100g), LH-13 (4.68 mg/100g), LH-26 (3.87 mg/100g) and HM-I (2.33 mg/100g). Soaking and dehulling caused significant reduction in total Zn contents whereas other treatments did not have significant effect on total mineral contents of lentil genotypes. Soaking caused reduction which ranged from 4 to 9 per cent, respectively in all lentil genotypes which might be due to leaching out of total Zn in soaking medium. Similarly, dehulling of soaked seeds also caused further reduction in total Zn content. It ranged from 10 to 13 per cent, respectively in all the genotypes. All the genotypes showed almost similar extent of reduction on dehulling might be due to removal of hulls which contained substantial amount of Zn. Other treatments like sprouting, roasting, pressure cooking and microwave cooking did not have significant effect on total Zn contents of all lentil genotypes.

In vitro availability of Zn from unprocessed lentil seeds ranged from 17.53 to 27.14 per cent, respectively. Maximum *in vitro* availability of Zn was found in Garima (27.14%) and minimum in HM-I (17.53%) genotype. Similarly as in case of Fe and Ca, Zn availability was also improved on processing and cooking methods. The extent of enhancement in Zn *in vitro* availability ranged from 10 to 16 per cent (soaking), 19 to 23 per cent (dehulling), 29 to 38 per cent (germination), 19 to 23 per cent (roasting), 46 to 51 per cent (pressure cooking)

and 19 to 25 per cent (microwave cooking). Pressure coking was found to be most effective treatment for improving the *in vitro* availability of Zn.

4.2.7.4 Magnesium

Total Mg content of unprocessed lentil genotypes are presented in Table 4.14. Total Mg content of all the six unprocessed lentil genotypes varied significantly ($P<0.05$) from 53.34 to 68.27 mg/100g, respectively. Garima genotypes had maximum (68.27 mg/100g) and Sapna genotype (53.34 mg/100g) had minimum Mg content. When all the lentil genotypes were subjected to various processing and cooking treatments, behaved in a similar way. Soaking for 12 h caused significant reduction in all the four minerals which ranged from 4 to 9 per cent, respectively. Dehulling caused further reduction in all minerals. The extent of reduction was ranged from 9 to 16 per cent, respectively. Whereas other treatments like roasting, germination, pressure cooking and microwave cooking did not have any significant effect on total minerals contents.

Table 4.14 : Effect of processing and cooking treatments on total magnesium (mg/100 g) content of lentil genotypes (on dry weight basis)

Treatments	Garima	Sapna	LH7-12	LH-13	LH-26	HM-1	Mean
Raw	68.27±0.13	53.34±0.18	69.71±0.10	67.53±0.26	55.68±0.19	62.66±0.17	63.86
Soaking (12h)	65.55±0.22 (-4)	50.34±0.27 (-6)	64.24±0.20 (-8)	61.28±0.20 (-9)	50.67±0.17 (-9)	59.66±0.20 (-5)	59.76
Dehulling (soaked)	60.12±0.27 (-12)	48.58±0.26 (-9)	60.12±0.20 (-14)	58.90±0.10 (-13)	46.92±0.23 (-16)	53.27±0.47 (-15)	58.15
Roasting	67.58±0.23 (-1)	53.96±0.13 (-0.83)	68.24±0.27 (-2)	66.80±0.23 (-1)	53.92±0.09 (-3)	61.87±0.23 (-1)	62.06
Germination (24h)	68.00±0.29 (-0.3))	53.10±0.27 (-0.45)	69.20±0.19 (-0.72)	67.20±0.18 (-0.49)	55.48±0.23 (-0.39)	62.48±0.20 (-0.28)	62.58
Pressure cooking	68.14±0.30 (-0.19)	53.08±0.19 (-0.49)	69.33±0.19 (-0.72)	67.26±0.17 (-0.42)	55.36±0.33 (-0.58)	62.16±0.27 (-0.82)	62.56
Microwave cooking	68.02±0.21 (-0.35)	53.01±0.13 (-0.62)	69.34±0.21 (-0.52)	66.95±0.11 (-0.86)	55.19±0.33 (-0.89)	62.24±0.17 (-0.67)	62.46
Mean	66.53	52.20	67.17	65.13	53.31	60.62	
CD ($P\leq0.05$) Variety: 1.12 Treatment: 1.19 Interaction (Variety X Treatment): 2.91							

Values are mean ± SE of three independent determinations
Figures in parentheses indicate per cent decrease (-) over the control values
CD (Critical difference). Differences of two means between the varieties / treatments exceeding this value are significant

4.3 Organoleptic evaluation of value added products

Different lentil based products were organoleptically evaluated in terms of colour, appearance, aroma, texture, taste and overall acceptability (Table 4.15 to 4.19). On the basis

of physico-chemical and nutritional characteristics, Garima genotype found superior and selected for product development. Various products such as *dal*, soup, roasted *dal, dhokla, bhalle*, chat, cutlet, *papad, sev*, biscuits and bread were developed by using various processing methods.

Dal and soup were made by using boiling method. *Dal* was found highly acceptable by the panelists as compared to soup. *Dal* had mean scores of colour (8.20), appearance (8.25), aroma (8.05), texture (8.25) and taste (8.15) which were found in the category of 'liked very much' whereas, soup had 7.00 mean scores of overall acceptability score which was fell in the category of 'liked moderately'. Roasted *dal* was also 'liked very much' by the panelists.

Table 4.15: Organoleptic characteristics of boiled and roasted products

Products	Colour	Appearance	Aroma	Texture	Taste	Over all acceptability
Boiled						
Dal	8.20± 0.11	8.25±0.13	8.05±0.16	8.25±0.11	8.15±0.18	8.15±0.12
Soup	6.90± 0.21	6.95±0.25	6.80±0.21	6.95±0.15	7.15±0.15	7.00±0.17
Roasted *dal*	8.35± 0.21	8.45±0.21	8.55±0.24	8.65±0.21	8.65±0.10	8.45±0.11

Values are mean ± SD of ten independent determinations

Dhokla and *Bhalle* are the fermented product prepared using fermentation process. *Dhokla* prepared from dehulled bengal gram flour (*besan*) served as control. In test samples bengal gram flour was replaced by dehulled lentil flour at 40, 50 and 60 per cent levels, respectively. Three types of *dhokla* such as type-I (60:40), type-II (50:50) and type-III (40:60) were prepared and compared with control sample. Control *dhokla* had 7.70 mean score of overall acceptability which fell in the category of 'liked moderately' whereas among the test samples, type-I (60:40) *dhokla* was found at par with control. Type I *dhokla* had mean scores of colour (7.25), appearance (7.45), aroma (7.15), texture (7.30) and taste (7.35), in the category of 'liked moderately'. Whereas type-I and type-II *dhokla* exhibited 6.80 and 5.85 mean scores of overall acceptability which fell in the category of 'liked slightly' and 'neither liked nor disliked', respectively. Both type of *dhokla* were found significantly ($P \leq 0.05$) different from control *dhokla*. Similar, trend was also observed in case of *bhalle* fermented product. *Bhalle* prepared from dehulled blackgram flour served as control. Three types of *bhalle* like type-I (60:40), type-II (50:50) and type-III (40:60) were prepared by supplementation of dehulled lentil flour at 40, 50 and 60 per cent, respectively. Control *bhalle* had mean scores of colour (8.20), appearance (8.15), aroma (8.15), texture (8.25), taste

(8.15) and overall acceptability (8.17), fell in the category of 'liked very much'. Among the three types of dehulled lentil flour supplemented *bhalle*, type-I (60:40) and type-II (50:50) *bhalle* had mean scores of overall acceptability were 7.80 and 7.30, respectively and found in the category of 'liked moderately'. However, type-III (40:60) *bhalle* had significantly ($P \leq 0.05$) lowest mean scores of colour (6.10), appearance (6.00), aroma (6.85), texture (6.20), taste (6.15) and overall acceptability (6.75), these scores found in the category of 'liked slightly' by the panelists.

Table 4.16: Organoleptic characteristics of fermented products

Values are mean ± SD of ten independent determinations

Products	Colour	Appearance	Aroma	Texture	Taste	Over all acceptability
Dhokla						
Control (Dehulled bengal gram flour)	7.60± 0.16	7.66±0.22	7.65±0.13	7.70±0.20	7.95±0.16	7.70±0.10
Type-I (DBF: DLF::60:40)	7.25± 0.26	7.45±0.16	7.15±0.18	7.30±0.20	7.35±0.20	7.30±0.14
Type-II (DBF: DLF::50:50)	7.00± 0.20	6.90±0.23	6.75±0.19	7.80±0.17	6.65±0.15	6.80±0.13
Type-III (DBF:DLF::40:60)	6.00± 0.18	5.95±0.16	6.15±0.13	5.25±0.23	5.51±0.19	5.85±0.18
CD (P≤0.05)	0.42	0.39	0.78	0.23	0.19	0.12
Bhalle						
Control (Dehulled black gram flour)	8.20± 0.11	8.15±0.12	8.15±0.13	8.25±0.08	8.15±0.21	8.17±0.10
Type-I (DBF: DLF::60:40)	7.90± 0.07	7.55±0.14	8.15±0.11	7.65±0.15	7.95±0.25	7.80±0.17
Type-II (DBF: DLF::50:50)	7.25± 0.27	7.50±0.13	7.15±0.21	7.25±0.23	7.35±0.20	7.30±0.13
Type-III (DBF: DLF::40:60)	6.10± 0.21	6.00±0.11	6.85±0.23	6.20±0.18	6.15±0.19	6.75±0.18
CD (P≤0.05)	1.00	0.65	1.30	1.10	0.89	0.72

DBF- Dehulled bengal gram flour
DBF- Dehulled black gram flour
DLF- Dehulled lentil flour

Two types of nutritious *chat* and cutlets were prepared by using sprouting process. Sprouted green gram served as control for both the products. *Chat* and cutlets prepared from sprouted lentil were significantly differed in terms of colour, appearance, texture, and taste from their control samples. Control samples exhibited mean scores of overall acceptability were 7.85 and 8.09, respectively. Whereas *chat* and cutlet based on sprouted lentil had 7.09 and 7.75 mean scores of overall acceptability which were found in the category of 'liked moderately'.

Table 4.17 : Organoleptic characteristics of sprouted products

Products	Colour	Appearance	Aroma	Texture	Taste	Over all acceptability
Chat						
Control (Sprouted green gram)	8.10± 0.11	8.15±0.29	7.85±0.11	8.15±0.25	7.85±0.21	7.85±0.23
Type-I (Sprouted lentil)	6.90± 0.24	7.05±0.23	6.90±0.19	7.20±0.17	7.40±0.16	7.09±0.15
't' value	1.44	0.99	0.89	1.00	0.20	0.69
Cutlets						
Control (Sprouted green gram+spinach+potato)	8.20± 0.11	8.15±0.19	8.00±0.17	8.15±0.15	7.95±0.16	8.09±0.13
Type-I (Sprouted lentil+spinach+potato)	7.60± 0.16	7.65±0.22	7.85±0.13	7.70±0.20	7.05±0.20	7.75±0.11
't' value	1.10	1.32	1.25	1.13	1.01	0.87

Values are mean ± SD of ten independent determinations

Two types of fried products namely *papad* and *sev* were developed. *Papad* prepared from dehulled black gram flour served as control. Control sample had mean scores of colour (7.85), appearance (7.75), aroma (7.75), texture (7.90), taste (7.75) and overall acceptability (7.85). Three types of *papad* were made by replacing dehulled black gram flour with dehulled lentil flour at 40, 50 and 100 per cent levels, respectively. Type-I (60:40) and type-II (50:50)

papad had significantly higher mean scores of taste i.e. 7.15 and 7.70, respectively as compared to control (7.75). Whereas type-III (0:100) prepared from dehulled lentil flour exhibited lowest mean scores of colour (5.95), appearance (5.90), aroma (6.00), texture (6.15), taste (5.65) and overall acceptability (5.85), fell in the category of 'neither liked nor disliked'. Among the three types of *papad*, type-I and type-II were found organoleptically acceptable by the panelists.

Table 4.18: Organoleptic characteristics of fried products

Products	Colour	Appearance	Aroma	Texture	Taste	Over all acceptability
Papad						
Control (Dehulled black gram flour)	7.85± 0.21	7.75±0.24	7.75±0.17	7.90±0.16	8.15±0.19	7.88±0.10
Type-I (DBF:DLF::60:40)	7.80± 0.08	7.55±0.28	7.75±0.28	7.60±0.21	7.95±0.11	7.73±0.12
Type-II (DBF:DLF::50:50)	7.75± 0.17	7.25±0.11	7.55±0.19	7.65±0.15	7.70±0.21	7.65±0.13
Type- III (DBF:DLF::00:100)	5.95± 0.21	5.90±0.23	6.00±0.23	6.15±0.18	5.65±0.22	5.85±0.22
CD (P≤0.05)	0.92	1.00	0.52	0.20	1.02	0.83
Sev						
Control (Dehulled bengal gram flour)	8.50± 0.14	8.55±0.34	8.45±0.25	8.60±0.12	8.55±0.16	8.55±0.22
Type- I (DBF:DLF::60:40)	7.65± 0.18	7.55±0.28	7.45±0.32	7.75±0.19	7.95±0.22	7.85±0.21
Type- II (DBF:DLF::50:50)	7.60± 0.16	7.60±0.22	7.50±0.22	7.55±0.21	7.50±0.19	7.65±0.19
Type- III (DBF:DLF::00:100)	7.55± 0.21	7.35±0.32	7.85±0.12	7.60±0.16	7.45±0.21	7.65±0.17
CD (P≤0.05)	1.1	0.75	0.69	0.70	0.45	0.25

Values are mean ± SD of ten independent determinations
DBF- Dehulled black gram flour
DBF- Dehulled bengal gram flour
DLF- Dehulled lentil flour

Sev was prepared by using dehulled bengal gram flour (*besan*) served as control. Control *sev* was found highly acceptable in terms of colour (8.50), appearance (8.55), aroma (8.45), texture (8.60), taste (8.55) and overall acceptability (8.55) and found in the category of 'liked very much'. Three types of *sev* were prepared by replacing dehulled bengal gram flour by dehulled lentil flour at 40, 50 and 100 per cent levels, respectively. All the three types of *sev* had 7.85, 7.65 and 7.65 mean scores of overall acceptability. These scores differed significantly (P≤0.05) from control sample and found in the category of 'liked moderately'.

Baked products like biscuits and bread were developed by supplementation of dehulled lentil flour with whole wheat flour and refined wheat flour, respectively. Control biscuits made from whole wheat flour exhibited mean scores of colour, appearance, aroma, texture and taste 8.30, 8.20, 8.10, 8.30 and 8.20, respectively, fell in the category 'liked very much' by the panelists. Two types of test samples type I and type-II were prepared by supplementation of dehulled lentil flour 40 and 50 per cent levels, respectively. Type-I

biscuits found at par with the control biscuits in terms a colour, appearance, aroma, texture and taste and found in the category of 'liked very much' whereas type-II biscuits exhibited overall acceptability score 7.50 found in the category of 'liked moderately' by the judges. Hence, biscuits can be prepared by replacing wheat flour with lentil flour up to 50 per cent without adversely affecting the overall acceptability score. Bread prepared from refined wheat flour served as control. Two types of bread type-I and type-II were prepared by replacing refined wheat flour at 30 and 40 percent levels, respectively. Control bread had overall acceptability score 7.35 which found in the category of 'liked moderately' whereas type-I and type-II bread exhibited overall acceptability scores i.e. 6.80 and 5.45 found in the category of 'liked slightly' and 'neither liked nor disliked' by the judges. Hence, significant reduction was observed in all sensory attributes of bread at 40 per cent levels of lentil flour supplementation.

Table 4.19: Organoleptic characteristics of baked products

Products	Colour	Appearance	Aroma	Texture	Taste	Over all acceptability
Biscuits						
Control (Whole wheat flour)	8.30± 0.15	8.20±0.13	8.10±0.18	8.30±0.15	8.20±0.25	8.25±0.15
Type-I (WWF:DLF::60:40)	8.25± 0.13	8.30±0.11	8.10±0.18	8.20±0.18	8.25±0.15	8.15±0.11
Type-II (WWF:DLF::50:50)	7.70± 0.21	7.40±0.16	7.60±0.12	7.40±0.22	7.45±0.16	7.50±0.13
CD (P≤0.05)	0.78	0.76	0.49	0.32	0.15	0.29
Bread						
Control (Refined wheat flour)	7.35± 0.17	7.60±0.18	7.20±0.26	6.95±0.13	7.30±0.15	7.35±0.12
Type-I (RWF: DLF::70:30)	7.00± 0.20	6.90±0.23	6.75±0.19	6.80±0.17	6.65±0.18	6.80±0.13
Type-II (RWF: DLF::60:40)	6.50± 0.21	5.60±0.21	5.45±0.27	5.15±0.17	4.60±0.19	5.45±0.15
CD (P≤0.05)	0.70	0.45	0.39	0.55	2.10	1.75

Values are mean ± SD of ten independent determinations
WWF- Whole wheat flour
RWF- Refined wheat flour
DLF- Dehulled lentil flour

4.4 Shelf life

Among the developed products, four products namely biscuits, *sev, papad* and roasted lentil *dal* were selected for storage upto 2 months depending on their storability. The stored products were organoleptically evaluated and analyzed for fat acidity and peroxide value at 15 days interval.

4.4.1 Organoleptic evaluation

Stored products were organoleptically evaluated at an interval of 15 days during the storage period i.e. for 60 days at 29-30^{0}C by a panel of 10 judges using 9-point Hedonic Scale. The results of sensory evaluation are presented in Table 4.20 to 4.23.

4.4.1.1 Biscuits

Control biscuits were made from 100 per cent whole wheat flour and two test samples namely type-I (60:40) and type-II (50:50) were made with supplementation of dehulled lentil flour in whole wheat flour at 40 and 50 per cent levels, respectively. Control biscuits exhibited mean scores of colour (8.30), appearance (8.20), aroma (8.10), texture (8.30), taste (8.20) and overall acceptability (8.25) at 0 day. However, no significant change was observed in organoleptic attributes upto 30 days of storage in aroma and taste i.e. 7.25 and 7.80 was found in 'liked moderately' category on 30th day. 0n 45th day of storage, non-significant change was observed in colour, appearance and texture whereas, significant reduction was observed in mean scores of aroma and taste i.e. 6.80 and 6.83, respectively and found in the category of 'liked slightly'. In type-I biscuits (60:40) the mean scores in terms of colour, appearance, aroma, texture, taste and overall acceptability were 7.70, 7.40, 7.60, 7.40, 7.40 and 7.50, respectively at 0 day whereas no such remarkable difference was observed on 15th day. On 30th and 45 day significant difference was observed in all organoleptic attributes.

Table 4.20: Sensory evaluation of stored biscuits

Biscuits	Storage period	Colour	Appearance	Aroma	Texture	Taste	Over all acceptability
Control (WWF -100%)	0 days	8.30± 0.15	8.20± 0.13	8.10± 0.18	8.30±0.15	8.20± 0.25	8.25± 0.15
	15 days	8.25± 0.13	8.15± 0.16	8.05± 0.16	8.10±0.21	8.15±0.18	8.13±0.14
	30 days	8.15± 0.18	8.05± 0.16	7.25± 0.10	8.00±0.18	7.80±0.26	8.08±0.16
	45 days	8.00± 0.13	8.00± 0.15	6.80± 0.17	7.13±0.19	6.83±0.22	7.29±0.15
	CD(P≤0.05)	NS	NS	0.21	NS	0.42	0.32
Type- I WWF:DLF (60:40)	0 days	7.70± 0.21	7.40± 0.16	7.60± 0.18	7.40±0.22	7.40±0.16	7.50±0.13
	15 days	7.60± 0.22	7.30± 0.22	7.45± 0.12	7.10±0.35	7.10±0.24	7.32±0.19
	30 days	6.50± 0.21	6.50± 0.21	6.15± 0.21	6.50±0.21	6.55±0.17	6.51±0.16
	45 days	6.03± 0.20	5.93± 0.19	5.90± 0.18	6.00±0.28	6.01±0.18	5.97±0.13
	CD(P≤0.05)	0.39	0.42	0.38	0.51	0.39	0.45
Type- II WWF:DLF (50:50)	0 days	8.25± 0.13	8.30± 0.11	8.10± 0.18	8.20±0.13	8.25±0.15	8.17±0.11
	15 days	8.15± 0.18	8.05± 0.16	7.85± 0.16	8.10±0.18	8.15±0.16	8.08±0.14
	30 days	7.60± 0.21	7.60± 0.18	6.50± 0.15	7.45±0.17	7.65±0.17	7.48±0.13
	45 days	7.00± 0.17	6.98± 0.15	6.48± 0.17	6.91±0.16	6.01±0.15	6.67±0.11

	CD(P≤0.05)	0.29	0.22	0.39	0.32	0.52	0.37

Values are mean ± SD of ten independent determination
NS- Non- significant
WWF-Whole wheat flour
DLF-Dehulled lentil flour

Type-I biscuits had mean scores of colour (6.03), appearance (5.93), aroma (5.90), texture (6.00), taste (6.01) and overall acceptability (5.97) on 45th day of storage. This showed that storage upto 45 day caused significant change in aroma and taste. In type-II (50:50) the mean scores of organoleptic characteristics such as colour (8.25), appearance (8.30), aroma (8.10), texture (8.20) and taste 8.25 on 0 day which were found at par with control on 0 day. No remarkable difference was observed on 15th day as in type-II but significant difference was observed on 30th and 45th day of storage. Maximum reduction was observed on 45th day in mean scores of colour, appearance, aroma, texture and taste i.e. 7.00, 6.98, 6.48, 6.91 and 6.01 in which mean scores of taste had maximum reduction whereas colour showed the minimum reduction. It was observed that as the time of storage increased the mean scores of overall acceptability got decreased i.e. 8.17, 8.08, 7.48 and 6.67 showing significant difference from 0 to 45 days.

4.4.1.2 *Sev*

Control *sev* prepared from dehulled bengal gram flour and two types of test samples namely type-I and type-II prepared by supplementation of dehulled lentil flour were stored for 45 days and organoleptically evaluated. Control *sev* had mean scores of colour (8.50), appearance (8.55), aroma (8.55), texture (8.60), taste (8.55) and overall acceptability (8.55) on 0 day and found in the category of 'liked very much' by the judges. On 15th day of storage also the mean scores of colour, appearance, texture, aroma, taste and overall acceptability was found at par with control. Whereas on 30th day of storage, there was significant reduction was observed in mean scores of colour (7.15), appearance (6.95), aroma (6.55), texture (7.30) and taste (7.45) but overall acceptability was found still in the category of 'liked moderately'. On 45th day of storage, significant change was occurred in mean scores of colour, appearance, aroma, texture and taste and fell in the category of 'liked slightly'.

Table 4.21: Sensory evaluation of stored *sev*

Sev	Storage period	Colour	Appearance	Aroma	Texture	Taste	Over all acceptability
Control (DBF-100%)	0 days	8.50±0.14	8.55±0.34	8.45±0.25	8.60± 0.12	8.55± 0.16	8.55 ±0.22
	15 days	8.35±0.12	8.35±0.12	8.15±0.12	8.50± 0.22	8.10± 0.12	8.30± 0.11
	30 days	7.15±0.15	6.95±0.16	6.55±0.19	7.30± 0.31	7.45± 0.29	7.35± 0.11
	45 days	6.00±0.14	6.61±0.14	6.38±0.15	6.13± 0.21	6.03± 0.17	6.23± 0.14
	CD(P≤0.05)	0.29	0.42	0.32	0.29	1.00	1.01
Type- I DBF:DLF (60:40)	0 days	7.65±0.16	7.55±0.28	7.45±0.32	7.75± 0.19	7.95± 0.22	7.85±0.21
	15 days	7.45±0.19	7.45±0.19	7.15±0.19	7.35± 0.11	7.30± 0.11	7.25± 0.15
	30 days	7.20±0.20	7.15±0.20	6.95±0.20	6.80± 0.16	6.85± 0.16	7.05± 0.16
	45 days	6.43±0.18	6.38±0.20	6.18±0.16	6.30± 0.16	6.36± 0.16	6.33± 0.17
	CD(P≤0.05)	0.27	0.62	1.01	0.26	0.78	0.48
Type- II DBF:DLF (50:50)	0 days	7.60±0.16	7.60±0.22	7.50±0.22	7.55±0.21	7.50±0.19	7.65±0.19
	15 days	7.45±0.16	7.50±0.26	7.35±0.26	7.25±0.23	7.25±0.20	7.35±0.25
	30 days	6.95±0.16	6.95±0.22	6.90±0.12	6.90±0.31	6.85±0.18	6.90±0.18
	45 days	6.43±0.18	6.35±0.26	6.25±0.13	6.23±0.23	6.20±0.18	6.29±0.20
	CD(P≤0.05)	1.02	0.86	0.48	0.39	0.76	0.23

Values are mean ± SD of ten independent determination
DBF-Dehulled bengal gram flour
DLF-Dehulled lentil flour

Type-I *sev* (60:40) had mean scores of colour (7.65), appearance (7.55), aroma (7.45), texture (7.75), taste (7.95) and overall acceptability (7.85) on 0 day and it was remained acceptable upto 15th day of storage. However, slight change was observed in colour (7.20), appearance (7.15) and overall acceptability (7.05) which found in the category

of 'liked moderately' but significant change was observed in aroma (6.95), texture (6.80) and taste (6.85) which found in the category of 'liked slightly'. On 45th day of storage, significant change was observed in all organoleptic attributes when compared to 0 day of storage. The values ranged from 6.18 to 6.43, respectively.

Type-II (50:50) *sev* exhibited mean scores of colour (7.60), appearance (7.60), aroma (7.50), texture (7.55), taste (7.50) and overall acceptability (7.65) these remained almost unchanged upto 15th day of storage. Whereas on 30th and 45th days of storage, there was significant reduction was observed in mean scores of all organoleptic attributed and found in the category of 'liked slightly'.

4.4.1.3 *Papad*

Control *papad* exhibited means scores of colour (7.85), appearance (7.75), aroma (7.75), texture (7.90), taste (8.15) and overall acceptability (7.80) with no major difference on 15th day of storage. It was observed that as the storage period increased the change in mean scores of all organoleptic attributes also increased. On 30th day, the mean scores of colour, appearance, aroma, texture, taste and overall acceptability were 6.95, 6.85, 6.80, 6.75, 7.30 and 6.80, respectively. Whereas, on 45th day 6.50, 6.36, 6.38, 6.43, 6.43 and 6.42 were observed, respectively. On both 30th and 45th days of storage, there was significant reduction in organoleptic attributes when compared to 0 day.

Table 4.22: Sensory evaluation of stored *papad*

Papad	Storage period	Colour	Appearance	Aroma	Texture	Taste	Over all acceptability
Control (DBF-100%)	0 days	7.85±0.20	7.75±0.24	7.75±0.17	7.90±0.16	8.15±0.20	7.80±0.10
	15 days	7.70±0.13	7.50±0.15	7.60±0.12	7.65±0.19	8.00±0.16	7.65±0.09
	30 days	6.95±0.15	6.85±0.21	6.80±0.12	6.75±0.20	7.30±0.08	6.80±0.15
	45 days	6.50±0.16	6.36±0.20	6.38±0.13	6.43±0.18	6.43±0.23	6.42±0.11
CD(P≤0.05)		1.02	0.75	0.39	0.89	0.92	0.59
Type- I DBF:DLF (60:40)	0 days	7.80±0.08	7.65±0.15	7.75±0.17	7.60±0.10	7.75±0.19	7.85±0.08
	15 days	7.65±0.15	7.25±0.24	7.25±0.28	7.15±0.21	7.65±0.24	7.60±0.12
	30 days	7.35±0.18	6.35±0.27	6.70±0.25	6.40±0.24	6.90±0.28	6.70±0.21
	45 days	6.60±0.14	6.08±0.22	6.23±0.23	6.05±0.18	6.82±0.15	6.36±0.14
CD(P≤0.05)		1.00	0.89	0.48	0.39	0.50	0.49
Type- II DBF:DLF (50:50)	0 days	7.75±0.17	7.25±0.11	7.55±0.19	7.66±0.15	7.90±0.11	7.66±0.12
	15 days	7.15±0.14	7.25±0.25	7.00±0.21	7.20±0.21	7.05±0.19	7.15±0.28
	30 days	6.20±0.21	6.30±0.15	6.85±0.18	6.65±0.24	6.35±0.20	6.05±0.24
	45 days	5.96±0.17	5.73±0.17	5.13±0.19	5.03±0.20	5.10±0.16	5.39±0.21
	CD(P≤0.05)	1.12	1.01	0.49	0.52	0.59	0.56

Values are mean ± SD of ten independent determinations
DBF-Dehulled black gram flour
DLF-Dehulled lentil flour
NS- Non- significant

On 0 day, in case of type-I *papad* (60:40) the mean scores of all organoleptic attributes such as colour, appearance, aroma, texture, taste and overall acceptability were 7.80, 7.65, 7.75, 7.60, 7.75 and 7.85, respectively. The mean scores of all attributes remained almost same on 15th day of storage. But on 30th day of storage, colour was not significantly affected but other parameters such as appearance, aroma, texture, taste and overall acceptability also affected significantly. The values of mean scores of colour (7.35), appearance (6.35), aroma (6.70), texture (6.40), taste (6.90) and overall acceptability (6.70) and fell in the category of 'liked slightly' as compared to 0 day which found in the category of 'liked moderately'. Similarly, further reduction in mean scores of all attributes were observed on 45th days of storage.

Similar trend was also observed in type-II *papad* (50:50) on 0, 15, 30 and 45 days of storage. On 0 day the mean scores of all attributes like colour, appearance, aroma, texture, taste and overall acceptability was found in the category of 'liked moderately' but on advancement of storage period i.e. on 30th day of storage, these occurred in the category of 'liked slightly'. Whereas on 45th day of storage, significant change was observed in all attributes as compared to 0 day which found in the category of 'neither liked nor disliked'. The values were observed (5.96) colour, (5.73) appearance, (5.13) aroma, (5.03) texture, (5.10) taste and (5.39) overall acceptability.

It may be concluded from the storage study that these products could be stored safely upto 30th day of storage without any significant change in sensory attributes.

4.4.1.4 Roasted *dal*

Roasted lentil *dal* had mean scores of colour (8.35), appearance (8.45), aroma (8.55), texture (8.65) and taste (8.65). Mean score of aroma was reduced as compared to other mean scores of other attributes on 15th day. Similarly no major difference was found on 30th day of storage and the mean scores in terms of colour, appearance, aroma, texture and taste were 7.90, 7.55, 7.15, 7.80 and 7.55, respectively. Significant difference was found in appearance, aroma, texture and taste i.e. 6.75, 6.65, 6.75 and 6.95 except colour on 45th day of storage. The mean scores of overall acceptability in roasted *dal* was observed 8.42, 8.05, 7.75 and 6.75 on 0, 15, 30 and 45 days, respectively which found in the category of 'liked very much' to 'liked slightly'.

Table 4.23: Sensory evaluation of roasted *dal*

Storage period	Colour	Appearance	Aroma	Texture	Taste	Over all

						acceptability
0 days	8.35±0.21	8.45±0.20	8.55±0.24	8.65±0.21	8.65±0.10	8.42±0.11
15 days	8.10±0.24	8.00±0.22	7.80±0.12	8.05±0.14	8.10±0.12	8.05±0.14
30 days	7.90±0.07	7.55±0.15	7.15±0.05	7.80±0.17	7.55±0.15	7.75±0.07
45 days	7.65±0.15	6.75±0.25	6.65±0.25	6.75±0.25	6.95±0.27	6.75±0.25
CD(P≤0.05)	0.52	1.00	0.59	0.89	0.39	0.42

Values are mean ± SD of ten independent determinations

4.4.2 Fat acidity

4.4.2.1 Biscuits

The data on fat acidity content of control as well as most acceptable supplemented biscuits are presented in Table 4.24. On zero day of storage, fat acidity content of control and supplemented biscuits i.e. type-I (60:40) and type-II (50:50) varied non-significantly. Control biscuits had 47.33 mg KOH/100g on zero day which was found to be increased with increase in storage period i.e. 49.20, 55.91 and 59.33 mg KOH/100g, respectively at 15, 30 and 45 days of storage.

Similar trend was also observed in supplemented biscuits. Type-I (60:40) and type-II (50:50) biscuits had 47.83 and 48.08 mg KOH/100g on zero day of storage. With the increase in storage period, fat acidity content of both types of biscuits was found to be increased. In type-I biscuits, the values were observed 50.60, 57.27 and 61.35 mg KOH/100g, respectively at 15, 30 and 45 days of storage. Similarly in case of type-II biscuits, the values were 51.13, 59.03 and 63.07 mg KOH/00g, respectively at 15, 30 and 45 days of storage. The increase in fat acidity could be attributed to hydrolysis of triglycerides resulting in the formation of free fatty acids with increase in storage period.

Table 4.24: Effect of storage on fat acidity (mg KOH/100g) contents of biscuits, *sev*, *papad* and roasted *dal* (on dry matter basis)

Supplementation level	**Storage period**			
	0	**15**	**30**	**45**
Biscuits				
Control (Whole wheat flour)	47.33± 1.13	49.20± 0.99	55.91± 1.48	59.33± 1.52
Type-I (WWF:DLF::60:40)	47.83± 1.17	50.60± 0.22	57.27± 1.37	61.35± 0.42
Type-II (WWF:DLF::50:50)	48.08± 1.12	51.13± 0.62	59.03± 0.93	63.07± 0.39
CD(P≤0.05)	NS	0.38	0.52	0.40
Sev				
Control (Dehulled bengal gram flour)	53.00± 0.17	58.25± 0.42	67.38± 0.37	76.45± 0.32
Type- I (DBF:DLF::60:40)	55.28± 0.92	59.33± 0.22	67.73± 0.79	78.67± 0.79
Type- II (DBF:DLF::50:50)	56.24± 1.09	60.15± 0.92	69.25± 1.03	79.57± 0.98
CD(P≤0.05)	0.48	0.86	0.92	1.12
Papad				

Control (Dehulled black gram flour)	40.00± 0.15	44.20± 0.23	49.15± 0.49	54.05± 0.42
Type- I (DBF:DLF::60:40)	40.28± 0.12	42.03± 0.79	47.05± 0.30	53.00± 0.85
Type- II (DBF:DLF::50:50)	40.96± 0.49	43.25± 0.42	47.25± 0.23	53.17± 0.80
CD(P≤0.05)	NS	0.85	0.73	0.82
Roasted *dal*	33.73± 0.19	39.55± 0.57	45.00± 0.41	52.72± 0.78

Values are means ± SD of three independent determinations
WWF-Whole wheat flour, DBF- Dehulled bengal gram flour, DBF- Dehulled black gram flour, DLF- Dehulled lentil flour, NS- Non-significant

4.4.2.2 *Sev*

The data on fat acidity content of control and lentil flour supplemented *sev* are presented in Table 4.24. Fat acidity content of control and supplemented *sev* i.e. type-I and type-II significantly (P≤0.05) increased upto 45 days of storage. Control *sev* had 53.00 mg KOH/100g on zero day. Whereas type-I and type-II *sev* had 55.28 and 56.24 mg KOH/100g, respectively on zero day. These values were found significantly higher as compared to control *sev.* However, increment in fat acidity content on storage was almost similar in control and supplemented *sev.* The fat acidity content of control *sev* was observed 58.25, 67.38 and 76.45 mg KOH/100g, respectively at 15, 30 and 45 days of storage. Similarly in case of type-I and type-II *sev*, the fat acidity contents were found 59.30 and 60.15, 67.73 and 69.25, 78.67 and 79.57 mg KOH/100g, respectively in type-I and type-II *sev* on 15, 30 and 45 days of storage. These values differed significantly.

4.4.2.3 *Papad*

Control and supplemented (type-I and type-II) *papad* exhibited fat acidity content i.e. 40.00, 40.28 and 40.93 mg KOH/100g, respectively on zero day of storage (Table 4.24). These values were non-significantly differed. However, on increasing the storage period, significant (P≤0.05) difference was observed among the fat acidity content of control, type-I and type-II *papad*. Control *papad* had 40.00, 44.20, 49.15 and 54.05 mg KOH/100g, respectively on 0, 15, 30 and 45 days of storage. In case of supplemented *papad*, type-I and type-II had 40.28 and 40.96, 42.03 and 43.25, 47.05 and 47.25, 53.00 and 53.17 mg KOH/100g, respectively on 0, 15, 30 and 45 days of storage. The increase in fat acidity might be due to formation of free fatty acids by the hydrolysis of triglycerides.

4.4.2.4 Roasted *dal*

Similar trend was also found in roasted *dal* which had 33.73, 39.55, 45.00 and 52.72 mg KOH/100g, respectively on 0, 15, 30 and 45 days of storage (Table 4.24).

4.4.3 Peroxide value

4.4.3.1 Biscuits

The data on peroxide value of the control as well as supplemented biscuits are presented in Table 4.25. Peroxide value of control and supplemented (type-I and type-II) biscuits varied significantly ($P \leq 0.05$) from 0 to 45 days of storage period. Control biscuits had 2.33, 3.20, 3.80 and 3.99 meq/100g peroxide value at 0, 15, 30 and 45 days of storage, whereas type-I and type-II biscuits had slightly higher peroxide value i.e. 2.43 and 2.58, 3.33 and 3.53, 4.11 and 4.30, 4.35 and 4.73 meq/100g peroxide value, respectively at 0, 15, 30 and 45 day of storage. Type-II biscuits had significantly higher peroxide value as compared to control and type-I supplemented biscuits. The peroxide value of control as well as supplemented biscuits was significantly ($P \leq 0.05$) increased with increasing the storage period. This increase might be due to oxidation of polyunsaturated fatty acids which lead to the rancidity and off flavour development.

Table 4.25: Effect of storage on peroxide value (meq/100g) of biscuits, *sev*, *papad* and roasted *dal* (on dry matter basis)

Supplementation level	Storage period			
	0	15	30	45
Biscuits Control (Whole wheat flour)	2.33± 0.13	3.20± 0.19	3.80± 0.18	3.99± 0.22
Type-I (WWF:DLF::60:40)	2.43± 0.18	3.33± 0.29	4.11± 0.17	4.35± 0.12
Type-II (WWF:DLF::50:50)	2.58± 0.27	3.53± 0.22	4.30± 0.21	4.73± 0.19
CD(P≤0.05)	0.40	0.58	0.39	0.75
Sev Control (Dehulled bengal gram flour)	2.78± 0.27	3.75± 0.24	4.08± 0.17	4.65± 0.32
Type- I (DBF:DLF::60:40)	2.82± 0.22	3.93± 0.12	4.25± 0.19	4.77± 0.29
Type- II (DBF:DLF::50:50)	2.94± 0.29	4.15± 0.22	4.45± 0.13	4.88± 0.24
CD(P≤0.05)	0.63	0.47	0.84	0.92
Papad Control (Dehulled black gram flour)	2.47± 0.25	2.59± 0.23	3.25± 0.39	4.05± 0.22
Type-I (DBF:DLF::60:40)	2.58± 0.18	2.83± 0.29	3.76± 0.24	4.45± 0.35
Type-II (DBF:DLF::50:50)	2.66± 0.16	2.95± 0.20	3.87± 0.28	4.67± 0.30
CD(P≤0.05)	0.79	1.02	0.87	0.89
Roasted *dal*	2.13± 0.10	2.48± 027	3.23± 0.21	4.00± 0.18

4.4.3.2 *Sev*

Control *sev* had 2.78 meq/100g at 0 day of storage which increased significantly on increasing the storage period (Table 4.25). The values were 3.75, 4.08 and 4.65 meq/100g on 15, 30 and 45 days of storage. Similar trend was also observed in supplemented *sev* i.e. type-I and type-II. Type-II *sev* had significantly (P≤0.05) higher content of peroxide as compared to control and type-I *sev*.

4.4.3.3 *Papad*

Similar trend was also observed in control as well as supplemented *papad* on storage (Table 4.25). At 0 day of storage, 2.47, 2.58 and 2.66 meq/100g of peroxide values were observed in control, type-I and type-II *papad*, respectively. Beyond 0 day of storage, there was significant increase in peroxide value of control as well as supplemented *papad*. The significant increase in peroxide value with advancement of storage period might be due to oxidation of polyunsaturated fatty acids which leads to rancidity and off flavour development.

4.4.3.4 Roasted *dal*

Roasted *dal* contained 2.13, 2.48, 3.23 and 4.00 meq/100g of peroxide value on 0, 15, 30 and 45 days of storage. Significant increment was observed in peroxide value on 15, 30 and 45 days of storage (Table 4.25).

CHAPTER-V

DISCUSSION

It is most important to analyze the newly released genotypes/cultivars for their nutritive value and consumer acceptability and those found inferior may be discarded from general cultivation. Hence, in the present study, some selected lentil genotypes were analyzed for physico-chemical and nutrient composition and these were subjected to various processing and cooking treatments for improving their nutritional quality.

Physico-chemical properties like seed weight, seed volume, seed density, hydration capacity, hydration index, swelling capacity and swelling index are important parameters need to be studied as they play an important role in the cooking quality of food legumes. Among the lentil genotypes, Garima genotype had significantly higher values of seed density, seed volume, hydration capacity, hydration index, swelling capacity and swelling index whereas HM-1 genotype had significantly lower values, however, other genotypes were also found at par with Garima genotype. The cooking time was found to be significantly negatively correlated with physical parameters. Hence, Garima genotype required less cooking time (36 min.) and HM-1 genotype required long cooking time (43 min.) as compared to other genotypes. Similar results were also reported by other workers in cowpea (Giami and Okwechime, 1993; Sinha, 1999), rice bean and faba bean (Saharan, 2002), chickpea and lentil (Jood *et al.*, 1998) and green gram (Grewal *et al.*, 2006).

Proximate composition of six lentil genotypes indicated that Garima contained highest amount of crude protein, crude fibre and ash contents whereas HM-I genotype had significantly lower content of moisture, crude protein, crude fat, crude fibre and ash contents. Whereas other genotypes like Sapna, LH7-12, LH-13 and LH-26 were also found at par with the Garima genotype. When all these genotypes were subjected to processing and cooking treatments, then all the processing methods caused slight change in proximate composition of lentil genotypes. Moisture content of all genotypes was least affected by all treatments. Non-significant difference in crude protein, crude fat and ash contents were observed on soaking and heat treatments like roasting, pressure cooking and microwave cooking whereas dehulling of soaked seeds caused significant reduction in crude fibre, crude fat and ash contents whereas non-significant increase was seen in crude protein content as compared to unprocessed seeds. Removal of hulls, which contain relatively less amount of protein might have accounted for higher expressed value of protein. Similarly, other workers also reported an increase in protein content of faba bean and cowpea on dehulling with regard to reduction of crude fibre on dehulling might be due to the fact that most of the fibre is found in tests,

which was removed during the process of dehulling (Wang *et al.*, 2008; Grewal and Jood, 2009).

Germination also caused non-significant change in crude protein and crude fat contents of all the six lentil genotypes as compared to raw seeds. The increase in protein content might be due to utilization of non-protein moieties and rapid protein synthesis (Akpapunam and Achinewhu, 1985; Arora *et al.*, 2010). Whereas decrease in case of fat may probably be due to the fat that lipid reserves present in the grain get utilized during germination. The depletion of fat in germinating seeds has also been reported earlier by King and Puwastein (1987) in lentils, Sinha (1999) in cowpea, Sood *et al.* (2002) in chickpea and Grewal and Jood (2009) in green gram cultivars.

Total reducing and non-reducing sugar contents of all the six lentil genotypes varied significantly. All the genotypes were subjected to various processing and cooking treatments. Soaking (12 h) of lentil seeds significantly reduced the level of total, reducing and non-reducing sugars. Losses of sugars during soaking would be on account of simple diffusion of sugars after being solubilized. The extent of diffusion of sugars from seed to soaking medium may be function of structure of seed coat. Soaking has been known to reduce the level of sugars in various pulses (Jood *et al.*, 1988; Sinha, 1999; Grewal and Jood, 2009). Dehulling of soaked seeds also significantly reduced the sugar contents of all lentil genotypes. Similar results were also reported on dehulling of soaked green gram cultivars (Grewal and Jood, 2009). Germination for 24 h caused significant increase in all sugar contents might be due to enzymatic hydrolysis of starch into simpler sugars. The extent of increment was observed from 20 to 28, 20 to 26 and 20 to 29 per cent, respectively in total, reducing and non-reducing sugars of all the lentil genotypes. Similar results were also reported in other pulses by various workers (Jood *et al.*, 1986; Sinha, 1999; Grewal and Jood, 2006).

When the soaked seeds were cooked by using dry and moist heat treatments, there was significant increase in all the sugar contents in all genotypes. All the six genotypes behaved almost in a similar way on processing and cooking methods. The extent of increase was found almost similar on roasting and microwave cooking but pressure cooking (moist heat) produced significantly great increase in total, reducing and non-reducing sugar contents. These results are in agreement as reported earlier in various food legumes on heat treatments (Jood *et al.*, 1986; Saharan *et al.*, 2002; Grewal and Jood, 2009; Arora *et al.*, 2010; Negi *et al.*, 2011). Cooking may cause rupturing of starch granules followed by hydrolysis of starch to oligosaccharides and then to monosaccharides, resulting from

increased concentration of sugars in the cooked legumes (Kataria *et al.*, 1990; Grewal and Jood, 2009).

Starch content of unprocessed seeds of all lentil genotypes varied significantly from 46.90 to 61.72 per cent, respectively. Maximum starch was found in Garima and minimum in HM-I genotype. Starch content of all the genotypes significantly ($P \leq 0.05$) affected by all treatments. Soaking for 12 h caused significant reduction in starch content which increased further on dehulling process. Leaching out of soluble portion of starch from seed to soaking medium may perhaps, explain the loss of starch during soaking. Similar results were also reported by other workers (Grewal, 2003; Wang *et al.*, 2008). Sprouting for 24 h also caused significant reduction in starch content of all the lentil genotypes. The extent of reduction was ranged from 24 to 29 per cent, respectively. It may be due to hydrolysis of oligosaccharides and ultimately to monosaccharides during germination (Grewal, 2003; Arora *et al.*, 2010). Heat treatments like roasting, pressure cooking and microwave cooking further increased the loss of starch as compared to unprocessed seeds. Pressure cooking had a more pronounced effect on starch content than roasting and microwave cooking. Significant decrease in starch content of seeds as a result of cooking may result from amylolysis and it may also explain the observed increase in the concentration of sugars during cooking. Cooking may cause rupturing of starch granules followed by hydrolysis of the starch (Jood *et al.*, 1986). The decrease in starch content and increase in sugar contents after cooking process has been observed by earlier workers in amphidiploids of mungbean and black gram (Kataria *et al.*, 1990), chickpea (Wang *et al.*, 2008) and faba bean (Negi *et al.*, 2011).

Dietary fibre constituents of unprocessed lentil genotypes varied significantly. Among the lentil genotypes, Garima exhibited higher content of soluble, insoluble and total dietary fibre. When raw seeds were soaked for 12 h did not cause any significant change in all the three dietary fibre constituents whereas dehulling of soaked seeds caused significant reduction in soluble (25 to 38%), insoluble (45 to 64%) and total (40 to 58%) dietary fibre contents. This decrease might be due to the removal of hulls which contributed to great reduction in the dietary fibre contents. Similarly, other workers also reported reduction in dietary fibre content on dehulling of pulses (Saharan *et al.*, 2002; Grewal, 2003; Wang *et al.*, 2008).

Sprouting also caused significant reduction in all the dietary fibre components. An emyme β-galactosidase from germinated cereals and pulses partially attacks galactomannam to yield galactose. Therefore, the decrease in the polysaccharides and mucilage content may be attributed to their breakdown and utilization by the growing sprouts (EI-Mahdy and EI-Sebiy, 1983; Arora *et al.*, 2010).

Heat treatments like roasting, pressure cooking and microwave cooking caused significant reduction in total and insoluble dietary fibre components. Whereas soluble fraction was increased by about 5 to 9, 27 to 42 and 10 to 18 per cent, respectively by roasting, pressure cooking and microwave cooking. Pressure cooking caused higher increase in soluble fraction by simultaneously decreasing the insoluble fractions. The results of present study are in agreement with those reported earlier in cooked vegetables where insoluble fraction was decrease, while the soluble fraction was increased (Vidal-Valverde and Frias, 1992). Similar results were also reported by other workers in cooked pulses (Grewal, 2003; Wang *et al.*, 2008; Arora *et al.*, 2010). Heat treatment might have resulted in conversion of insoluble dietary fibre to short length chains or units which could probably be precipitated along with soluble dietary fibre (Khatoon and Prakash, 2006). Similarly, Marconi *et al.* (2000) also reported the cooking procedures produced a redistribution of the insoluble non-starch polysaccharides to soluble fraction, although the total non-starch polysaccharides were not affected in cooked beans.

Antinutritional factors like phytic acid, polyphenols and trypsin inhibitor of raw lentil seeds differed significantly. Among the lentil genotypes, Garima had lowest amount and HM-I genotype and highest amount of phytic acid, polyphenols and trypsin inhibitor activity. When these lentil genotypes were subjected to various processing and cooking treatments showed significant reduction in the level of antinutrients. Soaking and dehulling of soaked seeds contributed significantly toward lowering of phytic acid contents in all the genotypes. On dehulling the losses may be because of removal of husk. As husk contained relatively higher concentration of phytic acid as compared to whole grain, and therefore, the removal of husk accounted for significantly lower phytic acid content in dehulled grains. Similar results have been reported by various workers (Duhan *et al.*, 2002; Saharan *et al.*, 2002; Grewal and Jood, 2006; Huma *et al.*, 2008). Like other treatments, germination also resulted in significant ($P \leq 0.05$) loss of phytic acid in all the lentil genotypes. The loss of phytic acid during germination may be caused by hydrolytic activity of phytase enzyme. In earlier studies, germination has also been reported to have a diminishing effect on the phytic acid content of various legumes like rice bean and faba bean (Saharan, 1994), pigeon pea (Duhan *et al.*, 2002), green gram (Grewal and Jood, 2006) and chickpea (Saleh *et al.*, 2006). Among the heat treatments, pressure cooking caused pronounced reduction in phytic acid content of all the lentil genotypes. The reduction observed in phytic acid content of legume seeds was possibly through its destruction by heat treatment. These results are in agreement with those reported earlier by other workers (Grewal and Jood, 2006; Arora *et al.*, 2010).

Similar trend was also observed in polyphenol content of all the lentil genotypes. Soaking and dehulling caused significant reduction in the polyphenol contents of all the genotypes. Similar results were also reported by other workers in soaked and dehulled food legumes (Saharan, 1994; Grewal and Jood, 2006). As polyphenols are mainly concentrated in the husk and the removal of tests significantly reduced the polyphenol content. Heat treatments like roasting, pressure cooking and microwave cooking also caused significant reduction in polyphenol contents. The extent of reduction was maximum by pressure cooking followed by microwave cooking and roasting. Pressure cooking and microwave cooking involving moist heat may destroy polyphenols to a great extent. Germination also caused reduction in polyphenol content of all the six lentil genotypes. Similar results were also reported in chickpea and black gram seeds by other workers (Jood *et al.*, 1987). This decrease in polyphenols during germination may be ascribed to the presence of polyphenol oxidase and enzymic hydrolysis (Jood *et al.*, 1987; Grewal and Jood, 2006).

Similar reduction was also observed in trypsin inhibitor activity of all the six lentil genotypes on processing and cooking treatments. Soaking and dehulling caused reduction in TIA but significantly lower than polyphenol and phytic acid contents. Loss of trypsin inhibitors during soaking may possibly be caused by leaching out of solids against the concentration gradient governing the rate of diffusion. Generally trypsin inhibitors are low molecular weight proteins, hence they are likely to pass out from the seed to the soaking medium easily (Saleh *et al.*, 2006; Grewal and Jood, 2006). Germination also caused reduction in TIA of all genotypes. A decrease in TIA during germination may perhaps be because of mobilization and breakdown of chemical constituents including trypsin inhibitor. Similar findings have been reported in various legumes including cowpea (Sinha, 1999), moth bean (Negi, 1999) and green gram (Grewal and Jood, 2006). Heat treatments like roasting, pressure cooking and microwave cooking caused significant reduction in TIA of all the genotypes. Pressure cooking had great effect on TIA followed by microwave cooking and roasting. The reduction in TIA on heat processing might be because of its heat labile nature. Saleh *et al.* (2006) and Grewal and Jood (2006) also reported reduction in TIA of green gram and chickpea cultivars, respectively.

In vitro protein digestibility was found maximum in unprocessed Garima genotype followed by Sapna, LH7-12, LH-13, LH-26 and HM-1 genotypes. Unprocessed seeds had significantly lower content of *in vitro* protein digestibility as compared to processed seeds. Low protein digestibility of legume grains, as reported earlier also, which may be due to the presence of antinutritional factors (Tan *et al.*, 1984; Jood *et al.*, 1989; Saleh *et al.*, 2006). Soaking and dehulling improved protein digestibility of the soaked legumes significantly.

Leaching out of antinutrients and removal of hulls during dehulling may account for improved digestibility of the soaked legumes over the unprocessed seeds (Sinha, 1999; Saharan *et al.*, 2002).

Germination increased protein digestibility of all the six lentil genotypes. In previous studies also germination increased protein digestibility as seed proteins are metabolized and antimetabolites including protease inhibitor, phytate, polyphenols etc are catabolized during germination (Boralkar and Reddy, 1985; Jood *et al.*, 1998; Grewal and Jood, 2006). The *in vitro* protein digestibility was also improved by cooking treatments. The cooked lentil seeds had significantly higher protein digestibility than for raw seeds. However, roasting and microwave cooking had almost similar effect on *in vitro* protein digestibility whereas pressure cooking had pronounced effect on protein digestibility of all the lentil genotypes. The improvement in digestibility may be attributed to denaturation of protein, destruction of the trypsin inhibitor or reduction of tannins and phytic acid. Khatoon and Prakash (2004) and Saleh *et al.* (2006) also reported that legumes treated by microwave cooking had lower *in vitro* protein digestibility than those treated by pressure cooking. Other workers also reported improvement in protein digestibility of cooked legumes (Jood *et al.*, 1998; Khatoon and Prakash, 2004, Saleh *et al.*, 2006).

In vitro starch digestibility of raw lentil seeds differed significantly. Soaking of the seeds improved the starch digestibility over the control values. Dehulling further improved the starch digestibility possibly due to reduction in levels of anti-nutritional factors like polyphenols and phytic acid as these are antinutrients which are known to inhibit α-amylase activity and thus lower the starch digestibility (Sinha *et al.*, 2002; Grewal and Jood, 2009). Sprouting for 24 h caused significant improvement in *in vitro* starch digestibility of lentil genotypes. These results are in agreement with those reported by earlier workers in various food legumes (Jood *et al.*, 1988; Jood *et al.*, 1998; Sinha *et al.*, 2002; Grewal and Jood, 2009).

Heat treatments like roasting, pressure cooking and microwave cooking significantly increased starch digestibility. Pressure cooking was found more effective in improving the starch digestibility than roasting and microwave cooking. Similar results were also reported by Grewal and Jood (2009) in green gram cultivars cooked by using ordinary cooking and pressure cooking. Other workers also reported similar results in peas (Bishnoi and Khetarpaul, 1993), red gram and bengal gram (Chopra and Sankhala, 2004) and in moth bean (Negi *et al.*, 2011). Enhancement in starch digestibility in cooked legumes may be attributed to swelling and rupturing of starch granules, which facilitates more randomized configuration for α-amylase to affect hydrolysis (Mulimani *et al.*, 1994; Jood *et al.*, 1998).

Total minerals like Ca, Fe and Zn content of all the six unprocessed lentil genotypes differed significantly. All the genotypes processed using various treatments like soaking, dehulling, germination, roasting, pressure cooking and microwave cooking. Soaking caused significant loss in all the three minerals might be due leaching out of these minerals into the soaking water. Dehulling caused further reduction in total mineral content of soaked lentil seeds. Minerals present in the hulls might have been lost during dehulling, therefore, contributing to the lower mineral contents in soaked and dehulled seeds. Similar results in other pulses like faba bean (Saharan, 1994), cowpea (Sinha, 1999) and in green gram (Grewal and Jood, 2006) have been reported. Whereas other treatments like germination and heat treatments did not cause any significant change in total mineral content of lentil genotypes. Other workers also reported retention of total minerals by microwave cooking and pressure cooking in chickpea seeds and kidney beans (Solama and Ragab, 1997; Seleh *et al.*, 2006).

On the other hand, significant improvement was observed in *in vitro* availability of Ca, Fe and Zn on soaking, dehulling, germination and cooking treatments as compared to the unprocessed seeds. It might be due to leaching out and destruction of antinutrients (Jood *et al.*, 1998; Duhan *et al.*, 2002; Grewal and Jood, 2006; Saleh *et al.*, 2006). Phytate, the major phosphorus bearing compound in cereals and pulses, chelates divalent and trivalent cations forming insoluble complexes and thereby decreasing the *in vitro* availability of minerals (Sharma *et al.*, 1996; Wang *et al.*, 1997). In the present study, all the six lentil genotypes were sprouted for 24 h which enhanced the *in vitro* availability of Fe, Ca and Zn. The increased mineral availability during germination may caused by increased phytase activity resulting in decreased phytate content in sprouts (Grewal and Jood, 2006). Other antinutrients like polyphenols, saponins which are also known to hinder the mineral availability are also catabolized during germination, leaching to improvement in mineral availability (Sharma *et al.*, 1996; Jood *et al.*, 1997). In the present study, heat treatments like roasting, pressure cooking and microwave cooking also caused significant improvement in *in vitro* availability of Fe, Ca and Zn of all lentil genotypes. Pressure cooking resulted great improvement followed by microwave cooking and roasting. Other workers also reported improvement in mineral availability of other pulses by conventional and microwave cooking (Jood *et al.*, 1998; Grewal and Jood, 2006). The decrease in antinutrient content mainly phytic acid, possibly through its destruction by heat treatments may result in the divalent and trivalent captions being faced from the phytate mineral complexes, thus accounting for the improved availability of minerals in processed seeds (Grewal and Jood, 2006; Saleh *et al.*, 2006).

On the basis of physico-chemical and nutritional characteristics, Garima genotype found superior and selected for product development. Various products such as *dal*, soup,

roasted *dal*, *dhokla, bhalle, chat,* cutlet, *papad, sev,* biscuits and bread were developed by using various processing methods.

Dal, soup and roasted *dal* were found organolepticaly acceptable in terms of colour, appearance, aroma, texture and taste and found in the category of 'liked very much' to the 'liked moderately'. Other researchers were also made *dal* and soup from lentil and found acceptable by the judges (Grewal, 2003; Khatoon and Prakash, 2006; Yadav *et al.*, 2007; Raghuvanshi *et al.*, 2011). Similarly fermented and germinated products like *dhokla, bhalle, chat* and cutlet prepared from lentil were also found highly acceptable in terms of colour, appearance, texture, aroma and taste. These results are in agreement with those reported by other workers by preparing *chat, tikki, dhokla* and *wadi* from green gram (Grewal *et al.*, 2007). Two types of fried products namely *papad* and *sev* were also developed by replacing dehulled bengal gram flour with dehulled lentil flour at 40, 50 and 100 per cent levels. Both the products upto 50 per cent level of supplementation were found acceptable in terms of colour, appearance, texture, aroma and taste and found in the category of 'liked moderately'. Similar products were also prepared by other workers from chickpea (Singh, 2003), pearl millet (Singh, 2003) and green gram (Grewal *et al.*, 2007).

Two types of baked products like biscuits and bread were developed by supplementation of dehulled lentil flour with wheat flour. Biscuits were found acceptable at 40 and 50 per cent levels, whereas bread were found acceptable at 30 and 40 per cent levels of supplementation. Similarly other workers also prepared biscuits by replacing wheat flour upto 40 per cent level of supplementation (Sangwan, 2002; Singh, 2003; Grewal *et al.*, 2007) and bread by replacing refined wheat flour with soybean, chickpea and fenugreek flour (Singh, 2003; Dhingra and Jood, 2004).

Among the developed products, flour products namely biscuits, *sev, papad* and roasted *dal* were stored for 2 months, however biscuits, *sev* and *papad* were found acceptable in terms of sensory attributes upto 30 days of storage whereas roasted *dal* were found acceptable upto 45 days without any significant change in sensory attributes. Other workers also reported similar results in stored supplemented biscuits (Hooda and Jood, 2005) *sev* and *papad* (Ritu, 2004) and roasted *dal* (Grewal, 2003).

CHAPTER-VI

SUMMARY AND CONCLUSION

The present investigation entitled, "Nutritional evaluation of lentil (*Lens culinaris*) genotypes and their utilization in development of value added products" was carried out in the Department of Foods and Nutrition, College of Home Science, CCS Haryana Agricultural University, Hisar.

Seeds of six lentil genotypes namely Garima, Sapna, LH7-12, LH-13, LH-26 and HM-1 were analyzed for physico-chemical properties. These were further processed by using various processing and cooking treatments like soaking, dehulling, germination, roasting, pressure cooking and microwave cooking to see their effects on nutrient and antinutrient contents.

The results of physico-chemical properties indicated that among the genotypes, Garima and LH7-12 had highest 2.90 g whereas HM-I had lowest 1.60 g seed weight. Seed volume and seed density of lentil genotypes varied from 0.019 to 0.024 g/ml and 0.79 to 1.15 g/ml, respectively. Swelling capacity and swelling index of all the six varieties varied from 0.017 to 0.024 ml/seed, respectively. Among the lentil genotypes, Garima showed maximum values of swelling capacity (0.024 ml/seed) and swelling index (1.133) whereas HM-I showed minimum values of swelling capacity (0.017 ml/seed) and swelling index (0.937) but other lentil genotypes like Sapna, LH7-12 and LH-26 also had at par values of swelling capacity and swelling index as compared to Garima genotype. Similar trend was also observed in case of hydration capacity and hydration index. The values ranged from 0.014 to 0.026 g/seed and 0.863 to 0.950, respectively. Cooking time of six lentil genotypes varied from 36 to 43 min., respectively. Lowest cooking time (36 min.) was observed in Garima genotype and highest (43 min.) in HM-I. Sapna, LH7-12 and LH-26 genotype took around 39 min. for cooking.

Moisture contents of raw seeds of lentil genotypes varied significantly from 6.87 to 8.19 per cent, respectively. Highest (8.19%) in Garima genotype and lowest (6.87%) in HM-I genotype. After soaking and dehulling of soaked seeds, the moisture content of all genotypes ranging from 7.12 to 8.52 and 6.98 to 8.26 per cent, respectively. After roasting treatment, moisture content reduced which ranged from 6.00 to 7.77 per cent, respectively. After germination, moisture content ranging from 7.02 to 8.20 per cent, respectively. Similarly cooking treatments like pressure cooking and microwave cooking caused non-significant increase in moisture contents as compared to raw values. The contents ranged from 7.22 to 8.4 and 7.18 to 8.23 per cent, respectively.

Crude protein contents of all the six lentil genotypes varied significantly from 21.37 to 27.49 per cent, respectively. Highest (27.49%) in Garima and lowest (21.37%) in HM-I genotype. Dehulling of seeds non-significantly increased the protein content of all the six lentil genotypes. Germination increased protein contents ranging from 21.90 to 27.95 per cent, respectively. Whereas heat treatments like roasting, pressure cooking and microwave cooking caused significant decrease in protein contents of all the genotypes.

Fat content of six lentil genotypes ranged from 1.36 to 1.82 per cent, respectively. Soaking for 12 h did not cause any significant change in fat content of all genotypes as compared to raw values. Whereas dehulling of soaked seeds caused significant reduction in fat content of all genotypes. The contents ranged from 1.22 to 1.59 per cent, respectively. Germination for 24 h also caused significant change in fat contents ranging from 1.49 to 1.87 per cent, respectively. On heat treatments, fat contents ranged from 1.25 to 1.64 per cent by roasting, 1.32 to 1.73 per cent by pressure cooking and 1.28 to 1.70 per cent, respectively by microwave cooking.

Crude fibre contents of unprocessed six lentil genotypes varied significantly from 1.74 to 2.99 per cent, respectively. Highest content was observed in Garima genotype and lowest in HM-I genotype. Soaking treatment caused non-significant change in crude fibre contents of all genotypes. Whereas dehulling of soaked seeds caused significant reduction in crude fibre contents of all genotypes. The values ranged from 0.85 to 0.97 per cent, respectively. Germination for 24 h caused significant change in crude fibre contents of all lentil genotypes. Crude fibre contents ranged from 1.35 to 2.28 per cent, respectively after 24 h germination in all the six genotypes. Heat treatments like roasting, pressure cooking and microwave cooking showed significant decrease in crude fibre contents of all genotypes.

Ash content of all genotypes varied significantly from 2.51 to 3.82 per cent, respectively. Highest (3.82%) in Garima and lowest (2.51%) in HM-I genotype. Soaking of seeds did not have significant effect on ash contents of lentil genotypes whereas dehulling of soaked seeds had significant effect on ash contents which ranged from 1.35 (HM-I) and 2.73 (Garima) per cent, respectively. Other treatments like roasting, germination, pressure cooking and microwave cooking did not have significant effect on ash contents of all the six genotypes.

Total sugar contents of six lentil genotypes varied significantly from 8.61 to 9.39 per cent respectively. The highest (9.39%) and lowest (8.61%) amount of total sugars were present in Garima and HM-I genotypes. Similarly, reducing and non-reducing sugars of lentil genotypes varied significantly. These ranged from 1.25 to 1.72 and 7.20 to 8.14 per cent, respectively. Soaking for 12 h of seeds significantly reduced the level of total soluble sugars, reducing sugars and non-reducing sugars. Dehulling of soaked seeds resulted in significant

loss of all the sugar contents as compared to raw lentil genotypes. The reduction was observed by 15 to 21, 6 to 12 and 16 to 25 per cent, respectively. Dry heating like roasting also caused significant increase in sugar contents. In case of total sugars, the extent of increase was found highest (13%) in LH-26 genotype and lowest (6%) in Garima genotype. Similarly, in case of reducing and non-reducing sugars, the extent of increase was ranged from 5 to 10 and 9 to 25 per cent, respectively. Germination for 24 h also caused significant improvement in total, reducing and non-reducing sugars. Pressure cooking of soaked seeds also increased the total, reducing and non-reducing sugars of all the lentil genotypes over the control. The increase was 24 to 36 per cent in total sugars, 20 to 29 per cent in reducing sugars and 23 to 34 per cent in non-reducing sugars of pressure cooked seeds of all lentil genotypes. Among the various treatments, pressure cooking had pronounced effect on sugar contents.

Starch content of unprocessed seeds of all lentil genotypes varied significantly from 46.90 to 61.72 per cent, respectively. Maximum was found in Garima and minimum in HM-I. Starch content decreased significantly on all processing and cooking methods. Soaking for 12 h, caused reduction in starch contents than the unprocessed controls. Dehulling of soaked seeds also resulted in the reduction of starch contents in all the six lentil genotypes. The extent of decreased ranged from 21 to 27 per cent, respectively. Higher reduction was observed in HM-I (27%) followed by Sapna (26%), LH-26 (24%), Garima (22%) and LH7-12 and LH-26 (21%). Heat treatments like roasting, pressure cooking and microwave cooking further increased the loss of starch. The extent of decrease was observed 15 to 19 per cent on roasting, 43 to 48 per cent on pressure cooking and 18 to 23 per cent on microwave cooking in all lentil genotypes. Pressure cooking had a more pronounced effect than roasting and microwave cooking. Sprouting also caused significant reduction in starch content.

Raw seeds of lentil genotypes contained 2.93 to 3.87 per cent soluble, 13.54 to 14.67 per cent insoluble and 16.92 to 17.97 per cent total dietary fibre contents. When raw seeds were soaked for 12 h caused non-significant decrease in soluble, insoluble and total dietary fibre constituents. The extent of reduction was ranged from 1 to 3 per cent (soluble), 0.1 to 2 per cent (insoluble) and 0.3 to 2 per cent (total), respectively in all the six lentil genotypes. On the other hand dehulling of soaked seeds caused significant reduction in all the three dietary fibre constituents. Similarly, germination for 24 h also caused significant reduction in all the dietary fibre constituents. The reduction was ranged from 30 to 42 per cent in soluble, 29 to 39 per cent in insoluble and 29 to 39 per cent in total dietary fibre contents. When the soaked seeds of all the six lentil genotypes were subjected to heat treatments like roasting, pressure cooking and microwave cooking caused significant reduction in total and insoluble

dietary fibre contents whereas soluble fraction was increased. Among the heat treatments, pressure cooking caused significantly higher reduction in insoluble and total dietary fibre and significant increase in soluble fraction.

Phytic acid content of unprocessed lentil genotypes varied significantly from 820.33 to 996.68 mg/100g, respectively. HM-I had significantly highest (996.68 mg/100g) and Garima had lowest phytic acid contents. Soaking and dehulling of soaked seeds significantly reduced the phytic acid content of all the six genotypes. Phytic acid content was also significantly decreased by sprouting for 24 h. The extent of reduction was ranged from 32 to 44 per cent, respectively. The highest (44%) reduction was observed in Garima and lowest (30%) in LH-26 as compared to control (raw). Dry and moist heat treatments like roasting, pressure cooking and microwave cooking also caused significant reduction in phytic acid content of all the six lentil genotypes. The highest reduction was noted after pressure cooking (32 to 46%) followed by microwave cooking (30 to 40%) and roasting (15 to 27%).

Polyphenol content of raw (unprocessed) whole seeds of six lentil genotypes varied significantly from 478.33 to 540.68 mg/100g, respectively. Higher (540.68 mg/100g) was observed in Sapna genotype followed by 520.33 mg/100g in HM-I, 503.33 mg/100g in LH-13, 502.00 mg/100g in LH7-12, 483.33 mg/100g in LH-26 and 478.33 mg/100g in Garima genotype. Soaking and dehulling caused significant reduction in the level of polyphenols of all six lentil genotypes. The extent of reduction was observed from 21 to 28 per cent, respectively. Sprouting (24 h) was also considerably effective in decreasing the polyphenol content of all the six lentil genotypes which ranged from 21 to 30 per cent, respectively over the control values. Maximum (30%) reduction was observed in LH-26 and minimum (21%) in LH-13 whereas other genotypes were also found at par in reduction of polyphenol contents. Heat treatments like roasting, pressure cooking and microwave cooking also caused significant reduction in polyphenol contents. The extent of reduction was 24 to 39 per cent by roasting, 34 to 46 per cent by pressure cooking and 20 to 30 per cent by microwave cooking. Among the heat treatments, pressure cooking had a greater effect in the reduction of polyphenol contents.

Unprocessed seeds of all the six lentil genotypes contained 490.48, 642.76, 582.68, 683.33, 630.58 and 537.33 TIA/g, respectively. Highest trypsin inhibitor content was observed in Sapna and lowest in Garima genotype. Soaking and dehulling caused comparatively lower reduction in trypsin inhibitor activity as compared to phytic acid and polyphenol content. Sprouting for 24 h also had great effect on the reduction of TIA of all the lentil genotypes. It was ranged from 33 to 42 per cent, respectively. Among the genotypes, maximum decrease was observed in Garima and LH7-12 genotypes and minimum in LH-26

genotype. Similarly, heat treatments like roasting, pressure cooking and microwave cooking also caused pronounced effect in TIA content of lentil genotypes. The extent of reduction was ranged from 29 to 37 per cent by roasting, 45 to 59 pe rcent by pressure cooking and 36 to 45 per cent by microwave cooking. Among the heat treatments, pressure cooking (moist heat) caused significantly higher reduction in all the three antinutrient content of lentil genotypes.

In vitro protein digestibility was found 49.61 (Garima), 42.26 (Sapna), 47.72 (LH7-12), 48.83 (LH-13), 42.63 (LH-26) and 40.62 (HM-I) per cent, respectively in unprocessed (raw) lentil genotypes. A significant enhancement in protein digestibility occurred when the seeds were soaked and dehulled as compared to unprocessed seeds. Protein digestibility also increased significantly when the soaked seeds were sprouted for 24 h as compared to unprocessed seeds. The extent of increment was ranged from 24 to 34 per cent, respectively in lentil genotypes. Heat processing also significantly increased protein digestibility of all lentil genotypes might be by destroying heat labile protease inhibitors and also by denaturing globulins, highly resistant to proteases in the native state. Among the heat treatments, pressure cooking gave the highest protein digestibility (30 to 42%) followed by microwave cooking (21 to 26%) and roasting (14 to 22%).

Starch digestibility (*in vitro*) expressed as mg maltose released/g flour, was ranged from 22.94 to 31.17 in raw (unprocessed) seeds of lentil cultivars. Similarly, starch digestibility increased markedly on all processing and cooking methods. All the treatments like soaking, dehulling, germination and heat treatments like roasting, pressure cooking and microwave cooking significantly increased the starch digestibility of lentil genotypes. Among them, pressure cooking was found more effective in improving the starch digestibility which ranged from 30 to 40 per cent, respectively.

Total iron, calcium, zinc and magnesium contents of six unprocessed lentil genotypes ranged from 4.00 to 6.21, 50.29 to 74.22, 2.33 to 5.12 mg/100g, respectively. Garima genotype had significantly higher content of all minerals as compared to other genotypes. Soaking for 12 h and dehulling of soaked seeds caused significant reduction in all the minerals whereas other treatments like germination, roasting, pressure cooking and microwave cooking did not cause any significant change in total Fe, Ca, Fn and Mg contents of all genotypes. On the other hand *in vitro* availability of Fe, Ca and Zn was significantly improved by all processing and cooking treatments as compared to unprocessed lentil genotypes. Soaking improved availability of Fe, Ca and Zn which ranged from 20 to 29, 12.00 to 18.00 and 10 to 16 per cent, respectively in all the genotypes. Similarly, dehulling caused significant improvement which ranged from 37 to 43, 19 to 24 and 19 to 23 per cent,

respectively. Germination also enhanced *in vitro* availability of Fe, Ca and Zn. Heat treatments like roasting, pressure cooking and microwave cooking enhanced significantly *in vitro* availability of all the three minerals. The increment ranged from 20 to 27, 12 to 19 and 19 to 23 per cent by roasting, 50 to 69, 35 to 41 and 46 to 51 per cent by pressure cooking and 33 to 39, 24 to 29 and 19 to 25 per cent, respectively by microwave cooking. Pressure cooking was found to be most effective treatment for improving the *in vitro* availability of Fe, Ca and Zn of all genotypes.

On the basis of physico-chemical and nutritional characteristics, Garima genotype found superior and selected for product development. Various products such as *dal*, soup, roasted *dal, dhokla, bhalle*, chat, cutlet, *papad, sev*, biscuits and bread were developed by using various processing methods.

Dal was found highly acceptable by the panelists as compared to soup. *Dal* had mean scores of colour (8.20), appearance (8.25), aroma (8.05), texture (8.25) and taste (8.15) which were found in the category of 'liked very much' whereas, soup had 7.00 mean scores of overall acceptability score which was fell in the category of 'liked moderately'. Roasted *dal* was also 'liked very much' by the panelists. *Dhokla* prepared from dehulled bengal gram flour (*besan*) served as control. In test samples bengal gram flour was replaced by dehulled lentil flour at 40, 50 and 60 per cent levels, respectively. Three types of *dhokla* such as type-I (60:40), type-II (50:50) and type-III (40:60) were prepared and compared with control sample. Control *dhokla* had 7.70 mean score of overall acceptability which fell in the category of 'liked moderately' whereas among the test samples, type-I (60:40) *dhokla* was found at par with control. Similar, trend was also observed in case of *bhalle* fermented product. *Bhalle* prepared from dehulled blackgram flour served as control. Three types of *bhalle* like type-I (60:40), type-II (50:50) and type-III (40:60) were prepared by supplementation of dehulled lentil flour at 40, 50 and 60 per cent, respectively. Control *bhalle* had mean scores of colour (8.20), appearance (8.15), aroma (8.15), texture (8.25), taste (8.15) and overall acceptability (8.17), fell in the category of 'liked very much'. Among the three types of dehulled lentil flour supplemented *bhalle*, type-I (60:40) and type-II (50:50) *bhalle* had mean scores of overall acceptability were 7.80 and 7.30, respectively and found in the category of 'liked moderately'. However, type-III (40:60) *bhalle* had significantly lowest mean scores of colour.

Two types of nutritious *chat* and cutlets were prepared by using sprouting process. Sprouted green gram served as control for both the products. *Chat* and cutlets prepared from sprouted lentil were significantly differed in terms of colour, appearance, texture, and taste from their control samples. Control samples exhibited mean scores of overall acceptability

were 7.85 and 8.09, respectively. Whereas *chat* and cutlet based on sprouted lentil had 7.09 and 7.75 mean scores of overall acceptability which were found in the category of 'liked moderately'.

Two types of fried products namely *papad* and *sev* were developed. *Papad* prepared from dehulled black gram flour served as control. Control sample had mean scores of colour (7.85), appearance (7.75), aroma (7.75), texture (7.90), taste (7.75) and overall acceptability (7.85). Three types of *papad* were made by replacing dehulled black gram flour with dehulled lentil flour at 40, 50 and 100 per cent levels, respectively. Type-I (60:40) and type-II (50:50) papad had significantly higher mean scores of taste i.e. 7.15 and 7.70, respectively as compared to control (7.75). Whereas type-III (0:100) prepared from dehulled lentil flour exhibited lowest mean scores.

Sev was prepared by using dehulled bengal gram flour (*besan*) served as control. Control *sev* was found highly acceptable in terms of colour (8.50), appearance (8.55), aroma (8.45), texture (8.60), taste (8.55) and overall acceptability (8.55) and found in the category of 'liked very much'. Three types of *sev* were prepared by replacing dehulled bengal gram flour by dehulled lentil flour at 40, 50 and 100 per cent level, respectively. All the three types of *sev* had 7.85, 7.65 and 7.65 mean scores of overall acceptability.

Baked products like biscuits and bread were developed by supplementation of dehulled lentil flour with whole wheat flour and refined wheat flour, respectively. Control biscuits made from whole wheat flour exhibited mean scores of colour, appearance, aroma, texture and taste 8.30, 8.20, 8.10, 8.30 and 8.20, respectively, fell in the category 'liked very much' by the panelists. Two types of test samples type I and type-II were prepared by supplementation of dehulled lentil flour 40 and 50 per cent levels, respectively. Type-I biscuits found at par with the control biscuits in terms a colour, appearance, aroma, texture and taste and found in the category of 'liked very much'. Bread prepared from refined wheat flour served as control. Two types of bread type-I and type-II were prepared by replacing refined wheat flour at 30 and 40 percent levels, respectively. Control bread had overall acceptability score 7.35 which found in the category of 'liked moderately' whereas type-I and type-II bread exhibited overall acceptability scores i.e. 6.80 and 5.45 found in the category of 'liked slightly' and 'neither liked nor disliked' by the judges.

Among the developed products, four products namely biscuits, *sev, papad* and roasted lentil *dal* were selected for storage upto 2 months depending on their storability.

Control biscuits exhibited mean scores of colour (8.30), appearance (8.20), aroma (8.10), texture (8.30), taste (8.20) and overall acceptability (8.25) at 0 day. However, no significant change was observed in organoleptic attributes upto 30 days of storage. But

beyond 30 day of storage there was significant decrease in mean scores of all sensory attributes. Similarly, in case of type-I and type-II biscuits, after 30 days of storage, a significant decrease was seen in mean scores of colour, appearance, texture, flavour and taste.

Similar trend was also observed in case of *sev, papad* and roasted *dal* and *papad* on 0, 15, 30 and 45 days of storage. On 0 day the mean scores of all attributes like colour, appearance, aroma, texture, taste and overall acceptability was found in the category of 'liked moderately' but on advancement of storage period i.e. on 30^{th} day of storage, these occurred in the category of 'liked slightly'. Whereas on 45^{th} day of storage, significant change was observed in all attributes as compared to 0 day which found in the category of 'neither liked nor disliked'. However, in case of roasted *dal,* after 45 days of storage also mean scores of all sensory attributes found in the category of 'liked slightly'. The fat acidity and peroxide value of control as well as supplemented biscuits, *sev, papad* and roasted *dal* increased significantly with increasing the storage period i.e. 0, 15, 30 and 45 days. It may be concluded from the storage study that these products could be stored safely upto 30^{th} day of storage without any significant change in sensory attributes.

It may be inferred from the present study that among the different lentil genotypes, Garima genotype had better physico-chemical and nutritional quality. Cultivar differences should be exploited so that the cultivar found nutritionally inferior may be discarded and better cultivars may be further utilized in breeding programmes to obtain desirable strains with improved nutritional quality of food legumes.

The various processing methods employed in the present study like soaking, dehulling, germination, roasting, pressure cooking and microwave cooking were responsible for lowering the concentration of antinutrients, improving the *in vitro* digestibility of proteins and starch and enhancing the availability of dietary essential minerals from all the genotypes. Among them, pressure cooking was found most effective treatment in improving the nutritional quality of lentil genotypes.

BIBLIOGRAPHY

Agarwal, V., Singh, N. and Kamboj, S.S. 2004. Some properties of seed and starches separated from mung (*Phaseolus mungo*) cultivars, *J. Food Sci. Technol*. **41**: 341-343.

Agrawal, K. and Singh, G. 2003. Physico-chemical and milling quality of some improved varieties of chickpea (*Cicer arietium*). *J. Food Sci. Technol*. **40** (4): 439-442.

Ahmed, M. and Shehaba, E.L.T. 1982. Cooking quality of fababeans. In 'Fababean Improvement' (Hawtin, G. and Webb, C. ed.) ICARDA, Aleppo, Syria, pp. 355-362.

Akinyele, I.O. and Akinlosotu, S. 1991. The effect of germination on the oligosaccharide and nutrient content of cowpea (*Vigna unguiculata). Food Chem.* **39**: 157-165.

Akpapunam, M.A. and Achinewhu, S.C. 1985. Effect of cooking, germination and fermentation on the chemical composition of Nigerian cowpea. *Plant Foods Hum. Nutr.* **35** : 353-358.

Alonso, R., Saharan, K., Kheterpaul, N. and Bishnoi, S. 2002. Antinutrients and protein digestibility of faba bean and rice bean as affected by soaking, dehulling and germination. *J. Food Sci. Technol*. **39** (4): 418-422.

AOAC. 2000. Official methods of Analysis, Association of Official Analytical Chemist. Washington, D.C.

Arora, S. and Jood, S. and Khetarpaul, N. 2010. Effect of germination and probiotic fermentation on nutrient composition of barely based food mixtures. *Food Chem.* **119** : 779-784.

Attia, R.S. 1994. Effect of cooking and decortications on the physical properties, the chemical composition and the nutritive value of chickpea (*Cicer arietnum* L.). *Food Chem.* **50:** 125-129.

Barroga, C.F., Laurence, A.C. and Mendoza, E.M.T. 1985. Polyphenols in mungbean [*Vigna radiata* (L.) Wilczek] : Determination and removal. *J. Agric. Food Chem*. **33** : 1006-1009.

Bejiga, G. 2006. Cereals and pulses (Brink, M., Beloy, G. eds.). Plant Resources of Tropical Africa. Wageniagen, Netherlands.

Bibi, N., Khattak, A.B., Khattak, G.S.S., Mahmood, Z. and Ihsanullah, I. 2007. Quality and consumer acceptability studies and their inter relationship of newly evolved *desi* type chickpea genotypes (*Cicer arietinum* L.). *Int.J. Food Sci. Technol.* **42**: 528-534.

Bishnoi, S. 1992. Effects of domestic processing and cooking methods on nutritional value of peas (*Pisum sativum*). M.Sc. Thesis, Haryana Agricultural University, Hisar.

Bishnoi, S. and Khetarpaul, N. 1993. Effect of domestic processing and cooking methods on *in vitro* starch digestibility of different pea cultivars (*Pisum sativum*). *Plant Foods Hum.Nutr.* **45:** 381-388.

Bishnoi, S. and Khetarpaul, N. Yadav, R.K. 1994. Effect of domestic processing and cooking methods on phytic acid and polyphenol content of peas. Plant Foods *Hum. Nutr*. **45** : 381-388.

Bishnoi, S. and Khetarpual, N. 1994. Protein digestibility of vegetable and field peas (*Pisum sativum*) : Varietal differences and effect of domestic processing and cooking methods. *Plant Foods Hum. Nutr*. **46** : 71-76.

Bishnoi, S. and Khetarpual, N. 1995. Effect of various domestic processing and cooking methods on the HCl-extractability of mineral from pea seeds. *Nahrung*. **39** : 514-520.

Boralkar, M. and Reddy, M.S. 1985. Effect of roasting, germination and fermentation on the digestibility of starch and protein present in soybean. *Nutr. Rep. Int.* **31** : 833-836.

Cerning, J. and Guilhot, J. 1973. Changes in carbohydrate composition during maturation of wheat and barley kernel. *Cereal Chem*. **50**: 220-222.

Chavan, J.K., Kachar, D.P. and Kadan, S.S. 1989. Influence of sprouting on nutritional quality of cowpea. *J. Maharastra Agric. Univ.* **14** : 106-107.

Cheryan, M. 1980. Phytic acid intereaction in food systems. CRC Crit. Rev. *Food Sci. Nutr.* **13** : 297-335.

Chimmad, B.V., Naik, R.K. and Rao, M. 2005. Nutritional quality of black bean seeds. *J. Food Sci. Technol.* **42** (1): 53-55.

Chopra, S. and Sankhala, A. 2004. Effect of soaking and sprouting on tannin, phytate and *in vitro* iron in underutilized legume horse gram and moth bean. *J. Food Sci. Technol.* **41**: 547-550.

Clegg, K.M. 1956. The application of anthrone reagent to the estimation of starch in cereals. *J. Sci. Food Chem. Agric.* **7**: 40-44.

Dahiya, S. and Kapoor, A. C. 1994. Development, nutritive content and shelf life of home processed supplementary foods. *Plant Foods Hum. Nutr.* **45:** 334-342.

Dave, S.,Yadav, B.K. and Tarafdar, J.C. 2008. Phytate phosphorus and mineral changes during soaking, boiling and germination legumes and pearl millet. *J. Food Sci. Technol*. **45** (4): 344-348.

Davies, N.T. and Reid, H. 1979. An evaluation of phytate, zinc, copper, iron and manganese content and availability of soya based textured vegetable protein meat substitute or meat extrudes. *Brit. J. Nutr.* **41**: 579-589.

Deshpande, S.S. and Cheryan, M. 1984. Effect of phytic acid, divalent cations and their interactions on alpha amylase activity. *J. Food Sci*. **49** : 516-519.

Dhaka, R. 2001. Formulation of food products incorporating cereal bran and legume seed coats. M.Sc. Thesis, CCS Haryana Agricultural University, Hisar, India.

Dhingra, S. and Jood, S. 2004. Effect of flour blending on functional, baking and organoleptic characteristics of bread. *Int. J. Food Sci. Technol.* **39** : 213-222.

Doshi, V. and Simlot, M.M. 1997. Effect of trypsin inhibitor on protein quality of black-soybean and mothbean meals. *J. Food Sci. Technol*. **34** : 208-211.

Duhan, A. 1992. Nutritional evaluation of pigeonpea (*Cajanus cajan*) varietal differences and effects of different domestic processing methods. M.Sc. Thesis, CCS Haryana Agricultural University, Hisar, India.

Duhan, A., Chauhan, B.M., Punia, D. and Kapoor, A.C. 1989. Phytic acid content of chick pea (*Cicer arietinum*) and black gram (*Vigna mungo*) varietal differences and effect of domestic processing and cooking methods. *J. Sci. Food Agric*. **49** : 449-452.

Duhan, A., Khetarpaul, N. and Bishnoi, S. 2001. Effect of soaking, germination and cooking on phytic acid and hydrochloric acid extractability of a pigeon pea cultivar. *J. Food Sci. Technol*. **38(4):** 374-378.

Duhan, A., Khetarpaul, N. and Bishnoi, S. 2002. Changes in phytates and HCl extractability of calcium, phosphorus and iron of soaked, dulled, cooked and sprouted pigeonpea cultivar. *Plant Foods Hum. Nutr*. **57** : 275-284.

Elias, L.G. Fernandez, D.G. and Bressani, R. 1979. Possible effects of seed coat polyphenols on the nutritional quality of bean protein. *J. Food Sci*. **44** : 524-527.

EL-Mahdy, A.R. and EL-Sebiy, L.A. 1983. Changes in phytate and minerals during germination and cooking of fenugreek seeds. *Food Chem.* **9** : 149-158.

El-Maki, H.B., Rahaman, S.M.A., Idris, W.H., Hassan, A.B., Babiker, E.E. and Tinay, A.H.E. 2007. Content of antinutritional factors and HCl-extractability of minerals from white bean (*Phaseolus vulgaris*) cultivars: Influence of soaking and cooking. *Food Chem*. **100** (1): 362-368.

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

FAO. 2009. http://www.faostat.org.produciton:crop-pulses

Furda, I. 1981. Simultaneous analysis of soluble dietary fibre. The analysis of dietary fibre in Food. W.P.T. James and O. Theander (Eds.) Marcel Dekkar, New York:163-172.

Garg, R. and Dahiya, S. 2003. Nutritional evaluation and shelf life studies of papads prepared from wheat-legume composite flours. *Plant Foods Hum. Nutr.* **58**: 299-307.

Garg, S. 2001. Development and nutritional evaluation of some novel food products of wheat and legume blends. M.Sc. Thesis, CCS, Haryana Agricultural University, Hisar, India.

Ghavidel, R.A. and Prakash, J. 2007. The impact of germination and dehulling on nutrients, antinutrients, *in vitro* iron and calcium bioavailability and *in vitro* starch and protein digestibility of some legume seeds. *Food Sci. Tech*. **40**: 1292-1299.

Giami, S.Y. and Okwechime, U.I. 1993. Physico-chemical properties and cooking quality of four new cultivars of Nigerian cowpea (*Vigna Unguiculata). J. Sci. Food Agric*. **63** : 281-286.

Gibson R.S., Perias, L. and Christine, H. 2006. Improving the bioavailability of nutrients in plant foods at the household level. *Proceed. Nutr. Soc*. **65 (2):**160-168.

Giri, J., Paravatham, R. and Sonthini, K. 1981. Effect of germination on the levels of pectins, phytins and mineral in three selected legumes. *Indian J. Nutr. Dietet*. **18** : 87-91.

Gorski, P.M. 1985. Variation in tannin content of fababean (*Vicia faba*) seed coat. *News Letter*. **11** : 26-28.

Grewal, A. 2003. Effect of processing on nutritional quality form products from newly released varieties of green gram. M.Sc. Thesis, CCS Haryana Agricultral University, Hisar, India.

Grewal, A. and Jood, S. 2006. Effect of processing treatments on nutritional and antinutritional contents of green gram. *J. Food Biochem.* **30** : 535-546.

Grewal, A. and Jood, S. 2009. Chemical composition and digestibility (*in vitro*) of green gram as affected by processing and cooking methods. *Brit. Food J.* **111** : 235-242.

Grewal, A., Jood, S. and Kumar, R. 2007. Effect of processing methods on nutritional quality of MHIK-25 newly identified green gram cultivars. *National J. Pl. Improv.* **9** (1) : 9-13.

Grewal, A., Jood, S. and Yadav, R.K. 2006. Variability in physico-chemical properties and chemical composition of newly released green gram cultivars. *Univ. J. Res.* **36** : 65-70.

Grewal, R. 1992. Nutritional improvement of soyabean through fermentation and its utilization in traditional foods of India. Ph.D. Thesis, Haryana Agricultural University, Hisar, India.

Gurusu, O., Earcan, R. and Denli, E. 1997. Effect of the addition of soyflour on quality and shelf-life of biscuit. *Gida.* **22** (2): 95-103.

Habib, F.G.K., Mahran, G.H., Hilal, S.H., Gabrial, G.N. and Morcos, S.R. 2005. Phytochemical and nutritional studies on pigeon pea and kidney bean cultivated in Egypt. *J. Zeitschrift Swissens Chaft*. **15** (2): 224-230.

Habibullah, Abbas, M. and Shah, H.U. 2007. Proximate and mineral composition of mung bean. *Sarhad J. Agri*. **23** (2): 462-466.

Henshaw, F.O. 2008 Varietal differences in physical characteristics and proximate composition of cowpea (*Vigna unguiculata*). *World J. Agri. Sci*. **4** (3): 302-306.

Hooda, S. 2002. Nutritional evaluation of fenugreek supplemented wheat products. M.Sc. Thesis, CCS Haryana Agricultrual University, Hisar, India.

Hooda, S. and Jood, S. 2005. Organoleptic and nutritional evaluation of wheat biscuits supplemented with untreated and treated fenugreek flour. *Food Chem.* **90** : 427-435.

http://www.agriculture.gov.sk.ca. 2009.

http://www.nationalspotexchange.com. 2010.

Huma, N., Anjum, M., Sehar, S., Issakhan, M. and Hussain, S. 2008. Legumes of soaking and cooking on nutritional quality and safety of legumes. *Nutr. Food Sci.* **38** : 570-577.

Igbedioh, S.O., Shaire S. and Aderiye, B.J.I. 1995. Effect of processing on the total phenols and proximate composition of pigeonpea (*Cajanus cajan*). *J. Food Sci. Technol.* **32:** 497-500.

Iqbal, A., Khalil, I. A., Ateeq, N. and Khan, M.S. 2006. Nutritional quality of important food legumes. *Food Chem.* **97** (2): 331-335.

Jaya, T.V. and Venkataraman, L.V. 1980. Effect of germination on the nitrogenous constituents, essential amino acids, carbohydrates, enzyme and antinutritional factors in chickpeas and green gram. *Indian Food Packer*. **34** : 3-11.

Jood, S. and Kapoor, A.C. 1997. Improvement in bioavailability of minerals of chickpea and black gram cultivars through processing and cooking methods. *Int. J. Food Sci. Nutr.* **48** : 307-312.

Jood, S., Bishnoi, S. and Sehgal, S. 1998. Effect of processing on nutritional and anti-nutritional factors of moongbean cultivars. *J. Food Biochem*. **22** : 245-257.

Jood, S., Bishnoi, S. and Sharma, S. 1998. Nutritional and phsico-chemical properties of chickpea and lentil cultivars. *Die Nahrung Food.* **42**: 70-73.

Jood, S., Chauhan, B.M. and Kapoor, A.C. 1987. Polyphenols of chickpea and black gram as affected by domestic processing and cooking methods. *J. Sci. Food Agric.* **39** : 145-149.

Jood, S., Chauhan, B.M. and Kapoor, A.C. 1988. Contents and digestibility of carbohydrates of chickpea and black gram as affected by domestic processing and cooking. *Food Chem*. **39** : 113-127.

Jood, S., Chauhan, B.M. and Kapoor, A.C. 1989. Protein digestibility (*in vitro*) of chickpea and black gram seeds as affected by domestic processing and cooking. *Plant Food Hum. Nutr.* **39** : 149-159.

Jood, S., Mehta, U. and Singh, R. 1986. Effect of processing on available carbohydrates in legumes. *J. Agric. Food Chem*. **34** : 417-422.

Kakati, P., Deka, S.C., Kotoki, D. and Saikia, S. 2010. Effect of traditional methods of processing on the nutrient contents and some antinutritional factors in newly developed cultivars of green gram [*Vigna radiata* (L.) Wilezek] and black gram [*Vigna mungo* (L.) Hepper] of Assam, India. *Int. Food Res. J*. **17:** 377-384.

Kapoor, R. and Kapoor, A. C. 1990. Effect of different treatments on keeping quality of pearl millet flour. *J. Food. Chem*. **35** : 277-286.

Kataria, A., Chauhan, B.M. and Punia, D. 1989. Antinutrients and protein digestibility (*in vitro*) of mungbean as affected by domestic processing and cooking. *Food Chem*. **32** : 9-17.

Kataria, A., Chauhan, B.M. and Punia, D. 1992. Digestibility of proteins and starch (*in vitro*) of Emphidiploids (black gram x mung bean) as affected by domestic processing and cooking. *Plant Foods Hum. Nutr*. **42** : 117-125.

Kataria, A., Chuhan, B.M. and Punia, D. 1990. Effect of domestic processing and cooking methods on the contents of carbohydrates of amphidiploids (black gram X mungbean). *Food Chem.* **36:** 63-67.

Kaur, D. 1986. Studies on nutrient composition and nutritional factors of rice bean (*Vigna umbellata*). M.Sc. Thesis, Haryana Agricultural University, Hisar, India.

Kaur, D. and Kapoor, A.C. 1990. Some antinutritional factors in ricebean (*Vigna umbellata*) : Effect of domestic processing and cooking methods. *Food Chem*. **37** : 171-179.

Kaur, D. and Kapoor, A.C. 1990. Starch and protein digestibility of ricebean (*Vigna umbellata*) : Effect of domestic processing and cooking methods. *Food Chem*. **38** : 263-272.

Kaushik, G., Satya, S. and Naik, S.N. 2010. Effect of domestic processing techniques on the nutritional quality of the soybean. *Mediterr. J. Nutr. Metab*. **3**: 39-46.

Khan, N.A. and Ghafoor, A. 1978. The effect on soaking, germination and cooking on the protein quality of mash bean (*Phaseolus mungo*). *J. Sci. Food Agric*. **29** : 461-463.

Khan, A.R., Slan, S., Ali, S., Bibi, S. and Khalil, I.A. 2007. Dietary fibre profile of food legumes. *Sarhad J. Agric.* **23** : 320-327.

Khatoon, N. and Prakash, A. 2006. Nutritive value and sensory profile of microwave and pressure cooked decorticated legumes. *J. Food Process. Preserv.* **30** : 299-313.

Khatoon, N. and Prakash, J. 2004. Nutritional quality of microwave cooked and pressure cooked legumes. *Int. J. Food Sci. Nutr.* **55** : 441-448.

Kim, H. and Zemel, M.R. 1986. *In vitro* estimation of the potential bioavailability of calcium from sea mustard, milk and spinach under stimulated, normal and reduced gastric acid condition. *J. Fd. Sci.* **51** : 957-963.

King, R.D. and Puwastein, P. 1987. Effect of germination on the proximate composition and nutritional quality of winged bean seed. *J. Sci. Food Agric.* **52** : 106-108.

Komalpreet and Punia, D. 2000. Antinutrients and digestibility (*in vitro*) of soaked, dehulled and germinated cowpea. *Nutrition and Health*. **14** : 109-117.

Kumari, A. 2002. Development of ready to eat breakfast foods: Their sensory and nutritional evaluation. Ph.D. Thesis, CCS Haryana Agricultral University, Hisar, India.

Li, W., Shu, C., Yan, S. and Shen, Q. 2010. Characterstics of sixteen mung bean cultivars and their protein isolates. *Int. J. Food Sci. and Technol*. **45**: 1205-1211.

Liener, J.E. and Kakade, M.L. 1980. Protease inhibitors. In : Toxic constituents of plant food stuffs, 2nd ed. (I.E. Liener Ed.) Academic Press, New York.

Lindsey, W.L. and Norwell, M.A. 1969. A new DPTA-TEA soil test for zinc and iron. *Agron. Abst.* **61**: 84-89.

Lowry, O.H., Rosebrough, N.J., Farr, A.L. and Randall, R.J. 1951. Protein measurement with the folin phenol reagent. *J. Biol. Chem.* **193**: 265-275.

Madhura, C.V., Premavalli and Arya, S.S. 1998. Studies on traditional Indian foods In: Development and storage of *rava idli* mix. *Indian Food Packer.* **52**(3): 33-37.

Marconi, E., Ruggeri, S., cappelloni, M., Leonardi, D. and Carnoval, E. 2000. Physiochemical nutritional and micro-structural characteristics of chickpeas (*Cicer arietinum* L.) and common beans (*Phaseolus Volgaris* L.) following microwave cooking. *J. Agric. Food Chem.* **48** (12) : 5986-5994.

Mehla, I.S., Waldia, R.S. and Dahiya, S.S. 2001. Variation and relationship among cooking quality attributes across the environment in *kabuli* chickpea. *J. Food Sci. Technol*. **38** : 283-286.

Mertz, E.I., Kirleiz,, A.W. and Axtell, J.D. 1983. *In vitro* digestibility of proteins in major food cereals. *Food Proc.* **42** (5) : 6026.

Miller, D.D., Schrickler, B.R., Rasmussen, R.R.. and Van Campen, D. 1981. An *in vitro* method for estimation of iron availability from meals. *Am. J. Clin. Nutr*. **34** : 2248-2251.

Mishra, M.K., Dubey, R.K. and Rao, S.K. 2010. nutritional composition of field pea (*Pisum sativum* var. arvense L.). *Legume Res*. **33**(2): 146-147.

Mubarak, A.E. 2005. Nutritional composition and antinutritional factors of mung bean seeds (*Phaseolus aureus*) as affected by some home traditional processes. *Food Chem*. **89**: 489-495.

Mulimani, V.H., Nanda, S.K. and Thippeswamy, S. 2003. Effect of processing on phytic acid content in different red gram (*Cajanus cajan* L.) varieties. *J. Food Sci. Technol*. **40** (4): 371-373.

Mulimani, V.H., Rudrappa, G. and Supriya, D. 1994. Amylase inhibitors in chickpea (*Cicer arietimim* L.). *J. Sci. Food Agric.* **64** : 413-415.

Murkya, M.S., Camp, J.W., Yiru, Y. and Huydhe-boert, A.D. 2000. Nutrient and antinutrient changes in finger millet during sprouting. *Lebens Mittel-Wissenchaft and Technologie.* **33:** 9-14.

Negi, A. 1999. Nutritional evaluation of some high yielding varieties of mothbean (*Phaseolus aconitifolius Jacq*.) : Effect of domestic processing and cooking methods. M.Sc. Thesis, Haryana Agricultural University, Hisar, India.

Negi, A., Boora, P. and Gupta, P.P. 2001. Starch and Protein digestibility of newly released moth bean cultivars. Effect of soaking, dehulling, germination, pressure cooking. *Nahrung*. **45** (4): 251-254.

Negi, A., Boora, P. and Khetarpaul, N. 2000. Effect of domestic processing and cooking methods on the carbohydrates contents of newly released moth bean (*Phaseolus aconitifolius* Jacq.). *Nut. Health*. **14**: 265-269.

Negi, A., Boora. P and Khetarpaul, N. 2011. Carbohyrate profile and starch digestibility of newly released high yielding moth bean (*Phaseolus aconitifolius Jacq*.) varieties as affected by microwave heating and pressure cooking. *J. Food Sci. Technol.* **48** (2) : 246-250.

Oberleas, D. 1983. Phytate content of cereal and legumes and methods of determination. *Cereal Food World*. **28** : 352-357.

Ologholbo, A.D. and Fetuga, B.L. 1984. Distribution of phosphorus and phytate in some Nigerian varieties of legumes and some effects of processing. *J. Food Sci*. **49** : 199-201.

Parihar, P., Mishra, A.,Gupta, O.P., Rajput, L.P.S. and Singh, A. 1999. Effect of processes on nutritional quality of some common pulses. *Adv. Plant Sci*. **12:** 15-20.

Prabhavathi, T., Bageballi, S. and Rao, N. 1979. Effects of domestic preparation of cereals and legumes in ionisable iron. *J. Sci. Food Agri*. **30** : 597.

Punia, D. and Chauhan, B.M. 1993. Chemical composition and cookability of *desi* and *kabuli* chickpea varieties. *Bull. Grain Technol.* **31** : 44-51.

Punia, D. and Chauhan, B.M. 1998. Nutrient make up, level of antinutrients, cookability and consumer preferred charactersitics of high yielding chickpea varieties. *Bull. Grain Technol*. **31** : 44-51.

Raghuvanshi, R.S., Singh, S., Bisht, K. and Singh, D.P. 2011. Processing of mungbean products and its nutritional and organoleptic evaluation. *Int. J. Food Sci. Technol.* **46** : 1378-1387.

Ramulu, P. and Rao, P.U. 1997. Effect of processing on dietary fibre content of cereals and pulses. *Plant Foods Hum. Nutr.* **50** : 249-257.

Rani, N. and Hira, C.K. 1993. Effect of various treatments on nutritional quality of fababean. *J. Food Sci. Technol.* **30** : 413-416.

Rani, N. and Hira, C.K. 1998. Effect of different treatments on chemical constituents of mash beans (*Vigna mungo*). *J. Food Sci. Technol*. **35** : 540-542.

Rani, S., Jood, S. and Sehgal, S. 1996. Cultivar differences and effect of pigeonpea seeds boiling on trypsin inhibitor activity and *in vitro* digestibility of protein and starch. *Nahrung*. **40** : 146-147.

Rani, V. and Grewal, R.B. 2009. Carbohydrate profile, dietary fibre, antinutrients and *in vitro* digestibility of nine cultivars of soybean (*Glycine max*. L.). *Merr. Legume Res*. **32**(1): 31–35.

Rao, B.S.N and Prabhavathi, T. 1978. An *in vitro* method of predicting the bioavailability of iron from Food. *Am. J. Clin. Nutri* .31:169.

Rao, P.U. and Prabhavathi, Y.G. 1982. Tannin content of pulses : Varietal differences and effects of geremination and cooking. *J. Sci. Food Agri*. **33** : 1013-1016.

Raymond, J. 2006. World's Healthiest Foods: Lentils. Health Magazine.

Reddy, N.R. and Salunkhe, D.K. 1981. Interactions between phytate, protein and minerals in whey fractions of black gram. *J. Food Sci.* **46** : 564-567.

Reddy, N.R., Pierson, N.D., Sathe, S.K. and Salunkhe, D.K. 1985. Dry bean tannins : A review of nutritional implications. *J. Am. Oil Chem. Soc*. **62** : 541-548.

Reddy, N.R., Sathe, S.K. and Salunkhe, D.K. 1982. Phytates in legumes and cereals. *Adv. Food Res*. **28** : 1-9.

Ritu. 2004. Development of value added products incorporating crude palm oil and its blends their sensory and nutritional evaluation. M.Sc. Thesis, CCS Haryana Agricultural Cultural University, Hisar.

Roy, D.N. and Rao, P.S. 1971. Evidence, isolation purification and some properties of a trypsin inhibitor in *Lathyrus sativus*. *J. Agric. Food Chem.* **19**: 257.

Saharan, K. 1994. Studies on the development of products from rice bean and faba bean:Their sensory and nutritional evaluation. Ph. D. Thesis. CCS Haryana Agricultural University.

Saharan, K., Khetarpaul, N. and Bishnoi, S. 2002. Antinutrients and protein digestibility of fababean and ricebean as affected by soaking, dehulling and germination. *J. Food Sci. Technol*. **39**: 418-422.

Saharan, K., Khetarpaul, N. and Bishnoi, S. 2002. Variability in physicochemical properties and nutrient composition of newly released rice bean and faba bean cultivars. *J .Food. Comp. Anal.* **15:** 159-167.

Salesh, A.A. and Tarek, A.E. 2006. Nutritional composition of chickpea (*Cicer arietinum* L.) as affected by microwave cooking and other traditional cooking methods. *J. Food Comp. Anal.* **19** : 806-812.

Sandberg, S. and Thomas, A. 2002. Phytogenic and microbial phytase in human nutrition. *Int. J. Food Sci. and Tech.* **32** (7) : 823-833.

Sangwan, V. 2002. Development and nutritional evaluation of wheat, sorghum, soybean, composite flour biscuits, Ph.D. Thesis. CCS Haryana Agricultural University, Hisar, India.

Saxena, A.K., Chadha, M. and Sharma, S. 2003. Nutrients and antinutrients in chickpea (*Cicer arietinum* L.) cultivars after soaking and pressure cooking. *J. Food Sci. Technol*. **40** (5): 493-497.

Saxena, A.K., kulkarni, S.G., Manan, J.K., Berry, S.K. 1989. Studies on the blends of different pulses (bengal gram, green gram, lentil and arhar) in the prepration of North Indian special *papads*. *J. Food Sci. Technol.* **26:** 133-136.

Serraino, M.R., Thompson, L.U., Savoie, L. and Parent, G. 1985. Effect of phytic acid on the *in vitro* rate of digestibility of rapeseed protein and amino acids. *J. Food Sci.* **50** : 1689-1692.

Shanthi, D., Manimegalai, G. and Chitra, P. 2000. Studies on the processing and evaluation of instant *idli* mixes. *J. Food Sci. Technol*. **37** (7): 433-435.

Sharma, A. and Sehgal, S. 1991. Proximate composition and protein fractions of fababean (*Vicia faba*). *Bull. Grain Technol*. **29** (2) : 104-107.

Sharma, A., Jood, S. and Sehgal, S. 1996. Antinutrients (phytic acid, polyphenols) and minerals (Ca, Fe) availability (*in vitro*) of chickpea and lentil cultivars. *Nahrung*. **40** : 182-184.

Shimelis, E.A. and Rakshit, S.K. 2007. Effect of processing on antinutrients and *in vitro* protein digestibility of kidney bean (*Phaseolus vulgaris* L.) varieties grown in East Africa. *Food Chem.* **103**: 161-172.

Shinde, G.B. and Adsule, R.N. and Kale, A.A. 1991. Effect of dehulling and cooking treatment on phytate phosphorous, polyphenols and trypsin inhibitor activity of cowpea (*Vigna unguiculata* L. walp) seeds. *Indian Food Packer*. pp. 63-65.

Singh, G. 2003. Development and nutritional evaluation of value added products from pearl millet (*Pennisetum glaucum*). Ph.D. Thesis. CCS. Haryana Agricultural University, Hisar, India.

Singh, U. 2001. Functional properties of grain legume flours. *J. Food Sci. Technol*. **38** (3): 191-199.

Singh, U. and Jambunathan, R.1981. Relationship between total nitrogen and non-protein nitrogen in chickpea (*Cicer arietinum* L.) seeds. *J. Agric. Food Chem*. **29:** 423.

Singh, U., Khedekar, M.S. and Jambunathan, R. 1982. Studies on *desi, kabuli* chickpea cultivars. The levels of amylase inhibitors, levels of oligosaccharides and *in vitro* starch digestibility. *J. Food Sci.* **47**: 510.

Singh, V. 2006. Development and nutritional evaluation of value added products from quality protein maize (*Zea mays* L.) Ph.D. Thesis, CCS Haryana Agricultral University, Hisar, India.

Sinha, R. 1999. Nutritional evaluation processing and utilization of cowpea (*Vigna unguiculata* L. Walp). Ph.D. Thesis, Haryana Agricultural University, Hisar, India.

Sinha, R., Kawatra, A. and Sehgal, S. 2002. Digestibility of carbohydrate of cowpea as affected by processing. *J. Food Sci. Technol.* **39** : 246-250.

Sinha, S., Kwatra, A. and Sehgal, S. 2007. Effect of processing on proximate composition of cowpea (*Vigna unguiculata*). *J. Dairying Foods Home Sci*. **26**(1): 11-14.

Solama, A. M. and Ragab, G.H. 1997. Composition of conventional and microwave cooking of kidney beans and carrot in relation to chemical composition, nutritive value and sensory characteristics. *J. Home Econ.* **7** : 213-2225.

Somogyi, M. 1945. A new reagent for the determination of sugar. *J. Biol. Chem.* 160-161.

Sood, M., Malhotra, S.R. and Sood, B.C. 2002. Effect of processing and cooking on proximate composition of chickpea (*Cicer arietium*) varieties. *J. Food Sci. Technol*. **39**: 69-71.

Srinavasa, R.P. 1976. Nature of carbohydrates in pulses. *J. Agric. Food Chem*. **24** : 958-961.

Srivastava, R.P., Srivastava, G.K. and Gupta, R.K. 2001. Nutritional quality of ricebean. *Ind. J. Agri. Biochem*. **14** : 55-56.

Supraja, T. 2001. Utilization of crude palm oil for development of Vit. A rich supplementary foods. M.Sc. Thesis CCS Haryana Aaricultral University, Hisar, India.

Swain, J. and Hills, W.E. 1959. The phenolic constituents of Prunus domestica the qualitative analysis of phenolic constituents. *J. Sci. Food. Agric*. **10** : 63.

Tajoddin, M.D., Sinde, M. and Lalitha, J. 2001. *In vitro* reduction the phytic acid content of mung bean (*Phaseodus aureus* L.) cultivars during germination. *J. Agric. Environ. Sci.* **10** (1) : 127-132.

Tan, N., Wong, K. and Lumen, B.O. 1984. Relationship of tannin levels and trypsin inhibitor activity of raw and heat treated winged beans. *J. Agric. Food Chem.* **32** : 819-821.

Thompson, L.V. and Yoon, J.G. 1984. Starch digestibility as affected by polyphenols and phytic acid. *J. Food Sci*. **49** : 1228-1229.

Tovar, J., Francisco, A., Bjrock, I. and Asp, N.G. 1991. Relationship between microstructure and *in vitro* digestibility of starch in pre-cooked leguminous seed flours. *Food Struct*. **10** : 19-26.

Vidal-Valverde, C. and Frias, J. 1992. Legume processing effects on dietary fibre components. *J. Food Sci.* **56** : 1350-1352.

Walker, A.F. and Kochhar, N. 1982. Effect of processing including domestic cooking on nutritional quality of legumes. *Proc. Nutr. Soc.* **41** : 41-51.

Wang, N., Hatcher, D.W., Toews, R. and Gawalko, E.J. 2008. Influence of cooking and dehulling of nutritional composition of several varieties of lentils (*Lens culinaris*). *Plant Foods Hum. Nutr*. **42** : 117-125.

Wang, N., Lewis, M.J., Brennan, J.G. and Westky, A. 1997. Effect of processing methods on nutrients and antinutritional factors in cowpea. *Food Chem*. **58** : 59-68.

Wein, E.M. and Schwartz, R. 1985. Dietary calcium extractability and bioavailability : Evaluation and potential use of an *in vitro* digestibility procedure. In : Nutritional bioavailability of calcium. (C. Kies, ed.) Amn. Chem. Soc. Washington, D.C.

Williams, P.C., Nakoul, H. and Singh, K.B. 1983. Relationship between cooking time and some physical characteristics in chickpea (*Cicer arietinum* L). *J. Sci. Food. Agri*. **34**: 492-496.

Williams, P.C., Nekoul, H. and Singh, K.B. 1982. International centre for agricultural research in the dry areas (ICARDA). Aleppo, Syria.

Yadav, S. 1992. The preparation, acceptability and nutritional evaluation of *wadi*-an indigenous legume fermented product. M.Sc. Thesis, CCS Haryana Agricultural University, Hisar, India.

Yadav, S.S., Mcneil, D. and Stevenson, P.C. 2007. Lentil-An ancient crop for modern times. Published by Springer, Netherlands, p. 47.

Yemm, E.W. and Willis, A.J. 1954. The estimation of carbohydrates in plant extracts by anthrone. *Biochem. J.* **57:** 508.

Youseff, M.M., Abd El-Aal, M.H., Ziena, H.M. 1987. Effects of dehulling, soaking and germination on chemical composition, mineral elements and protein patterns of fababeans (*Vicia faba* L.). *Food Chem.* **29** : 129-138.

Youssef, M.K.E. and Abdel-Gawad, A.S. 1992. Proceeding of the second Alexandria conference on *Food Sci. and Technol*. : 164-172.

APPENDIX- I

Nine Point Hedonic Rating Scale

Name ---------- Dated ----------

Products ----------

Test these samples and check how much you like or dislike each one. Use appropriate scale to show your attitude by assigning points that best describe your feelings about the sample. An honest expression of your feelings will help us.

Sr. No.	Colour Appearance	Aroma	Texture	Taste	Overall acceptability	Remarks

Rate	Organoleptic score
Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like nor dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

ABSTRACT

1. Title of the thesis	:	**Nutritional evaluation of lentil (*Lens culinaris*) genotypes and its utilization in development of value added products**
2. Full name of the degree holder	:	**Deepika Ahlawat**
3. Admission No.	:	2009HS87M
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7. Year of award of degree	:	2011
8. Major subject	:	Foods and Nutrition
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Keyword: Lentil genotypes, physico-chemical properties, processing methods, nutritional analysis, product development, sensory evaluation, shelf life.

An investigation was conducted to study the physico-chemical and nutritional characteristics of six lentil (*Lens culinaris*) genotypes and their utilization in development of value added products through various processing and cooking methods. The results of physico-chemical properties of six lentil genotypes indicated that Garima genotype had maximum values of seed volume, seed density, swelling capacity, swelling index, hydration capacity and hydration index which resulted in less cooking time i.e. 36 min. Whereas HM-I genotype had minimum values which might have contributed towards more cooking time i.e. 43 min. The contents of proximate composition, sugars, dietary fibre, *in vitro* protein and starch digestibility, total and available minerals and antinutritional factors differed significantly among all the genotypes. All the genotypes were subjected to various processing and cooking methods like soaking dehulling, germination, roasting, pressure cooking and microwave cooking. Soaking, dehulling, germination, roasting, pressure cooking and microwave cooking had non-significant effect on moisture, crude protein, crude fat, ash and total minerals whereas dehulling caused significant decrease in crude fibre, dietary fibre and total minerals. On the other hand, all the processing and cooking methods significantly improved *in vitro* protein and starch digestibility and *in vitro* availability of minerals by reducing the levels of phytic acid, polyphenols and trypsin inhibitor activity. Germination brought significant decrease in all the three dietary fibre constituents whereas heat treatments like roasting, pressure cooking and microwave cooking caused significant increase in soluble fraction and decrease in insoluble fraction but total dietary fibre was remained almost same. Soaking and dehulling had non-significant effect on sugar and starch contents whereas germination and heat processing significantly increased sugar contents by hydrolyzing the starch contents. Similar trend was observed in all the genotypes. Among the processing methods, pressure cooking was found most effective treatment for improving the nutritional quality of lentil genotypes. Among lentil genotypes, Garima was found superior in terms of physico-chemical and nutritional characteristics, therefore used as unprocessed and processed for development of various value added products. All the products wee found organoleptically acceptable as compared to their control. Among the developed products, four products namely biscuits, *sev*, *papad* and roasted *dal* were stored for 2 months, however, biscuits, *sev* and *papad* were found acceptable in terms of sensory attributes upto 30 days of storage and roasted *dal* was found acceptable upto 45 days without any significant change in sensory attributes.

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