Common buckwheat (*Fagopyrum esculentum* Moench) is an important pseudocereal belonging to the Polygonaceae family. Considering the nutritional particularly nutraceutical significance of various edible plant parts in sustaining human health extensive efforts are being made to improve production technology of different under utilized crops including buckwheat at the national level. However, systematic information on the genotypic variability in relation to biochemical consistuents among different buckwheat genotypes appears to be still limited. In addition, studies related to the effect of storage on retention of dietary nutrients in pseudocereals in general and buckwheat in particular are also scanty. The literature also revealed inadequate systematic information with regard to variability in biochemical parameters of fresh leaves of buckwheat genotypes. Keeping these aspects in view the research work, which has mostly been carried out abroad and that too in India is reviewed briefly under following sub- heads:

2.1 **Variability in biochemical constituents of grains**

2.1.1 Variations in proximate composition

2.1.2 Protein fractionation and protein quality indexing

2.1.3 Variation in minerals, dietary fibre and oxalate content of buckwheat

2.2 **Variation in biochemical constituents in leaves**

2.2.1 Variation in proximate composition

2.2.2 Variation in minerals, dietary fibre and oxalate content
2.3 Variation in total phenols and rutin in grains and leaves

2.4 Variation in biochemical constituents during storage

2.1 Variability in biochemical constituents of buckwheat grain

2.1.1 Variations in proximate composition

The proximate composition of any foodstuff including pseudocereals represents the moisture, crude protein, fat, minerals, crude fibre and carbohydrates which taken together on a percentage basis and the extent of variability in buckwheat grains studied so far is reviewed appropriately as follows:

Marshall and Pomeranz (1982) reported protein content in whole buckwheat and buckwheat groats as 13.8 and 16.4 per cent, respectively.

Kusano et al. (1983) determined the nutritive components of tetraploid buckwheat grains in comparison to those of diploid grains. It was observed that moisture, protein, lipid, carbohydrates and ash content varied from 11.0 to 11.5, 15.1 to 16.3, 6.1 to 6.9, 73.3 to 74.7 and 3.5 to 3.9 per cent on dry weight basis, accordingly.

Tahir and Farooq (1985) studied the chemical composition of grains of four buckwheat cultivars viz., Fagopyrum esculentum Moench, F. sagittatum Gilib., F. kashmirianum Munshi and F. tataricum Gaertn and reported lipid content as 1.66 per cent in hull, 2.5 per cent in groat and 2.31 per cent in the grains in Fagopyrum esculentum Moench.

Dietryoh-szostak and Ploszynski (1986) evaluated the ash, crude fiber, fat and crude protein content in different fractions of buckwheat groat and reported variation in these parameters from 2.11 to 2.64, 0.24 to 0.60, 3.04 to 4.64 and 12.50 to 13.13 per cent, respectively on dry matter basis.
Bonafaccia et al. (1994) analysed five buckwheat samples selected from different geographical areas of Italy. 1000-grain weight, moisture content, protein, ash, fat and soluble carbohydrates were observed to vary from 25.40 to 28.70 g, 12.80 to 13.40, 11 to 13.60, 2.23 to 2.65, 2.93 to 3.37 and 61.00 to 64.90 per cent on dry matter basis.

Wang et al. (1995) studied the nutritional composition of buckwheat and reported 13.0 moisture, 9.3 protein, 2.3 fat, 6.5 fiber, 64.5 carbohydrates and 2.4 ash content per cent in common buckwheat.

Li and Zhang (2001) reported protein, carbohydrate, fat, fiber and ash content in grains of buckwheat as 12.3, 73.3, 2.3, 10.9 and 2.1 g/100g, in that order.

Steadman et al. (2001) analysed the general composition of buckwheat groat and observed that buckwheat contained 11.8 per cent moisture, 12.3 per cent protein, 3.8 per cent lipids and 2.4 per cent minerals.

Gupta et al. (2002) evaluated the nutritive value of hulled and dehulled buckwheat grains and reported that protein, crude fibre, fat, total minerals ranged from 10.81 to 12.86, 4.38 to 16.96, 2.11 to 2.62 and 2.07 to 2.39 g/100g dry matter basis, respectively.

Bonafaccia et al. (2003a) analysed the chemical composition of grain, bran and flour of common buckwheat. They reported protein, ash and fat content as 11.7, 2.19 and 2.88 per cent in the grains, 21.6, 4.1 and 7.2 per cent in the bran and 10.6, 1.8 and 2.3 per cent, in that order (on dry weight basis) of buckwheat.

Ikeda et al. (2005) reported protein content to range from 4.2 to 13.6 g/100g in buckwheat groats grown in Japan, Europe and Canada.

Subsequent studies revealed the chemical composition of buckwheat flour (% w/w wet basis) as protein, 12.7; lipids, 2.95; moisture 13.0; and ash, 1.59 (Tang, 2007).

Amelchanka et al. (2010) analysed ether extract in buckwheat fresh, buckwheat ensiled and buckwheat grain meal and noticed its value to range from 16.6 to 18.2 g/kg on dry matter basis.
2.1.2 Protein fractionation and protein quality indexing

Based on solubility characteristics the all proteins are usually characterised as: albumins (soluble in water and dilute buffers at neutral pH); globulins (soluble in salt solutions but insoluble in water); glutelins (soluble in dilute acid or alkali solutions); and prolams (soluble in aqueous alcohols of 70 – 90%). The pertinent information of these fractions have been related to variability in various grains protein of buckwheat have been reviewed as under:

2.1.2.1 Protein fractionation

Imai and Shibata (1978) fractionated the wheat and buckwheat flour proteins and observed the range of 40 to 77 per cent albumins and globulins, 0.7 to 2 per cent prolams, 23 to 59 per cent glutelins and some residual protein in commercial buckwheat flour, whereas values for these proteins varied from 24 to 32; 25 to 33; 41 to 44 per cent in wheat flour in that order.

Pomeranz (1983) reported about 80 per cent buckwheat protein was composed by albumins and globulins.


Bonafaccia et al. (1994) evaluated the protein fractions in buckwheat cultivated in Italy. The study indicated that almost half of the protein content in the five samples analysed was constituted by globulin with its values over 44 per cent, while prolams represented the smallest fraction (0.7%). The albumin (18%) and glutenin (22%) contents were constant in all the samples.

2.1.2.2 In vitro protein digestibility
Eggum et al. (1981) determined chemical composition and protein quality of buckwheat and reported that due to high contents of crude fibre and tannin, the true protein digestibility of buckwheat grains was slightly below 80 per cent.

Dietryoh-szostak and Ploszynski (1986) reported in vitro protein digestibility in five different fractions of buckwheat groat to range from 78.9 to 88.3 per cent of dry matter.

Gupta and Sehgal (1991) reported that in vitro protein digestibility of cereals and pulse mixtures varied from 80.22 to 84.43 per cent. Processing of cereals and pulses brought about 24.93 to 28.29 per cent increase in protein digestibility (in vitro) of weaning mixtures.

Ikeda and Kishida (1993) evaluated the digestibility of albumin and globulin of buckwheat grains and reported susceptibility of albumin, globulin, haemoglobin and ovalbumin to pepsin action. There was a striking difference in the susceptibility to pepsin action among the protein examined; with hemoglobin being the most digestible by pepsin. Ovalbumin is relatively less digestible by proteases as compared with some other proteins. The two buckwheat proteins were less digestible than ovalbumin. Buckwheat globulin was more digestible by pepsin than buckwheat albumin.

Guo et al. (2006) reported in vitro pepsin digestibility of Chinese tartary buckwheat protein fractions viz., albumin, globulin, prolamin and glutelin content as 81.2, 79.56, 66.99 and 58.09 per cent, respectively.

Tang (2007) evaluated the in vitro digestibility of buckwheat products and soy protein isolates by TCA-soluble nitrogen release during digestion of pepsin and trypsin, in simulated gastric fluid and reported it to vary from 50.1 to 68.0 per cent by pepsin and 72.5 to 81.3 per cent by pepsin and trypsin in that order.

### 2.1.2.3 Limiting amino acids (Methionine and Tryptophan)

Robinson (1980) analysed the average amino acid concentrations in buckwheat and found that methionine content as 0.15 per cent in grain and 0.21 per
cent in groat, while tryptophan content was observed as 0.14 per cent in grain and 0.19 per cent in buckwheat groat samples.

Marshall and Pomeranz (1982) reported methionine content in whole buckwheat and buckwheat groats as 2.3 and 2.8 per cent, respectively.

Javornik and Kreft (1984) reported the methionine content of buckwheat sample as 2.38 per cent.

Thacker et al. (1984) analysed essential amino acid composition of buckwheat and found methionine content as 0.19 per cent protein in buckwheat whole grain, while histamine and isoleucine content was 0.33 per cent and 0.46 per cent protein, respectively.

Bonafaccia et al. (1994) determined methionine content in five different samples of buckwheat grown at five different geographical areas, and observed its value to vary from 2.15 to 2.73 g/100g of protein.

Wang et al. (1995) reported methionine and tryptophan content of buckwheat grains as 140 and 174 mg/100g.

Karlubik et al. (1997) evaluated amino acid content and biological value of proteins in buckwheat grains. It was found that buckwheat proteins had favourable essential amino acid make up (2.8-3.5%). Lysine was observed to be higher than the cereals. High biological value of buckwheat proteins was noticed as compared to cereal grains.

Zheng et al. (1998) noticed that methionine content in groat of buckwheat grains was 1.9 per cent on dry weight basis.

Bonafaccia et al. (2003a) reported further that the methionine content in bran and flour of common buckwheat as 1.09 and 1.41 g/100g protein, respectively.

Wei et al. (2003) evaluated amino acid profile and found very low amount of prolamin in buckwheat kernel. Leucine was the first limiting amino acid and buckwheat protein was assessed to be a semi-nutritional protein.
Kim et al. (2004) studied buckwheat sprouts for various biochemical constituents of nutritional significance and reported that presence of satisfactory amounts of lysine, GABA and sulphur containing amino acids in buckwheat sprouts made it a high nutritional value vegetable.

2.1.3 Variation in minerals, dietary fibre and oxalate content in buckwheat

2.1.3.1 Variation in mineral composition of grains

Minerals are well known to be essential for optimum human nutrition. Each mineral element has many diverse physiological functions. The interest in nutritional functions of minerals is rapidly growing, thus, mineral nutrition is a major nutritional subject. Buckwheat is reported to contain appreciable amounts of minerals. As such, the status of minerals in food grains in general and buckwheat genotypes in particular is reviewed as follows-

Marshall and Pomeranz (1982) evaluated status of various minerals in buckwheat and reported values for of calcium, iron, magnesium, phosphorus, potassium, copper, manganese and zinc content as 110, 4, 390, 330, 450, 0.95, 3.37 and 0.87 mg/100g, respectively.

Kusano et al. (1983) determined the mineral composition of tetraploid and two diploid varieties of the original (Kataoka) and the traditional (Ina) grains. The range of variation for calcium, copper, iron, potassium, magnesium, manganese, sodium, zinc and phosphorus content was observed from 12.0 to 18.8, 1.2 to 4.3, 18.5 to 19.5, 547.3 to 644.3, 465.0 to 362.1, 1.6 to 3.4, 2.5 to 4.0, 2.7 to 5.9 and 692.0 to 721.0 mg/100g, in that order.

Pomeranz (1983) analysed mineral composition of whole buckwheat grain and noticed wide variation in calcium, iron, magnesium, phosphorus, potassium, copper, manganese, and zinc content as 110, 4, 390, 330, 450, 0.95, 3.37 and 0.87 mg/100g, accordingly.
Amarowicz and Fornal (1987) determined various mineral elements in buckwheat grains and reported potassium, magnesium, manganese, iron, zinc and copper content as 244.1, 168.6, 5.44, 4.82, 3.40 and 0.59 mg/100 g in that order.

Lin and Jia (1988) evaluated the common buckwheat flour for mineral composition and reported potassium, sodium, calcium, magnesium and iron content as 0.29, 0.29, 0.03, and 0.14. 0.014 per cent, respectively. However, copper and manganese, zinc content was observed as 4.0, 10.30 and 17.00 ppm, accordingly in buckwheat flour.

Ikeda and Yamashita (1994) analysed the contents of zinc, copper and manganese in different buckwheat samples. Variation in zinc and copper content among various buckwheat grains was found to range from 1.37 to 2.73 mg/100g flour and 0.41 to 0.68 mg/100g flour, whereas, manganese content was observed to vary from 0.59 to 1.79 mg/100g flour on dry weight basis. Values for zinc, copper and manganese content were noticed to range from 0.70 to 4.47, 0.35 to 0.64 and 0.46 to 3.34 mg/100g in buckwheat flour (values presented on dry weight basis).

Wang et al. (1995) reported mineral composition comprising of potassium, sodium, calcium, magnesium, iron, manganese, zinc, copper and phosphorus content in buckwheat as 320, 2.3, 39, 94, 4.4, 1.31, 2.02, 0.89 and 244 mg/100g, in that order.

Gupta et al. (2002) analysed the nutritive value of hulled and dehulled buckwheat grain and reported calcium and phosphorus content to vary from 0.20 to 0.28 and 0.30 to 0.36 g/100g on dry matter basis.

Bonafaccia et al. (2003) observed zinc in different fractions of common buckwheat i.e., grain, bran and flour, and noticed as 26, 30.2 and 20.1 mg/kg, whereas iron as 60.5, 90.6 and 82.7 mg/kg, respectively.

Wei et al. (2003) analyzed the mineral content in five different fractions of three common buckwheat and one tartary buckwheat varieties. The buckwheat kernel was found to be rich in potassium and zinc in albumin; calcium, magnesium and manganese in globulin and sodium in prolamin and glutelin fractions.
Ikeda et al. (2005) studied the composition of seven important minerals, namely zinc, copper, manganese, calcium, magnesium, potassium and phosphorus in various buckwheat groats. The zinc content per 100g dry matter of buckwheat groats ranged from 1.29 to 2.61 mg; copper 0.31 to 0.63 mg; manganese 0.79 to 2.53 mg; calcium 6.7 to 16.9 mg; magnesium 141 to 217 mg; potassium 322 to 518 mg and phosphorus 265 to 510 mg.

Siener et al. (2006) while compiling the data related to potassium, calcium, magnesium, iron and zinc content reported their content as 484, 214, 308, 9.0 and 3.7 mg/100g in edible portion of buckwheat nuts.

Ikeda et al. (1999) reported mineral content of buckwheat grains i.e., flour and hull on dry weight basis. Calcium, magnesium, phosphorus, potassium, zinc, copper and manganese content in flour were noticed as 14.5, 248, 379, 411, 2.79, 0.63 and 0.89 mg/100g, whereas in the hull the values for the these parameters were found as 97.4, 112, 127, 1267, 1.24, 0.61 and 9.16 mg/100g, respectively.

2.1.3.2 Variations in dietary fibre components in grain

Amarowicz and Fornal (1987) analysed the dietary fibre content and its composition in buckwheat grain and its products i.e., flour, seed coat and groat on per cent dry matter basis. Buckwheat grain, flour, seed coat and groat contained dietary fibre as 24.75, 3.94, 80.31 and 4.51 per cent, whereas 20.39, 3.98, 61.98 and 2.29 per cent acid detergent fibre, respectively. Hemicellulose and cellulose were observed in buckwheat grain, flour, seed coat and groat as 4.36, 0.0, 18.33 and 2.2 per cent, and 9.81, 2.34, 29.93 and 1.81 per cent, whereas cellulose content as 10.58, 1.64, 32.05 and 0.48 per cent, accordingly in buckwheat grain and its products.

Bjorkman and Chase (2006) reported that when there is a shortage of hay, buckwheat can be good alternative forage. The forage contained 70 % moisture at flowering stage of buckwheat and fibre analysis revealed that it contained 16.4 per cent fibre, acid detergent fibre (32.9) and neutral detergent fibre (41.8%). The buckwheat was picked up when the grains were 30 to 50 per cent brown and grains had mostly
filled, but are not yet hard and the analysis showed 9 per cent crude protein, 36 per cent acid detergent fibre and 43 per cent neutral detergent fibre whereas buckwheat grains of which are 50 to 65 per cent contained 4.5 per cent crude protein, 41 per cent acid detergent fibre and 50 per cent neutral detergent fibre on dry weight basis.

Amelchanka et al. (2010) analysed buckwheat fresh, buckwheat ensiled and buckwheat grain meal for dietary fibre composition and noticed that dry matter, crude protein, neutral detergent fibre, acid detergent fibre and lignin to vary from 142 to 854; 119 to 137; 256 to 555; 154 to 427; 72 to 94.9 g/kg on dry weight basis respectively.

2.1.3.3 Anti-nutritional factor: Oxalate Content

Oxalate occurs widely in the plant kingdom. The root and leaves of buckwheat is listed as being high in oxalic acid. It arises biosynthetically via the incomplete oxidation of carbohydrates. Many metal ions form insoluble precipitates with oxalate, a prominent example being calcium oxalate, the primary constituent of the most common kind of kidney stones (Bohn et al., 2004).

Siener et al. (2006) determined the oxalate content in Polygonaceae family. Soluble oxalate ranged from 56.7 to 104.9 mg/100g and 86.0 mg/100g whereas total oxalate content ranged from 119 to 178 mg/100g and 155 mg/100g in nuts and whole meal flour of buckwheat, respectively.

2.2 Variation in biochemical constituents in leaves

2.2 Variations in proximate composition in leaves

Dietryoh-szostak and Ploszynski (1986) evaluated the chemical composition of buckwheat plant residues and hulls and reported dry matter, ash, crude fibre and fat content as 92.07, 8.54, 13.42 and 4.36 per cent on dry matter basis.

Dietryoh-szostak and Ploszynski (1988) studied chemical composition of leaves, inflorescence and unfilled grains. The leaves contained 91.4 dry matter per cent, 8.3 per
cent ash, 10.1 per cent fiber, 3.5 per cent fat and 13.5 per cent protein on dry weight basis.

Farooq and Tahir (1989) studied the biochemical composition of leaves of four species of *Fagopyrum* and reported total nitrogen and total sugars as 0.379 and 1.0 per cent respectively on fresh weight basis in *Fagopyrum esculentum*.

Lahanov *et al.* (2004) studied amino acid composition of leaves of plants species and subspecies of buckwheat. *Fagopyrum esculentum* ssp. *esculentum* leaves contained 24.3 per cent crude protein. The value for ash content in the leaves of *Fagopyrum esculentum* ssp. *esculentum* was observed as 14.1 per cent.

### 2.2.1 Ascorbic acid

Gopalan *et al.* (2004) compiled data pertaining to biochemical constituents of different leafy vegetables including spinach and reported vitamin C content as 28 mg/100g in spinach.

Siener *et al.* (2006) reported vitamin C content in spinach leaves as 51 mg/100g.

#### 2.2.2 *In vitro* protein digestibility of leaves

Dietryoh-szostak and Ploszynski (1986) analysed the chemical composition of buckwheat plant residues and hulls and reported 47.5 per cent *in vitro* digestibility in leaves and stems.

Ly and Preston (2001) determined *in vitro* digestibility (pig pepsin/pancreatin) and water-soluble nitrogen (N) in samples from seventeen tropical forage feeds available in Indochina and reported *in vitro* protein digestibility in *Ipomoea aquatica* as 68.8 per cent.

### 2.2.2 Variation in minerals, dietary fibre and oxalate content

#### 2.2.2.1 Variation in minerals composition in leaves
Dietryoh-szostak and Ploszynski (1986) analysed the mineral composition of buckwheat plant residues and hulls and reported phosphorus, potassium, calcium and magnesium content to range from 0.31, 1.87, 0.91 and 0.20 in leaves per cent on dry matter basis.

Dietryoh-szostak and Ploszynski (1988) studied the mineral composition in leaves (inflorescence and unfilled grains) and stems of buckwheat genotypes and reported phosphorus, potassium, calcium and magnesium content to range from 0.66 to 0.78, 1.49 to 2.74, 3.4 to 4.6 and 0.24 to 0.37 per cent on dry matter basis in that order.

Ikeda et al. (1999) analysed the mineral composition of buckwheat straw and leaves and aqueous extract of ash of buckwheat straw and leaves. Buckwheat straw and leaves contained relatively high levels of some minerals viz., potassium, calcium and manganese when compared to buckwheat flour. Calcium, magnesium, phosphorus, potassium, zinc, copper and manganese content were noticed to be present as 894.2, 305, 1132, 5139, 6.69, 0.27 and 38.81 mg/100g, accordingly on dry weight basis. However, ash aqueous extract of straw and leaves exhibited values for these parameters as 1.7, 2, 345, 20399, 0.17, 1.17 and 0.02 mg/l in that order.

### 2.2.2.2 Variation in dietary fibre components in leaves

Dietryoh-szostak and Ploszynski (1986) analysed the chemical composition of buckwheat plant residues and hulls and reported hemicellulose and cellulose content 19.8 and 13.9 per cent on dry matter basis in the leaves and stems.

Buntha and Ty (2006) analysed the fresh foliages of guinea grass (*Panicum maximum*), cassava (*Manihot esculenta*), stylo (*stylo santhesis guiensis*) and water spinach (*Ipomoea aquatica*) to compare the water extractable dry matter of these feeds with neutral detergent fibre values as predictors of whole tract dry matter digestibility and found that neutral detergent fibre for water spinach leaves was 42.8 per cent.

Chumpawadee et al. (2006) reported neutral detergent fibre, acid detergent fibre and acid detergent lignin in Chinese spinach (*Amaranthus viridus* L.) as 40.06, 19.96 and 4.99 per cent on dry matter basis.
Gang et al. (2006) studied the digestibility of foliages i.e., water spinach, sweet potato vines, mixture of water spinach and sweet potato vines and observed value for neutral detergent fibre and acid detergent fibre of water spinach as 35.6 and 22.9 per cent.

Dong et al. (2008) reported neutral detergent fibre and acid detergent fibre content as 40.2 and 24.2 per cent on dry matter basis in water spinach leaves.

2.2.2.3 Variation in oxalate content

Siener et al. (2006) evaluated the oxalate content in raw leaves of Sorrel Rumex acetosa L var. hortensis belonging to Polygonaceae family. The study showed the presence of soluble oxalate content as 258 mg/100g, and total oxalate content as 1391 mg/100g in raw leaves of Sorrel Rumex acetosa L var. hortensis, whereas soluble oxalate content ranged from 800 to 1257 mg/100g and total oxalate content ranged from 1634 to 2285 mg/100g in raw leaves of spinach (Spinacia oleracea) respectively.

2.3 Variation in total phenols and rutin in grains and leaves

2.3.1 Total Phenols

Phenolic compounds are secondary metabolites synthesized in various plants species and these compounds are reported to possess biological properties such as anti-oxidant, anti-apoptosis, anti-aging, anti-carcinogen, anti-inflammation, anti-atherosclerosis, cardiovascular protection, improvement of the endothelial function, as well as inhibition of angiogenesis and cell proliferation activity. Most of these biological actions have been attributed to their intrinsic reducing capabilities (Johnson et al., 2008). Literature reviewed related to variability in the total phenol content amongst various buckwheat varieties/genotypes is presented as under-

Eggum et al. (1981) evaluated two varieties of buckwheat for the status of various biochemical constituents including secondary plant metabolites and
reported 1.76 and 1.54 per cent tannins on dry weight basis. It was also reported that tannins concentration was higher in buckwheat as compared to wheat grains.

Tahir and Farooq (1985) evaluated chemical composition of grains in four buckwheat cultivars and reported phenolics content 0.73, 0.79 and 0.77 per cent on dry weight basis in hull, groat and whole grain in that order.

Farooq and Tahir (1989) studied the leaf composition of *Fagopyrum* species and reported phenolics content as 0.58 per cent on fresh weight basis in *Fagopyrum esculentum*.

Oomah *et al.* (1996) determined phenolic acid content in grains from five buckwheat cultivars grown at three locations in western Canada for four years and reported 12-16 g/kg of total phenolic acids, about 3 g/kg of esterified phenolic acids, and 8-13 g/kg of etherified phenolic acids. Variation in phenolic acids was mainly due to cultivar, seasonal effects and their interaction, while growing location had no significant effect. Phenolic acid contents of buckwheat were independent of seed color and protein content.

Velioglu *et al.* (1998) analysed total phenolics compounds of some fruits and vegetables and reported that buckwheat grains contained total phenols content as 726 mg/100g as ferulic acid equivalents.

Dietrych–Szostak and Oleszek (1999) isolated and identified flavonoid content in buckwheat grains and observed its value in the grains and hulls in the order of 18.8 and 74 mg/100g of dry matter, respectively.

Ikeda *et al.* (2001) reported high levels of polyphenols in buckwheat groats and suggested that the polyphenol content of buckwheat sample might be associated with their colour characteristics and their anti-oxidative characteristics.

Mukodo *et al.* (2001) conducted *in vitro* studies and animal experiment using buckwheat hull extract (BWHE) and reported anti-oxidant activities in its grain products.

Holasova *et al.* (2002) noticed total that phenolics content was 3303 mg/kg in buckwheat grains and 3903 mg/kg in dehulled grains, respectively, on dry matter basis.
Amelchanka et al. (2010) analysed total phenol content in buckwheat fresh, buckwheat ensiled and buckwheat grain meal and reported its values as 35.7; 34.5 and 7.3 g/kg in that order on dry matter basis.

2.1.4.3 Rutin

Kitabayashi et al. (1995) estimated rutin content in seed and leaves of 27 cultivars of common buckwheat grown in Japan, China, Nepal and Europe. The rutin content in seed showed a wide range of variation from 12.6 to 35.9 mg/100g dry matter basis. Besides, the rutin content in leaves also showed significant variations to range from 1,880 to 3600 mg/100g.

Oomah and Mazza (1996) reported that rutin content in hulls of four buckwheat cultivars from Canada was higher than in grains and it value ranged from 50.5 to 97.4 mg/100g in hulls and 44.2 to 51.1 mg/100g in grains, respectively. In buckwheat hulls from these nuts the rutin content was 46 to 80 mg/100g.

The leaves (inflorescence and unfilled grains), stems and seed hulls contained 3.96, 0.95 and 0.17 per cent rutin on dry matter basis, respectively (Dietryoh-szostak and Ploszynski, 1988).

Dietrych-szostak (2004) studied the flavonoids content in the hulls of Polish buckwheat and reported rutin as pre-dominant flavonoid in all the analysed hulls to range from 46.1 to 79.9 mg/100g.

Park et al. (2004) carried out study to compare rutin content in grains and plants of 50 tartary buckwheat strains collected from various parts of the world and reported that leaf and grains of Fagopyrum esculentum contained rutin content from 115.6 and 22.6 mg/100g, whereas Fagopyrum tataricum contained it from 2876.0 and 1469.8 mg/100g respectively. However, strains of Fagopyrum tataricum collected from India exhibited rutin content as 4259.6 mg/100g in the leaves and 1199.4 mg/100g in grains, respectively.
Suzuki et al. (2005) analysed the rutin content in different types of leaf discs cut from tartary buckwheat leaves and found to vary from 17.1 (mesophyll) to 53.1 (upper epidermis) per cent on fresh weight basis.

Zhanrong and Xiulian (2006) evaluated the tartary and common buckwheat varieties (strains) for rutin content and reported the range of variation for this parameter in tartary buckwheat from 1.54 to 2.56 per cent and in common buckwheat from 0.19 to 0.92 per cent.

2.4 Analysis of biochemical constituents during storage

Storage of various food grains including pseudo cereals is considered as a complex process and requires effective interaction among scientific disciplines like biological and engineering groups. In India and other developing countries, studies on storage of pseudo cereals including common buckwheat are limited. Furthermore, the exact data on losses during storage of these food grains are lacking. Storage of crop is influenced by many important factors viz. i). moisture content of the commodity, ii). Storage temperature. Literature reviewed relating to the biochemical and nutritional changes occurring in various food grains in general during storage have been reviewed as under-

Ching and Schoolcraft (1968) studied the physiological and chemical differences in aged grains of crimson clover and ryegrass. Changes in moisture content, germination percentage, seedling length and contents of sugar, amino acids, inorganic phosphate, starch and insoluble protein were studied in new and ten years old canned crimson clover and perennial ryegrass grains. The study indicated that loss of viability and vigour was not due to depletion of food, but appeared to be related to the activity of proteases and phosphatases since an increase in permeability, amino acids and inorganic phosphate was observed in the aged material. The magnitude of these increases was related to species, seed moisture and to a lesser degree storage temperature.
Molina et al. (1975) determined methionine, available lysine, protein content and true protein digestibility of the raw black beans (*Phaseolus vulgaris*) at different storage intervals for six months while keeping seed samples in cloth bags under ambient conditions and observed an increase in the content of both amino acids during the storage period. The protein content of all samples was unaffected either by storage or by any of the processes evaluated.

Storage studies in sorghum, bajra and maize seed viability in relation to moisture content were carried out by Nagarajan and Karivaratharaju (1976). The grains were stored under ambient conditions, in moisture pervious and moisture vapour proof containers with and without seed treatments. With the advancement of the storage period the moisture content of the grains increased, while, the viability decreased.

Sefa-Dedeh et al. (1979) studied changes in cowpea (*Vigna unguiculata*) stored under different humidities and temperatures and found that moisture contents changed with storage time. The changes were affected by the relative humidity of the storage chamber.

Pushpamma and Rao (1981) made a study on home-level storage of legumes for nine months in rural areas in Andhra Pradesh. A progressive decrease in true protein content occurred during storage of all legumes with a maximum loss in green gram (11 per cent) after nine months of storage. There was an increase in non-protein nitrogen with longer storage due to insect infestation.

Gupta et al. (1984) studied chemical and nutritional changes in black gram (*Phaseolus mungo*) during storage and observed that the moisture content, weight loss, protein, fat, calcium, phosphorus, free amino acids, free fatty acids, total ash, reducing sugars, crude fibre increased during six months of storage period, while viability, 1000 kernel weight, non-reducing sugars and starch decreased, but changes in quantitative and qualitative constituents were not significant in uninfested black gram during storage.

Kammar and Naik (1987) studied changes in the nutritive composition of green gram during storage up to six months and reported an increase in the contents of
moisture, protein, fibre, ether extract, whereas, carbohydrates decreased with storage. However, changes in the biochemical attributes were negligible in uninfested samples.

Further studies on this aspect showed that polyethylene and aluminum foil materials were moderately effective in preventing moisture uptake and maintaining seed viability, while paper and cloth containers were least effective (Wilson and McDonald, 1992).

It has been stated that moisture content is of great importance for the safe storage of cereals and their products against microorganisms, and certain species of fungi (Hoseney, 1994).

Das et al. (1998) studied the effect of packaging material, storage condition and duration of storage on seed viability, vigour and seedling survivability in rajmash (Phaseolus vulgaris). The grains were packed in three different containers namely plastic container, polythene bags and cloth bags at room temperature and in cold storage. With increase in the duration of storage moisture content increased, whereas germination per cent, seedling survivability and seed vigour decreased.

Braccini et al. (2000) carried out the study for the purpose of verifying the biochemical changes associated to soybean (Glycine max L. Merrill) grains osmo conditioning. Initially, grains were osmo conditioned in a polyethylene glycol (PEG 6000) solution, with the osmotic potential of -0.8 MPa and 20°C for a period of four days. After that, grains were dried back until the initial moisture content (10-11%) and stored in natural conditions for three and six months. Two controls were used: untreated grains (dry grains) and water soaked grains. Seed changes in protein and lipid, hexanal accumulation and fatty acids contents were evaluated. The results showed that seed storage under laboratory natural conditions caused reduction in protein, lipid and polyunsaturated fatty acids content and promoted hexanal production. Storage periods reduced protein levels for all treatments; however the PEG 6000 treatment showed lower protein reduction. The pattern of reduction for this characteristic may be related to oxidation of the amino acids, due the increase in the respiratory activity and advance in the deterioration process of the stored grains. Thus, prolonged seed storage would increase the metabolic activity of the grains and consequently decrease the reserve substance content and reduce the dry material weight of the grains.
Nasir et al. (2003) reported that crude protein content decreased with storage period in wheat flour at different levels of moisture content was packed in polythene bags. Among the treatments, the changes were more in treatments having higher moisture content in wheat flour favoured proteolytic activity, whereas moisture content increase was due to their lower initial moisture content, which rendered them to absorb moisture from the atmosphere.

Sharma et al. (2007) studied germination percentage, seedling vigour, lipid composition and carbohydrate composition and its related enzymes in cotyledons of soybean during storage for 180 days. The grains were sun dried to about 9% moisture level and placed in polythene or jute bags in storage at room temperature and 15°C (BOD incubator) for a period of 6 months. Seed samples were drawn at an interval of 30 days. Grains were surface sterilized with 0.1% mercuric chloride, soaked in sterile distilled water for 6 h and were allowed to germinate on wet paper rolls in dark at 25°C in the BOD incubator. The cotyledons were separated from the embryonic axis and a weighed quantity of tissue was oven dried at 60°C for 48 h to constant weight. After drying, the tissue was immediately placed in a desiccator before the final weighing and evaluated the sugar content. The decrease in total soluble sugars during initial period of storage up to 90 DOS suggested that carbohydrates in the cotyledons are the primary constituents utilized during germination before seedling growth commences. The decrease in total soluble sugars might be due to their utilization in respiration, incorporation into cell walls or translocation to the growing embryo.

Tatipata (2009) noticed that the quality of soybean seed gets easily decreased, which makes it difficult to keep them for a long time. The environmental factors influencing the life span of grains were relative humidity, temperature, and initial moisture content of seed.

Thakur and Awasthi (2009) studied the effect of storage on biochemical constituents viz., moisture, protein, total sugars and total free amino acids of sesame grains samples procured from different sources in India at an interval of two months for the period of six months, which were stored in different storage containers viz., gunny bags, polythene bags and metallic bin. The study indicated that moisture content increased significantly in different storage containers with an increase in storage period.
Protein and total sugars content decreased significantly with increase in storage period, whereas total free amino acid content changed non-significantly with marginal numerical increase in storage period. Among different storage containers, metallic bins accompanied by polythene bags were found to be superior packaging material for storage.