# DEVELOPMENT AND NUTRITIONAL EVALUATION OF MULTI GRAIN BAKERY PRODUCTS SUPPLEMENTED WITH POMEGRANATE PEEL POWDER

**By**
**NEHA**
**2017HS16M**

*Thesis submitted to the Chaudhary Charan Singh Haryana Agricultural University in the partial fulfillment of the requirements for the degree of*

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**2019**

## CERTIFICATE – I

This is to certify that this thesis entitled, "**Development and Nutritional Evaluation of Multi grain Bakery Products Supplemented with Pomegranate Peel Powder**", submitted for the degree of **Master of Science**, in the subject of **Foods and Nutrition** to the Chaudhary Charan Singh Haryana Agricultural University, Hisar, is a bonafide research work carried out by **Ms Neha (Admn. No. 2017HS16M)** under my supervision and that no part of this dissertation has been submitted for any other degree.

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

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## CERTIFICATE – II

This is to certify that this thesis entitled, "**Development and Nutritional Evaluation of Multi Grain Bakery Products Supplemented with Pomegranate Peel Powder**" submitted by **Ms Neha (Admn. No. 2017HS16M)** to the Chaudhary Charan Singh Haryana Agricultural University, Hisar, in partial fulfillment of the requirements for the degree of **Master of Science**, in the subject of Foods and Nutrition, has been approved by the Student's Advisory Committee after an oral examination on the same in collaboration with an External Examiner.

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**CHAPTER-I**

# INTRODUCTION

One of the major segments of food processing in India is Baking industry. Baked products are most popular because of their easy availability, ready to eat convenience and long shelf life (Vijaykumar *et al.* 2013). Biscuits, muffin, cake, bread, pastries and pies are some common bakery products greatly used as snacks by children and adults (Dhankar, 2013). Their increasing demand also provides a wider scope for their production, fortification and other nutritional improvement. The purpose of fortification is mainly to maintain the nutritional quality of the products, to keep adequate nutrient levels in order to correct or prevent specific nutritional deficiencies in the population from certain deficiencies, to increase the added nutritional value of a product from a commercial viewpoint and to provide certain technological functions in food processing (Dukwal, 2004). Keeping in view the competition in the market for more healthy and functional products, several attempts are being made lately to enhance the nutritional qualities and functionalities of baked products (Masoodi & Bashir 2012).

Now a days to improve the nutritional quality of bakery products, whole natural product components and their by byproducts are becoming part of baked products which improve their quality and bioavailability in a cost-effective way. Recently, the antioxidant properties of phenolic constituents from pomegranate fruits (*i.e.*, arils and peels) has gained attention (Shiban *et al.* 2012; Tharshini 2016). It is because waste products (*e.g.* fruit peels) obtained from the processing of agricultural commodities could provide practical and economic sources of active antioxidants (Balasundram *et al.* 2006; Reddy *et al.* 2007; Moure *et al.* 2001).

From centuries, pomegranate fruit parts, including peels have been used due to their medicinal properties which help in curing inflammation, fever, bronchitis, diarrhoea, dysentery, vaginitis, urinary tract infection, and even in malaria (Li, Y. *et al.* 2006; Iqbal *et al.* 2008; Ahmed *et al.* 2014). The presence of phenolic constituents, ellagi-tannins and ellagic acid exert such beneficial effects.

Pomegranate (*Punica granatum*) is a fruit that belongs to the *Punicaceae* family. Pomegranate is an ancient fruit native to the Middle East and nowadays widely cultivated in Western countries as well. India is the largest producer of pomegranate after Iran. Pomegranate requires semi-arid conditions for good growth. During fruit development and ripening it thrives best under hot and dry summer and cold winter provided irrigation facilities are available (Venkatesha & Yogish 2016). Maharashtra is the leading producer of pomegranate followed by Karnataka, Gujarat, Andhra Pradesh and Telangana (Indiastat, 2016). It is a popular fruit in India and is known for medicinal benefits. For thousands of years, pomegranate is believed to be beneficial for health, fertility and longevity by many cultures (Jain *et al.* 2014). Pomegranate fruit and peel has good amount of natural antioxidants and hence helps to fight against cancer, infections and other diseases in humans. After juice production pomegranate peels are discarded but they can turn out to be one of the most valuable by-products of the food industry (Moorthy *et al.* 2015).

Pomegranate peel has several medicinal properties like quick wound healing properties, immune modulatory activity, antibacterial activity, anti-atherosclerotic and anti-oxidative capacities (Akhtar *et al.* 2015). The anti-oxidative properties of pomegranate peel powder contribute in decreasing risk of several diseases (Whitley *et al.* 2003).

About 50 per cent of fruit weight is constituted by peel and it is characterized by the presence of high molecular weight phenolics, ellagitannins, proanthocyanidins, complex polysaccharides, flavonoids and good quantities of microelements. Nearly 48 phenolic compounds (anthocyanins, gallotannins, hydroxycinnamic acids, hydroxybenzoic acids and hydrolysable tannins *i.e.* ellagitannins and gallagyl esters) have been identified in pomegranate peel and other anatomical parts of the fruit (Akhtar *et al.* 2015).

Protein which is present in pomegranate peel powder contains a much higher content of lysine, leucine, aromatic amino acids (phenylalanine and tyrosine), threonine and valine than the reference protein pattern and therefore the amino acid score of these amino acids is higher than 100. The pomegranate peel powder has slightly lower contents of sulphur containing amino acids (methionine and cysteine) and isoleucine (Rowayshed *et al.* 2013). The incorporation of pomegranate peel powder into food products prepared from wheat, millets and pulses will be cost effective, help in supplementing amino acid pattern and thereby contribute to human nutrition. Apart from their established nutritional and nutraceutical significances, stabilization of food systems and improvement in physiological properties are some other attractive features of pomegranate peel. There has been successful experience of utilization of pomegranate peel powder and peel extracts in various food preparations including edible oils, bakery products, jellies and meat and meat products (Iqbal *et al.* 2008; Naveena *et al.* 2008; Kanatt *et al.* 2010; Devatkal *et al.* 2012; Altunkaya *et al.* 2013; Ventura *et al.* 2013).

The use of composite flour (wheat+pulses+millets+pomegranate peel powder) in bakery industry is not a new concept and is receiving great attention in present times. However due to high quality of gluten in wheat, it is mainly the base for making baked products. Wheat is a concentrated source of protein and energy but lacks in some essential amino acids. So to increase the nutritional value of wheat based products, other legumes and grains can be mixed with it. Further wheat flour can be substituted with pearl millet flour, chick pea flour and pomegranate peel powder for development of different types of value added baked food products.

Wheat (*Triticum aestivum L.*) is the most important staple food crop for one third of the world population and contributes more calories and proteins to the world diet than any other cereal crops (Kumar *et al.* 2011). It is grown across a wide range of climatic conditions around the world and has the highest adaptation among all the crop species and is an important source of nutrients especially for poor (Naresh *et al.* 2014). Wheat contains 71.2 per cent carbohydrates, 11.8 per cent protein, 1.5 per cent fat, 1.2 per cent crude fibre and energy about 341 Kcal/100g. Also, significant amounts of minerals like calcium (41mg/100g), phosphorous (306mg/100g) and iron (5.3 mg/100g) are found in wheat. Whole wheat is rich in thiamine and niacin whereas it was found relatively poor in riboflavin. Wheat germ is enriched with vitamin E (Gopalan *et al.* 2004).

Chickpea (*Cicer arietinum* L) is a legume rich in protein, dietary fiber, carbohydrates, folate and trace minerals (Fe, Mo, Mn) (Meng *et al.* 2010). The functional properties possessed by chickpea proteins are good emulsifying and foaming characteristic (Boye *et al.* 2010; Karaca *et al*. 2011), high absorption capacity (Aydemir &Yemenicioglu, 2013). They also provide good baking characteristic in gluten- free and wheat breads supplemented with chickpea flour (Minnaro *et al*. 2012; Mohammed *et al*. 2014). The total fat content of raw chickpea seeds varies from 2·70 to 6·48 per cent (Kaur *et al.* 2005; Alajaji & EL-Adawy 2006). Chickpea seeds contain a number of phenolic compounds (Wood & Grusak, 2007) and two important phenolic compounds found in chickpea are the isoflavones biochanin A and formononetin. In Asia and Africa, chickpea is used in stews and soups/salads, and consumed in roasted, boiled, salted and fermented forms (Gecit, 1991). A wide range of products developed from chickpea in combination with other grains provide consumers with valuable nutritional and potential health benefits.

Pearl millet (*Pennisetum glaucum*) is an excellent dietary source of calcium, iron, manganese and methionine. There are hundreds of millions of the poor who live on starchy foods such as cassava, plantain, polished rice and maize meal and thus lack methionine in the diets. The use of millets is diverse and can be used in porridge, soups, sprouts, bread and stuffing’s, fermented beverages and baby foods (FAO, 2005). It is a unique source of pro-vitamin A and mineral like calcium, magnesium and phosphorus (Kaur *et al.* 2014). The protein content of pearl millet ranges between 8 and 19 per cent and has better amino acid balance than most common cereals.

Pearl millets are highly nutritious and nutritionally comparable and even superior in energy, protein, vitamins and minerals content than other major cereals. Also, they are termed as “nutri-cereals” being excellent source of dietary fibres, phyto-chemicals and micro nutrients, (Sehgal & Kawatra, 2003). The favorable amino acid balance with a high level of essential amino acids, coupled with the superior *in vitro* pepsin digestibility values, makes pearl millet a nutritious and highly-digestible source of calories and protein for humans (Ejeta *et al.* 2007).

Pearl millet possess anti-allergic characteristics and also recommended for the treatment of severe constipation, stomach ulcers and weight loss due to its high fiber content. Millets are limited to customary buyers and to individuals of lower monetary strata because for the most part it is utilized as whole flour for preparation of food.

The utilization of whole wheat flour supplemented with chickpea flour, pearl millet flour and pomegranate (*Punica granatum*) peel powder can be exploited to develop bakery value added food products like biscuits and cake-rusk.

Keeping this in mind, the present study was planned with the following objectives.

1. To assess the physico-chemical properties of wheat, chickpea, pearl millet flour and pomegranate peel powder
2. To develop baked products using wheat, chickpea, pearl millet flour and pomegranate peel powder
3. To study the organoleptic acceptability, nutrient composition and shelf-life of developed baked products

# CHAPTER-II

## REVIEW OF LITERATURE

In this chapter, the relevant literature pertaining to the objectives of the present investigation has been reviewed and presented under the following headings and sub-headings:

2.1 Physico-chemical properties of grain and flour of wheat, chickpea, pearl millet and pomegranate peel powder

2.2 Nutritional composition of wheat, chickpea and pearl millet flour and pomegranate peel powder

2.3 Development of food products utilizing wheat, chickpea and pearl millet flour and pomegranate peel powder and their organoleptic acceptability

2.4 Nutritional composition of developed food products and their shelf life studies

### 2.1 Physico-chemical properties of grain and flour of wheat, chickpea, pearl millet and pomegranate peel powder

Physico-chemical properties play vital role in utilization of food grains for product development. Studying physicochemical properties of wheat grains, wheat flour, pearl millet, chickpea flours and pomegranate peel powder is highly desirable to enhance their utilization in various baked product formulations.

**Adeleke and Odedeji (2010)** reported that wheat flour had 2.45 g/g water absorption and 21.45g/g fat absorption capacity. **Viuda-Martos *et al.* (2012a)** reported that co-product of pomegranate bagasse powder (left over residue after juice is extracted) had more water holding capacity *i.e.* 4.86g/g of its own weight.

**Acuña *et al*. (2012)** reported that water and oil absorption capacity of soybean is 1.82 ml/g and 1.43ml/g, respectively. **Chandra and Samsher (2013**) found that wheat flour had 140 and 146 per cent water and oil absorption capacity, respectively.

**Anand *et al.* (2013)** compared two Indian varieties of wheat. They found that the total grain weight of variety HD-2733 was higher (42.47 g) than variety HD-2687(35.21 g) and there was a variation from 79.5 to 85.9 in grain hardness index. **Rakhi (2013)** analyzed four varieties of wheat and their physiochemical properties and reported the variations in color in these varieties. Two wheat varieties *i.e.* WH-1081 and WH-1124 had amber colour whereas slight amber color was found in variety DBW-17 and WH-147 was of yellowish color. Thousand grain weight of four varieties was reported to be ranging from 39.89 to 43.52g and grain hardness ranged from 6.20 to 7.40 kg/grain.

**Xu *et al.* (2014)** compared three *kabuli* chickpea varieties and found that seed weight of Sierra (60.0g/100g) variety were higher as compared to Commercial (31.9g/100g) and

Pedro (27.5g/100g) varieties. Similarly, moisture content of Sierra (7.38%) variety was higher as compared to Commercial (6.87%) and Pedro (6.47%) varieties. Bulk density of Pedro and Commercial were similar. Hydration capacity of Pedro, Sierra and Commercial cultivar was 0.29, 0.58 and 0.34 g/seed, respectively. Swelling capacity of Pedro variety was 0.17 ml/seed which was lower than that of Sierra (0.30 ml/seed) and Commercial (0.20 ml/seed) cultivars.

**Parmar (2014)** studied the physicochemical properties of WH-1025, WH-1080 and C-306 varieties of wheat and found that thousand grain weight was reported to be ranging from 40.14 to 43.60g, grain hardness ranged from 9.6 to 10.66 kg/grain and all the three varieties had light yellow colored grains. **Hasnaoui *et al.* (2014)** analyzed 12 different varieties of pomegranate peel and reported that water holding capacity ranged from 2.31 to 3.53 ml/g.

**Pandey (2015)** conducted study on three Indian varieties of wheat and found that grain variety C-306 was light golden yellow coloured and two varieties *viz*., WH-1129 and HD-2967 were amber colored. HD- 2967 was reported to have higher thousand grain weight (45.46g) as compared to WH- 1129 (41.44g) and C-306 (41.95 g) variety. The grain hardness was ranging from 5.42 to 8.13 kg/grain. The colour of wheat flour of all the three varieties was reported as creamish white and that of soybean flour was light yellow. Water absorption capacity of wheat varieties varied from 0.77 to 0.85 g/g and that of soybean flour was 1.93 g/g on dry matter basis. Sedimentation value of wheat ranged from 30.33 to 38.67 ml. Range of wet gluten content of wheat flour was between 25.27 and 27.62 per cent and dry gluten ranged from 8.26 to 9.22 per cent.

**Tikle and Mishra (2018)** studied the comparison between the physical properties of two *kabuli* (Kripa, RVKG 101) and two *desi* (JAKI 9218, JG 130) varieties of chickpea seeds. 100 seed weight of Kripa, RVKG101, JAKI 9218 and JG130 was observed to be 56.74g, 45.88g, 24.79g and 25.62g, respectively. 100 seed volume ranged from 32.67-70.67ml. Seed volume and seed weight was found highest in *kabuli* chickpea variety. Bulk density of Kripa, RVKG 101, JAKI 9218 and JG 130 varieties was 0.80, 0.74, 0.75 and 0.76g/ml, respectively.

**Samta (2018)** analyzed the physico chemical properties of durum wheat flour and found that water absorption capacity, oil absorption capacity and swelling power of durum wheat flour was 1.12, 1.28 and 6.45g/g, respectively. Durum wheat flour was reported to have 0.62g/ml bulk density, 0.55g/g solubility and 14.0g/100ml gelation capacity.

**Rao (2018)** studied the physico-chemical properties of wheat flour and chickpea flour and found the water absorption capacity to be 0.98 and 0.67 ml/g, oil absorption capacity 1.23 and 0.78g/g, swelling power 7.85 and 5.28g/g and bulk density 0.64 and 0.68g/ml, solubility 0.72 and 0.52g/gm and least gelation capacity 9.0 and 8.50 g/100ml, respectively.

**Khatak *et al.* 2018)** studied the physico-chemical, functional and nutritional properties of pearl millet white grain variety (ICMV-221), hybrid varieties (HHB-226, HHB-

223 and HHB-197) and HC-20. The 1000-kernel weight, bulk density, hydration capacity, hydration index, swelling capacity and swelling index of five varieties of pearl millet ranged from 7.86 to 13.47 g, 1.11 to 1.30 g/ml, 3 to 4 mg/seed, 0.37 to 0.44, 5 to 6 µl/seed and 0.28 to 0.53, respectively and the time required to cook the pearl millet grains was 28.56, 26.34, 22.58, 26.23 and 22.52 min, respectively. Water absorption capacity of HHB-226, HHB-223 and HHB-197 and HC-20 was 1.70, 1.67, 1.60 and 1.53 g/g, respectively. The oil absorption was found maximum in HHB-226 (1.45 g/g) and minimum in HHB-223 (1.15 g/g). Wide variation was observed in gelation capacity and it was ranging from 8 to 12.5 per cent. The values of flour solubility and gel consistency in different pearl millet varieties varied from 10.9-14.53 per cent and 54.56-66.23 mm, respectively.

### 2.2 Nutritional composition of wheat, chickpea and pearl millet flour and pomegranate peel powder

**Gulzar *et al.* (2010)** studied variations in moisture, ash content, fat, fiber, crude protein and carbohydrates in different wheat varieties. The varieties contained 10.17 to 10.57 per cent moisture, 0.60 to 1.43 per cent ash, 1.18 to 1.43 per cent fat, 0.10 to 0.15 per cent fiber, 10.30 to 11.72 per cent crude protein and 75.68 to 76.53 per cent carbohydrates. Rehman and Kader (2011) conducted study on five Bangladeshi wheat varieties and found that moisture content ranged from 8.10 to 9.17 per cent, crude protein from 9.10 to 10.01 per cent, the fat content from 1.0 to 1.8 per cent, ash from 1.8 to 2.16 per cent and fiber from 1.93 to 2.1 per cent.

**Mirzaei-Aghsaghali *et al.* (2011)** reported that dry matter, crude fibre, ether extract, ash, Neutral Detergent Fiber (NDF) and nitrogen free content of pomegranate peel was 96.20, 3.60, 0.61, 5.4, 20.80 and 69.57 per cent, respectively. Ebrahimi *et al.* (2011) reported that dry matter, crude protein, Neutral Detergent Fiber and ash content of pomegranate peel was 90.53, 7.78, 32.44, and 9.21 per cent, respectively. According to Taher-Maddah *et al.* (2012) dried pomegranate peels contained 94.76, 3.37, 0.70, 4.00, 18.20, and 73.73 per cent of dry matter, crude protein, ether extract, ash, Neutral Detergent Fiber and nitrogen free content, respectively.

**Salgado *et al.* (2012)** reported that total phenolic content of pomegranate peel was 242.9mg/g and antioxidant activity was found to be 68.3 per cent. Ullah *et al.* (2012) analysed pomegranate peel powder and reported that it possessed 4 per cent moisture, 5 per cent ash, 9.4 per cent fat, 4.86 per cent acidity, 21 per cent crude fiber, 31.38 per cent total sugar, 30.40 per cent reducing sugar, 0.98 per cent non-reducing sugar and 8.72 per cent protein. The mineral content of pomegranate peel powder was 60.5(iron), 4.5(manganese) and 4.0 ppm (zinc).

**Nehra and Sharma (2012)** reported that the total carotenoids, phenolic, ascorbic acid content and radical scavenging activity of pomegranate peel (dry matter basis) were 5.81

mg/100g, 32.2 GAE g/100g, 3.11 mg/100g and 66.45 per cent, respectively. Viuda-Martos *et al.* (2012b) concluded that total phenolic content was 54.84 mg gallic acid equivalents/g, total flavonoid content was 42.36 mg rutin equivalent /g and total catechin content was 21.25 mg catechin equivalent/g in pomegranate peel powder. Viuda-Martos *et al.* (2012b) analysed the chemical composition of pomegranate bagasse powder co-product and found that bagasse powder co-product contained 10.94, 20.86, 2.55, 50.29, 19.88 and 30.41 per cent of protein, fat, ash, total dietary fiber, soluble and insoluble dietary fiber, respectively.

**Gamal *et al.* (2012)** reported 11.4, 10.5, 0.5, 1.0 and 1.6 per cent moisture, crude protein, ash, fat and fiber, respectively in wheat flour. Anand *et al.* (2013) analysed HD-2687 and HD-2733 Indian wheat varieties and found 10.1 and 10.7 per cent moisture, 11.8 and 12.6 per cent protein, 1.16 and 1.20 per cent fiber, 1.5 and 1.7 per cent fat, 74.9 and 73.4 per cent carbohydrates, respectively. Ash content was 1.6 per cent in both the wheat varieties.

**Mehder (2013)** analysed pomegranate peel powder and reported that it contained 3.77, 1.08, 6.02, 12.52 and 76.61 per cent of crude protein, crude fat, ash, crude fiber and carbohydrates, respectively.

**Kushwaha *et al.* (2013)** analyzed the detanninated pomegranate peel powder and found that it contained 17.63 per cent dry matter, 3.29 per cent ash content and 1.43 per cent ether extract while fresh pomegranate peel powder had 30.57 per cent dry matter, 5.49 per cent ash content and 2.43 per cent ether extract. Amount of dry matter, ash content and ether extract values in detanninated pomegranate peel powder was lower than fresh pomegranate peel powder. The detanninated pomegranate peel powder was reported to have higher crude protein (6.43per cent), crude fibre (24.36 per cent), Neutral Detergent Fiber (28.54 per cent) and lignin (7.59 per cent) than fresh pomegranate dried peel powder. For dried peel powder, values of crude protein, crude fibre, Neutral Detergent Fiber and lignin were 3.95, 12.61, 17.83 and 4.29 per cent, respectively. Detanninated pomegranate peel powder had lower content of Vitamin A (11.04 µg/g) and minerals like sodium (362.74 mg/kg), potassium (6679.5 mg/kg), magnesium (524.80 mg/kg), iron (18.33 µg/g) and copper (4.67 µg/g) than fresh pomegranate peel powder which had slightly higher values of Vitamin A (14.06 µg/g) and minerals like sodium (763.66 mg/kg), potassium (16237.4 mg/kg), magnesium (1644.47 mg/kg), iron (22.6 µg/g) and copper (6.2 µg/g).

**Mallick *et al.* (2013)** evaluated ten Indian wheat varieties and found that protein content ranged between 10.71 and 12.83 per cent and fat ranged from 1.27 to 1.71 per cent. The range of iron, zinc, phytic acid and phenolic content was in the range of 3.82 to 4.45, 2.50 to 3.95, 0.35 to 1.60 and 3.36 to 8.63 mg/100g, respectively. Trypsin inhibitor ranged between 66.33 to 394.09 Trypsin Inhibition Unit. Sangwan and Dahiya (2013) reported 10.21 per cent crude protein, 1.33 per cent crude fat, 2.07 per cent crude fiber, 1.79 per cent ash, 74.33 per cent carbohydrates and 66.29 per cent starch in wheat flour.

**Rakhi (2013)** analyzed chemical composition of four wheat varieties and found that moisture content ranged from 10.90 to 11.76 per cent, protein from 9.73 to 10.37 per cent, crude fiber from 1.56 to 2.16 per cent, crude fat 1.23 to 2.10 per cent and ash 1.52 to 1.67 per cent. The iron content ranged from 4.26 to 5.66, zinc 2.20 to 3.57 and magnesium 132.50 to 152.80 mg/100g, respectively. The *in-vitro* protein ranged from 54.39 to 62.31 per cent. Digestibility of starch ranged between 34.37 to 39.78 mg maltose released/g meal. The phytic acid content ranged from 206.71 to 240.10 mg/100g and polyphenol content was in the range of 487.16 to 502.33mg/100g in different wheat varieties.

**Parmar (2014)** conducted study on newly released varieties of wheat and reported that crude protein was in the range of 12.36 to 12.51 per cent, fat 2.41 to 2.56 per cent and crude fibre 1.74 to 2.46 per cent. The *in vitro* protein and starch digestibility ranged from 68.02 to 71.60 per cent and 36.40 to 36.74 mg maltose released/g meal, respectively. The phytic acid content was in the range of 234.5 to 253.9 mg/100g and polyphenols content was in the range of 307.56 to 338.4 mg/100g.

**Ismail *et al.* (2014)** revealed that pomegranate peel had 9.34 per cent moisture content, 2.70 per cent ash content, 0.70 per cent crude protein, 17.53 per cent crude fiber and 0.40 per cent fat. Mineral content of pomegranate peel were 1192.04 mg/kg (calcium), 592.94 mg/kg (sodium), 2749.4 mg/kg (potassium), 0.02 mg/kg (manganese), 0.02 mg/kg (copper), 1.21 mg/kg (iron) and 3.68 mg/kg (zinc). Total phenolic contents, DPPH (2,2-diphenyl-1-picrylhydrazyl) and FRAP (Ferric Reducing Antioxidant Power) were 1387.00 mg GAE/100 g, 87.40 per cent and 275.00mmol/100g, respectively.

**Hasnaoui *et al.* (2014)** analyzed 12 cultivars of dried pomegranate peel powder and found that the total dietary fibre content was in the range of 33.10 and 62 g/100 g. The ratio of insoluble to soluble dietary fibre was around 1, which indicated a well-balanced composition of dietary fibre of pomegranate peel.

**Srivastava *et al.* (2014)** reported that dried pomegranate peel powder had 6.02 per cent moisture content, 4.23 per cent ash content, 3.38 per cent protein, 0.41 per cent fat and 31.1 per cent of dietary fiber. Mineral content was 21.03 mg/100g of Iron and 1124.01 mg/100g of calcium. Radical scavenging activity, total poly phenol and beta carotene content of pomegranate peel powder was 92.35 per cent, 15.75 g/100g and 108.3 mg/100g, respectively.

**Sayed-Ahmed (2014)** reported that pomegranate peel powder contained 5.50 per cent ash, 5.76 per cent protein, 19.54 per cent fiber, 3.59 per cent fat, 65.61 per cent carbohydrates, 116.75 mg GAE/g total phenols and 88.88 per cent DPPH. Singh and Immanuel (2014) reported that pomegranate peel had 249.41 mg/g of total phenolic content, 0.6 mg/g of antioxidant content and 92.7 per cent of antioxidant activity.

**Pandey (2015)** studied different wheat varieties and reported 10.60 to 11.75 per cent moisture, 1.63 to 1.83 per cent ash, 2.37 to 3.35 per cent fat, 1.74 to 2.57 per cent fiber and10.31 to 13.88 per cent crude protein. The iron, zinc, phosphorus, calcium and magnesium content was in the range of 4.98 to 5.46, 3.43 to 2.29, 497.33 to 354.67, 55.45 to 54.40 and 142.50 to 156.33 mg/100g, respectively. The *in-vitro* protein and starch digestibility of wheat varieties ranged from 68.19 to 69.36 per cent and 36.12 to 36.82 mg maltose released/g meal, respectively. The phytic acid and polyphenol content was in the range of 270.43 to 278.42 and 338.07 to 366.33 mg/100g, respectively in wheat varieties.

**Maniyan *et al.* (2015)** reported that out of pomegranate, grape and passion fruit peels, highest amount of tannin was in pomegranate peel (42.46 µg/ml) followed by that of grape peel (35.72 µg/ml) and least amount was found in passion fruit peels (1.43 µg/ml).

**Rani (2017)** analysed and reported the moisture content of pearl millet varieties *Dhanshakti*, 86-M-86, JK26, HHB-67 and JK676 to be 7.27, 7.63, 8.13, 8.61 and 8.20 g/100g, respectively. The crude protein content in *Dhanshakti*, 86-M-86, JK26, HHB-67 improved and JK676 was 11.26, 10.16, 9.53, 12.48 and 9.07 g/100g, respectively, on dry matter basis. The fat content of *Dhanshakti*, 86-M-86, JK26 and JK676 was 5.43, 5.63, 7.24 and 5.21 g/100g, respectively. The ash content in *Dhanshakti*, 86-M-86, JK26, HHB-67 improved and JK676 was 1.87, 1.73, 1.80, 1.79 and 1.67 g/100g, respectively while Crude fibre was in the range of 1.08 to 1.67g/100g. Fibre content was highest in HHB-67(1.67%) and lowest in JK26 (1.08%).

**Rani (2017)** studied various varieties of pearl millet and found that calcium was in the range of 52.98-54.87 mg/100 g, iron was in the range of 3.16- 4.60 mg/100 g and zinc was in the range of 5.41 to 9.12 mg/100 g. Johari (2013) analysed mineral content of pearl millet HC-20 and found that it possessed 65.70, 11 and 5.20 mg/100 g of calcium, iron and zinc, respectively.

**Johari (2017)** studied nutritional parameters of blanched products of HHB-256 pearl millet variety and reported 49.23 per cent *in vitro* protien digestibility and starch digestibility was found to be 17.14 mg maltose released per gram. The polyphenols content was repeated to be 407.17 and phytic acid content 410.11 mg/100g.

**Saharan (2017)** studied nutritional composition of wheat flour and found that protein, fat, crude fibre and ash content was 12.40, 1.90, 2.14 and 2.90 per cent, respectively. Wheat flour contained 7.90, 1.21 and 6.69 per cent of total, soluble and insoluble dietary fiber, respectively.

**Samta (2018)** reported that durum wheat flour contained 13.72, 2.00, 1.62 and 1.54 per cent protein, fat, crude fiber and ash, respectively. Durum wheat flour contained 7.80 g/100g of total, 2.31 g/100g of soluble and 5.49 g/100g of insoluble dietary fiber. Polyphenol content and anti-oxidant activity of durum wheat flour was 321.67 mg/100g and 14.23 per cent, respectively.

**Rao (2018)** reported that wheat and chickpea flour contained 12.03 and 20.25 per cent crude protein, 2.56 and 4.98 per cent crude fat, 1.58 and 1.60 per cent crude fibre and 1.89 and 2.25 per cent ash, respectively. Mineral content was higher in chickpea flour than wheat flour. Chickpea flour possessed 4.99, 58.00, 2.00 and 339.25 mg/100g of iron, calcium, zinc and phosphorus, respectively. Wheat flour contained 3.55 mg/100g iron, 43.55 mg/100g calcium, 1.98 mg/100g zinc and 334.59 mg/100g phosphorus. Anti-oxidant activity in wheat flour and chickpea flour was 12.03 and 15.32 per cent, respectively. β-carotene content of wheat flour was 3.87 µg/100g and that of chickpea flour was 159.89 µg/100g.

**Tanvi (2018)** compared two pearl millet varieties *viz*., *Dhanshakti* and HHB-299 and reported that they possessed 7.73 and 8.56% moisture, 5.59 and 6.29% fat, 2.33 and 1.92% crude fiber and 2.04 and 2.69% ash content, respectively. Mineral content of HHB-299 was higher than that of *Dhanshakti* variety. *Dhanshakti* and HHB-299 variety of pearl millet contained 53.43 and 58.61 mg/100g calcium, 8.19 and 9.24 mg/100g iron and 5.43 and 6.44 mg/100g zinc, respectively. *In vitro* protein and starch digestibility of *Dhanshakti* was 61.20% and 23.16 mg maltose/g and that of HHB-299 was 72.52 per cent and 18.6 mg maltose/g, respectively. The polyphenol content of *Dhanshakti* was higher (267.63 mg/100g) than the other variety. Total antioxidant activity of *Dhanshakti* and HHB-299 was 0.36 mg/g and 0.42 mg/g, respectively.

**Kumar and Neeraj (2018)** studied the effect of different drying methods on the chemical composition of two varieties *i.e. Bhagwa* and *Ganesh* of pomegranate peel. They reported that moisture (9.65%), protein (1.33%), ash (3.75%) and fat (0.46%) content of *Bhagwa* freeze-dried peel was higher compared to that of *Ganesh* freeze-dried peel. The moisture, protein, ash and fat content of *Ganesh* variety was 7.73, 0.96, 2.54 and 0.39 per cent, respectively. Moisture, protein, ash and fat content of *Bhagwa* tray-dried and *Bhagwa* sun-dried pomegranate peel was higher than *Ganesh* tray-dried and *Ganesh* sun-dried pomegranate peel. Total phenolic content of *Bhagwa* –freeze (485.1 GAEmg/g), tray (453.2 GAEmg/g) and sun-dried (406.8 GAEmg/g) pomegranate peel was higher compared to *Ganesh* -freeze, tray and sun-dried pomegranate peel (395.7 GAEmg/g, 355.5 GAEmg/g and 399.1 GAEmg/g, respectively).

### 2.3 Development of food products utilizing wheat, chickpea and pearl millet flour and pomegranate peel powder and their organoleptic acceptability

**Altunkaya *et al.* (2013)** prepared wheat bread fortified with pomegranate peel powder at 2.5, 5.0 and 10.0 per cent levels. They reported that bread prepared with supplementation of 2.5 per cent pomegranate peel powder scored better on parameters like color, aroma, texture, taste and mouth feel in comparison to other supplementation levels.

**Mehder (2013)** investigated effectiveness of pomegranate peel in the improvement of nutritional, physical and sensory characteristics of pan bread. The wheat flour was substituted by pomegranate peel powder at 1, 2 and 5 per cent level for the purpose of bread preparation. The general appearance and texture of pan breads made by substituting with 1 and 2 per cent of pomegranate peel powder were close to the consumer preference of control. Whereas, all other attributes and attributes of pan bread made up of 5 per cent pomegranate peel powdere was significantly lower than the control sample attributes.

**Srivastava *et al.* (2014)** assessed the effect of pomegranate peel powder supplementation at different levels on textual, organoleptic and nutritional characteristics of multi grain biscuits. They reported that 0 to 10 per cent incorporation of dried pomegranate peel powder decreased spread ratio. Sensory evaluation, indicated that biscuits incorporated with 7.5 per cent dried pomegranate peel powder were the most acceptable.

**Sayed-Ahmed (2014)** prepared pan bread supplemented with 2.5, 5 and 7.5 per cent pomegranate peel powder. Sensory scores revealed that color, taste, flavor, general appearance and overall acceptability of pan breads supplemented with pomegranate peel powder at 2.5 and 5.0 per cent level were higher than that of 7.5 per cent pomegranate peel powder fortified bread.

**Ismail *et al.* (2014)** investigated the effect of supplementation of pomegranate peel on organoleptic properties of cookies. Wheat flour was substituted with variable concentration of pomegranate peel *i.e.* 0 (control), 1.5, 3.0, 4.5, 6.0 and 7.5 per cent to make cookies. Color acceptability score was highest for control compared to cookies supplemented with pomegranate peel powder. A decline in organoleptic scores was observed with increasing supplementation levels of peel powder, but all the products were acceptable.

**Paul and Bhattacharyya (2015)** studied the sensory properties of cookies fortified with 2.5, 5, 7.5 and 10 per cent of pomegranate peel powder. Results indicated significant reduction in the appearance scores of the cookies when incorporated with 10 per cent peel powder. It decreased from an average of 8.31 in control to an average of 6.52 in the supplemented cookies. Cookies prepared from all proportions of peel powder had acceptable textures. There was a tendency of decline in the overall acceptability of the fortified cookies compared to control.

**Vaijapurkar *et al.* (2015)** prepared biscuits by 40, 50 and 60 per cent substitution of wheat flour by pearl millet and 3 per cent of pomegranate peel powder. Replacement up to 50 per cent pearl millet and 3 per cent pomegranate peel powder was most acceptable.

**Topkaya and Isik (2018)** made muffin cakes using pomegranate peel powder. Partial substitution of wheat flour (5, 10 and 15 %) was done with pomegranate peel powder. Hardness and springiness values were significantly increased after addition of pomegranate peel. Smell and flavor scores of control cakes and cakes having 5 and 10 per cent pomegranate peel were similar. They reported that addition of pomegranate peel more than 15 per cent level significantly reduced smell, flavor and color scores of products.

**Essa and Mohamed (2018)** studied the sensory characteristic of wheat flour spaghetti supplemented with pomegranate peel powder in the concentration of 3, 5, and 7 per cent. A significant increase in solid loss and weight increase (%) was observed after the increment in pomegranate peel powder addition. Sensory evaluation results revealed that substitution of wheat flour in spaghetti with up to 7 per cent pomegranate peel powder recorded satisfying consumer acceptability. It was found that spaghetti supplemented with pomegranate peel powder reported significant increase in the appearance, taste, color, odour and overall acceptability scores at all supplementation levels.

**Thorat *et al.* (2018)** prepared two types of wheat flour noodles supplemented with dehulled cowpea flour and peel powder of pomegranate at 5 and 10 per cent and 5 and 7 per cent, respectively. Sensory and cooking quality results revealed that, noodles containing 10 per cent dehulled cowpea flour and 7 per cent pomegranate peel powder were more acceptable.

**Tharshini *et al.* (2018)** studied the organoleptic attributes of cookies and cake supplemented with wheat flour, soybean flour and pomegranate peel powder. The concentration of soybean (10%) was kept constant. The level of supplementation with pomegranate peel in the cookies was 5, 7.5 and 10 per cent. All the developed cookies and cake were organoleptically acceptable. Aroma, texture and overall acceptability scores of value added cookies and cake were higher compared to control.

### 2.4 Nutritional composition of developed food products and their shelf life studies

**Mehder (2013)** examined pomegranate peel powder fortified pan bread and concluded that the fiber and ash contents in bread increased whereas the protein and carbohydrate contents decreased with the increase in the level of pomegranate peel powder in pan bread.

**Ismail *et al.* (2014)** developed wheat flour cookies incorporated with pomegranate peel powder (1.5, 3.0, 4.5, 6.0 and 7.5 %). They reported gradual and significant reduction pattern in protein content of cookies from 12.11 to 10.95 per cent. Cookies prepared with 100 per cent wheat flour had six times lower crude fiber content than that of 7.5 per cent pomegranate peel powder supplemented cookies. A significant improvement was observed in mineral content (calcium and potassium) of pomegranate peel powder supplemented cookies. Supplementation of pomegranate peel powder at 7.5 per cent replacement level improved iron and zinc contents of cookies from 0.46 to 0.56 mg/kg and 2.65 to 2.77 mg/kg, respectively. When pomegranate peel powder was increased from 0 to 7.5 per cent, total phenolic contents of cookies also increased from 90.7 to 161.9 mg/100 g.

**Sayed-Ahmed (2014)** prepared pan bread supplemented with pomegranate peel powder and reported a significant decrease in protein content at 5 and 7.5 per cent level of supplementation compared to the control bread. At 5 and 7.5 per cent level of pomegranate peel powder incorporation the fat content of pan bread increased significantly compared to the control bread. Ash and fiber content of pomegranate peel powder supplemented bread was also higher compared with control bread. However, in breads fortified with pomegranate peel powder a significant decrease in carbohydrate content was observed.

**Ismail *et al.* (2014)** reported that with increased storage time, free fatty acids of both control cookies and cookies supplemented with 7.5 per cent pomegranate peel powder increased progressively. They also reported that the levels of free fatty acids on termination of storage study (4 months) in control and 7.5 per cent pomegranate peel powder supplemented cookies were 0.40 and 0.20 per cent, respectively. It indicated 50 per cent higher stability of pomegranate peel powder supplemented cookies as compared to the control.

**Paul and Bhattacharyya (2015)** reported that cookies made with incorporation of pomegranate peel powder had more protein content. There was a non-significant difference in the ash and carbohydrate contents of control and the fortified cookies. The results of the present study indicated high radical scavenging activities and total phenolic compounds in cookies fortified with pomegranate peel powder than that of control.

**Pandey and Sangwan (2016c)** used a combination of wheat flour: sorghum flour: soybean flour in different ratios for the preparation of value added cakes and reported the nutritional superiority of value added cakes than control.

**Tharshini *et al.* (2018)** prepared cookies by using wheat and soybean flour supplemented with pomegranate peel powder and found 8.89 per cent protein and 20.34 per cent fat content in control cookies which was lower than Type- I cookies (10.79% protein and 21.72% fat). They revealed that the crude fiber (4.21%) and ash (2.28%) contents were highest in cookies containing 10 per cent pomegranate peel powder. Total dietary fiber content of control cookies was 8.43 per cent while that of pomegranate peel powder supplemented (5, 7.5 and 10 %) was 9.21, 9.53 and 9.88 per cent, respectively, which was significantly higher than that of control. The mineral content of supplemented cookies i.e calcium, iron, zinc and magnesium were also higher in supplemented cookies. As the supplementation level of pomegranate peel powder increased the fat acidity content of cookies decreased. They reported that pomegranate peel powder supplemented cookies could be stored for 90 days.

**Tharshini *et al.* (2018)** reported that cake prepared using wheat flour, soybean flour and pomegranate peel powder had high protein and fat content compared to control cake. The protein and fat contents of 5 per cent pomegranate peel powder cake were found to be 11.23 and 23.72 per cent, respectively. The protein and fat contents of pomegranate supplemented product was significantly higher than that of control cake. A significant increase in the crude fibre and ash content of all types of supplemented cakes varied from 2.23 to 3.03 and 1.81 to 2.15 per cent, respectively with the increase in level of substitution of pomegranate peel from 5 to 10 per cent. Total dietary fibre content of Type I (8.29 per cent), Type II (8.67 per cent) and Type III (9.07 per cent) cakes was found significantly higher than that of control cake (7.51 per cent). The cake with 100 per cent wheat flour had lower content of soluble and insoluble dietary fibre than supplemented cakes. Also, the calcium, phosphorus, iron, zinc and magnesium content of control cake was significantly ($P \leq 0.05$) lower than value added cake. The starch and protein digestibility was 50.63 mg maltose released/g meal and 73.24 per cent, respectively in the 100 per cent wheat flour cake, was significantly higher than that of value added cakes.

**Topkaya and Isik (2018)** studied the crude protein and ash content of cake muffin formulated with 5, 10 and 15 per cent pomegranate peel powder and found a decrease in the protein content from 8.76 per cent to 8.23 per cent and increase in the ash content from 1.93 per cent to 2.29 per cent. There was an increase in soluble (1.10 to 2.33%), insoluble (1.70 to 4.15%) and total dietary fibre (2.80 to 6.48%) content as the level of supplementation of pomegranate peel increased from 5 to 10 per cent. Mineral content were higher in supplemented muffin cake as compared to control muffin cake.

**Essa and Mohamed (2018)** reported that the moisture (10.7-10.22%) and ash (1.40-1.56%) content of spaghetti increased as the level of incorporation of pomegranate peel powder increased from 3 to 7 per cent. There was an increase in total (2.88-7.86%), soluble (1.52-2.14) and insoluble dietary fibre (2.54-4.95%). The content of polyphenols and flavonoids also increased to 102.74-488.96 mg GAE/100 g and 139.72-190.82 mg QE/100 g, respectively.

**Throrat *et al.* (2018)** reported that the protein, fibre and fat content of noodles prepared from wheat flour supplemented with cowpea flour (5 and 10 %) and pomegranate peel powder (5 and 7%) ranged from 9.55-10.14, 8.94-9.46 and 1.94-1.97 per cent, respectively. Total phenolic content of noodles was in the range of 11.74-15.24 per cent. Noodle samples containing 10 per cent dehulled cowpea flour and 7 per cent pomegranate peel powder possessed higher phenolic content compared to other supplemented noodle samples.

# CHAPTER-III

## MATERIALS AND METHODS

The present investigation 'Development and nutritional evaluation of multigrain bakery products supplemented with pomegranate peel powder' was carried out in the Department of Foods and Nutrition, I.C. College of Home Science, CCS Haryana Agricultural University, Hisar.

This chapter constitutes relevant information concerning to the research design and methodological steps used for the present investigation. The research procedures to achieve the objectives have been distinctly described under the following headings and sub-headings:

3.1 Procurement of raw material

3.2 Processing of wheat grains, pearl millet, chickpea and pomegranate peel

3.3 Physicochemical properties

- 3.3.1 Grain
- 3.3.1.1 Grain color
- 3.3.1.2 Grain hardness
- 3.3.1.3 1000 kernel weight

3.3.2 Flour and pomegranate peel powder

- 3.3.2.1 Flour colour
- 3.3.2.2 Water absorption capacity
- 3.3.2.3 Sedimentation value
- 3.3.2.4 Gluten content
- 3.3.2.5 Oil absorption
- 3.3.2.6 Gelation capacity
- 3.3.2.7 Bulk density
- 3.3.2.8 Swelling power

3.4 Nutritional composition of wheat, chickpea and pearl millet flours

- 3.4.1 Proximate composition
- 3.4.1.1 Moisture
- 3.4.1.2 Crude protein
- 3.4.1.3 Fat
- 3.4.1.4 Crude fibre
- 3.4.1.5 Ash
- 3.4.2 Dietary fibre
- 3.4.3 Total minerals (Calcium, iron, magnesium, zinc and phosphorus)
- 3.4.4 *In vitro* digestibility

3.4.4.1 *In vitro* starch digestibility

3.4.4.2 *In vitro* protein digestibility

3.4.5 Extraction of samples for antioxidant activity:

3.4.5.1 Total phenols

3.4.5.2 Total flavonoids

3.4.5.3 Antioxidant activity by DPPH

3.5 Nutritional composition of pomegranate peel powder

3.5.1 Proximate composition

3.5.2 Dietary fibre

3.5.3 Total minerals (Calcium, iron, magnesium, zinc and phosphorus)

3.5.4 Extraction of samples for antioxidant activity:

3.5.4.1 Total phenols

3.5.4.2 Total flavonoids

3.5.4.3 Antioxidant activity by DPPH

3.6 Development of baked products from wheat, chickpea and pearl millet flour blends and pomegranate peel powder

3.6.1 Biscuits

3.6.2 Cake-rusk

3.7 Organoleptic evaluation of baked products

3.8 Nutritional evaluation of baked products

3.9 Shelf life studies of baked products

3.9.1 Organoleptic evaluation

3.10 Statistical analysis

**3.1 Procurement of raw material**

Wheat grains (*Triticum aestivum*,C-306), pearl millet (*Pennisetum glaucum* 86-M-86) and chickpea (*Cicer arietinum* HC-5) used in the study were procured in a single lot from the Wheat and Barley Section, Department of Genetics and Plant Breeding, CCS HAU, Hisar.

Pomegranate was acquired in bulk from the fruit market of Hisar. All other ingredients required for the development of bakery products were procured from the local market of Hisar.

**3.2 Processing of wheat, pearl millet, chickpea grains and pomegranate peel**

The wheat grains, pearl millet and chickpea were cleaned and ground in an electric grinder (Cyclotec, M/s Tecator, Hoganas, Sweden) and flour obtained was sieved through a 60 mesh sieve and packed in airtight plastic containers for further use. The pomegranate fruits were first washed thoroughly after that fruit was peeled and cut into small pieces. Then the cut pieces were dried in open air under shade. Dried peel was grinded into fine powder and packed in airtight plastic container for further use.

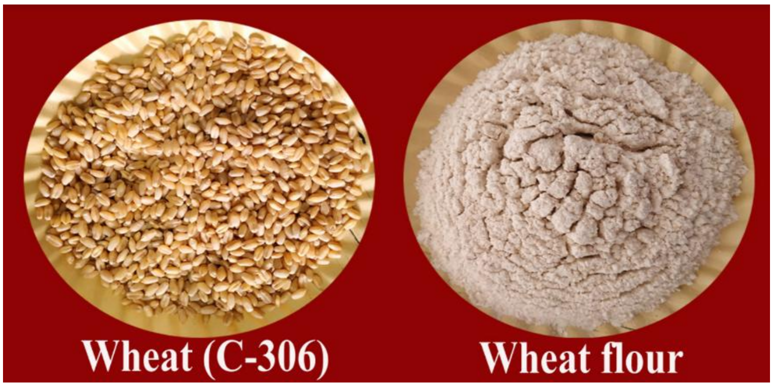


**Plate 1:Wheat grains and Wheat flour**


**Plate 2: Chickpea grains and Chickpea flour**


**Plate 3: Pearl millet grains and Pearl millet flour**


**Plate 4: Pomegranate peel and Pomegranate peel powder**

### 3.3 Physicochemical properties

### 3.3.1 Grain

#### 3.3.1.1 Grain colour

Colour of the wheat, pearl millet and chickpea grains was observed visually.

#### 3.3.1.2 Grain hardness

Grain hardness was measured by pressing 10 average sized well fitted grains under the grain hardness tester (Kiya Seisakusho Ltd., Japan). Force was applied to crush grain by turning the knob and output was displayed on the dial in Kg of force.

#### 3.3.1.3 Thousand kernel weight

Weight of thousand kernels was determined according to AACC (2000) method. Thousand wheat, pearl millet and chickpea grains were counted and weighed in electronic analytical balance. This was repeated four times and then the four values obtained were averaged and multiplied by ten to get thousand kernel weight.

### 3.3.2 Flour and pomegranate peel powder

#### 3.3.2.1 Colour

Colour of wheat, chickpea and pearl millet flours and pomegranate peel powder was observed visually.

#### 3.3.2.2 Water absorption capacity

The water absorption capacity was determined by the method of Singh and Singh (1991). A sample of 3 g was mixed with 25 ml distilled water and placed in pre-weighed centrifuge tubes. The tubes were stirred using vortex mixer. Samples were then allowed to stand at 30°C in a water bath for 30 min. The content was then centrifuged for 30 minutes at 3000 rpm. The supernatant was removed and its volume was recorded. Water absorption capacity was expressed as the number of grams of water absorbed per gram of sample.

#### 3.3.2.3 Sedimentation value

**Reagents**

Lactic acid –sodium dodecyl sulphate (SDS) solution was prepared by dissolving 20 g SDS in 1 litre of distilled water then 20 ml of stock dilute lactic acid was added to it (1 part by volume of 88% lactic acid + 8 part by volume of distilled water).

**Procedure**

Sedimentation value in flours was determined using procedure given by Mishra *et al.* (1998). A sample (5 g) was weighed and transferred into 100 ml stoppered graduated cylinder then distilled water (50 ml) was added into it and cylinder was shaken horizontally *i.e.* left-right, for time specified and then left undisturbed for few minutes. After this lactic-acid-sodium dodecyl sulphate (SDS) solution (50 ml) was added and mixed. The volume of sediments left was noted after 5 minutes as sedimentation value (ml).

#### 3.3.2.4 Gluten content

AACC (2000) method was used for wet gluten estimation. Sample (25 g) was weighed and transferred into a clean dry mixing bowl with 13.5 ml water. A stiff dough ball was prepared using the contents. The dough ball was dipped into water for half an hour and then washed with hands under the tap water until free from starch. The gluten left was weighed and then stated as percentage wet gluten. Wet gluten was dried (100°C) and weighed. Results were reported as per cent dry gluten.

$$\text{Wet gluten (\%)} = \frac{\text{Wt. of moist gluten}}{\text{Wt. of sample taken}} \times 100$$

$$\text{Dry gluten (\%)} = \frac{\text{Wt. of dry gluten}}{\text{Wt. of sample taken}} \times 100$$

**3.3.2.5 Oil absorption capacity**

Oil absorption capacity was determined by using the method of Rosario & Flores (1981) with minor modification by Iyer & Singh (1997). One gram sample was mixed with 15 ml oil for 30 minutes. The contents were allowed to stand in a water bath at 30ºC for 30 min. The contents were then centrifuged at 3,000 rpm for 20 min and the volume of the supernatant was recorded. Results were expressed as g/g sample.

**3.3.2.6 Gelation capacity**

The gelation capacity was determined according to the method of Singh & Singh (1991). Sample suspensions containing 5-15% (w/v) flour in 0.5% increments were prepared in 10 ml of distilled water. The test tubes were heated for 1 h in boiling water, rapidly cooled under running cold tap water. These test tubes were refrigerated for 3 h at 5ºC. The least gelation concentration was determined as that concentration at which the sample did not fall down or slip from inverted test tube.

**3.3.2.7 Bulk density**

Bulk density was determined by using the method of Wang & Kinsella (1976). A pre-weighed, 100 ml graduated cylinder was filled to 100 ml with the sample. The sample was packed by gently tapping the cylinder on the bench top 10 times from a height of 5 cm . The volume of sample was recorded

$$\text{Bulk density (g/ml)} = \frac{\text{Weight (g) of sample}}{\text{Volume (ml) of sample after tapping}}$$

**3.3.2.8 Swelling power**

Swelling power of the flour was estimated as per the method of Subramanian *et al.* (1986). The flour sample (0.5g) was weighed and transferred into centrifuge tube, and twenty ml distilled water was added. The tube was placed in a heating block at 90˚C for one hour. The tubes were periodically shaken. After cooling, the contents were centrifuged at 5,000 rpm for 10 min. The aliquot was decanted into a test tube for determination of water soluble fraction. The inner sides of the centrifuged tube were wiped out by tissue paper for excess moisture. Then the weight of the tube with swelled material was recorded. The swelling power of the flour was calculated as a ratio of the final weight ($W_t$) to the initial weight ($W_i$)

$$\text{Swelling power} = \frac{W_t}{W_i} \times 100$$

## 3.4 Nutritional composition of wheat, pearl millet and chickpea flours

### 3.4.1 Proximate composition

#### 3.4.1.1 Moisture

Moisture content was determined by employing the standard method of analysis (AOAC 2000).

**Procedure**

First the weight of dry petri- dish was measured then a five gram sample was weighed and transferred in petri dish and dried in oven at $105^0$C for 6 h. To avoid any moisture absorption by dry sample first the sample was cooled in desiccator. Moisture content was calculated by using following formula:

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

#### 3.4.1.2 Crude protein

Crude protein was estimated by standard method of analysis (AOAC 2000), using KEL PLUS Automatic Nitrogen Estimation System. A factor of 3.36 was applied to convert the amount of nitrogen to crude protein in chickpea and a factor of 5.7 was used for wheat and 6.25 was used for peel powder and 5.95 was used for pearl millet.

**Reagents**

i. Hydrochloric acid (0.1N)

ii. Boric acid solution (4%): Boric acid (40g) was dissolved and diluted in one litre distilled water.

iii. Sodium hydroxide solution (40%): 400 g of carbonate free sodium hydroxide (NaOH) was dissolved in distilled water and diluted to one litre.

iv. Digestion mixture: $K_2SO_4$: $CuSO_4$ (5: 1)

v. Mixed indicator solution: 0.5 g of bromocresol green and 0.1 g methyl red were taken and dissolved in 100 ml of 95 per cent ethanol. The solution was adjusted with drops of dilute NaOH to bluish purple colour.

**Procedure**

**Digestion**

The temperature of digestion system was set to 420$^0$C in the controller. For digestion first the samples and chemicals were prepared. The digestion tubes with sample (0.2g) + sulphuric acid (10 ml) + digestion mixture (3 g) were placed in insert rack and then the manifold was placed over the tubes. The insert rack and manifold were then loaded in the digestion block. The water connection was opened so that they condense the fumes generated. After one to two hours the rack was removed to check whether all the samples got digested. If not, the tubes were replaced in the block and were digested for another 15 minutes. When digestion tube start showing bluish green colour and reduction in flames, indicates the end point of the digestion process. After that insert rack was removed from the block and was placed in the cooling stand. It was removed slowly after 15 min till the tubes got cooled. Then finally, the water connection was shut and the samples were ready for distillation.

**Distillation**

Firstly, the macro tube containing the digested sample was loaded in the space provided in the apparatus. One empty conical flask was put on the receiver side and the programme of the equipment was run. The apparatus automatically drop Boric acid (20 ml) into the conical flask. Intially its colour was pink. After that 40 ml of 40 per cent NaOH was slowly added automatically in the order of 10 ml each time until the colour in the test tube turned brown precipitate from bluish green. Then the process was set. The colour of contents in the conical flask changes from pink to green after 6 minutes. This colour change indicates the end point of distillation of the sample. Then the flask was taken out for titration.

**Titration**

The solution prepared above was titrated with 0.1 N HCl until the colour changes from green to permanent pale pink. This was the end point of titration.

$$\text{Total N (\%)} = \frac{14 \times \text{Titrant value (ml)} \times \text{Normality of acid}}{1000 \times \text{sample weight (g)}} \times 100$$

Where,

Titrant value = Volume of N/10 HCl used for titration.

**3.4.1.3 Crude Fat**

Crude fat was estimated by employing the standard method of analysis (AOAC 2000) using the Automatic SOCS plus Solvent Extraction System.

**Procedure**

The fat extraction beakers were washed thoroughly. Then the beakers were dried in hot air oven at 60$^0$C. The weight of empty beakers was measured. Five gram of moisture free sample was transferred into a pre-weighed extraction thimble dried overnight. The thimble holder along with the sample was kept into the fat extraction beaker. Required quantity (100 ml) of petroleum ether (boiling point 60-80$^0$C) was poured into the beaker. The beakers were inserted into the system and the temperature was set to 90$^0$C (according to boiling point of solvent) in the controller. The extraction was carried out for one hour at 90$^0$C. After the completion of extraction period, the temperature was raised to 110$^0$C, the stopper was closed in order to collect the solvent in the solvent compartment. The beakers were removed along with the fat and kept in hot air oven at 60$^0$C temperature till a constant weight was obtained. The beakers were weighed after cooling it in a desiccator.

$$\text{Fat (\%)} = \frac{W_2 - W_1}{W} \times 100$$

Where,

$W$ = Weight of sample (g)

$W_1$ = Weight of empty beaker

$W_2$ = Weight of beaker with fat

**3.4.1.4 Crude fibre**

The crude fibre was estimated by employing the standard method of analysis (AOAC 2000) using Automatic Fibra plus system.

**Reagents**

i. Sulphuric acid stock solution (10%) v/v: 55 ml concentrated sulphuric acid is diluted to one liter.
ii. Sulphuric acid working solution (1.25%): Diluted 125 ml of stock solution to one liter.
iii. Sodium hydroxide stock solution (10%) w/v: Dissolved 100 g of NaOH in distilled water and diluted to one liter.
iv. Sodium hydroxide working solution (1.25%): Diluted 125 ml stock solution to one liter with distilled water.

**Procedure**

One gram fat free oven dried sample was placed in crucibles. The crucibles were placed in apparatus. One hundred fifty milliliter of 1.25 per cent $H_2SO_4$ was filled in each beaker through funnels. After that the instrument was connected to water supply. Before switching on the instrument, the knobs were set to close mode first then the instrument was switched on. The temperature was fixed to 550°C by pushing the set button. As the solution in beakers starts boiling, the temperature was reduced to 400°C and the instrument was allowed to run for 45 min. Then the instrument was switched off and allowed to cool. The water source was then changed from direct to suction apparatus. All the knobs were turned open position and the big knob was changed from pressure to vacuum. The suction pump apparatus was switched on. This whole process was repeated twice with distilled water followed by 1.25 per cent NaOH solution and again two times with distilled water. Then, the instrument was switched off. The crucibles were taken off and put in hot air oven till dry. Then weight of crucibles was noted. Crucibles were transferred to muffle furnace at 550°C for 2 h. After cooling, the crucibles were taken out, put in desiccator and weighed again.

$$\text{Crude fibre (\%)} = \frac{W_2 - W_3}{W_1} \times 100$$

Where,

$W_1$ = Weight of sample (g)

$W_2$ = Weight of insoluble matter (wt. of crucible + Insoluble matter - wt. of crucible)

$W_3$ = Weight of ash (wt. of crucible + wt. of 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 g of oven dried sample was weighed in a pre-weighed silica crucible. It was ignited till no charred particles remained in the crucible. Then the crucible was put in muffle furnace (550$^0$C) for 5-6 hours until a white ash was obtained. Then crucible was cooled in a dessicator and weighed. The loss in weight represented the organic matter and residue being the ash content which was calculated using the following formula:

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

### 3.4.2 Dietary fiber

Total, soluble and insoluble dietary fiber constituents were determined by the enzymatic method given by Furda (1981).

**Reagents**

i. HCl (0.005N)

ii. Phosphate buffer (pH 10)

iii. EDTA

iv. Enzymes: Alpha amylase and protease enzymes.

v. Ethanol (75% and absolute )

vi. Acetone

**Procedure**

i. Sample preparation: Five gram sample of less than 1mm particle size was defatted on a Socs- Plus apparatus.

ii. Extraction of water-soluble material: The one gram prepared sample was dispersed in 200 ml of 0.005 N HCl and boiled for 20 min. The suspension was then cooled down to 60$^{\circ}$C; 0.3 g of disodium EDTA was added and then adjusted to pH 6.0 to 6.5 with 12 ml of phosphate buffer (pH 10). The extraction was continued for an additional 40 min at 60$^{o}$C to ensure the extraction of pectin with minimal degradation.

iii. Starch and protein hydrolysis: The pH was adjusted to 6.0 to 6.5 to bring the solution closer to the pH optimum of amylase and protease. The suspension was cooled to 20-30$^{o}$C before incubation overnight with 10 mg of alpha-amylase and 10 mg of protease. The incubation was accompanied by slow stirring with a magnetic bar.

iv. Isolation of insoluble dietary fiber (IDF): The suspension was filtered through a coarse-tarred Gooch crucible containing glass wool and the insoluble residue was washed with a small amount of water. The filtrate was kept for the next step. The insoluble residue was then washed with water, alcohol and acetone before being dried at 70$^{o}$C in an oven overnight. The dried residue constitutes insoluble dietary fiber (IDF).

v. Precipitation and isolation of soluble dietary fiber (SDF): The filtrate was acidified with a few drops of concentrated hydrochloric acid to pH 2 to 3; this pH tends to facilitate the rapid precipitation of polysaccharides. Four volume of ethanol was slowly added and the suspension left to stand for about 1h. Filter the precipitate on a coarse tarred Gooch crucible containing glass wool, then washed with 75% ethanol, absolute ethanol, and acetone before drying at 70$^{o}$C in an oven overnight. The residue was weighed in the crucible to give soluble dietary fiber (SDF) content of the original material. The SDF fraction was corrected for ash and for co-precipitated protein.

vi. Total dietary fiber (TDF): The sum of insoluble dietary fiber and soluble dietary fiber were calculated.

$$TDF = IDF + SDF$$

### 3.4.3 Total Minerals

**Acid digestion**

one gram ground sample in a 150 ml conical flask was mixed with 25-30 ml of diacid mixture ($HNO_3$ : $HClO_4$5:1, v/v) and kept overnight. The contents were digested by heating until clear white precipitate settled down at the bottom. The volume was 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 calcium, iron, zinc, magnesium and phosphorus.

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

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

**Estimation of phosphorus**

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

**Reagents**

i. Ascorbic acid (10%)

ii. Ammonium molybdate (2.5%)

iii. Reagent C: 6N $H_2SO_4$, water, 2.5 per cent ammonium molybdate and 10 per cent ascorbic acid were mixed in the ratio of 1:2:1:1 (v/v), respectively. This reagent was prepared fresh.

iv. Standard phosphorus solution: 0.351 g pure and dry anhydrous monopotassium dihydrogen orthophosphate was dissolved in a few ml of water and 10 ml 10N $H_2SO_4$. The volume was made to one litre with water. This stock contained 80 µg P/ml.

v. Working standard phosphorus solution: Twenty five ml stock solution was diluted to one litre, which served as working standard solution and contained 2 µg P/ml. Two or three drops of chloroform were added to preserve the solution.

**Procedure**

Mineral extract (0.1ml, obtained from acid digestion) was pipetted in a test tube and volume was made to four ml with water. Four ml reagent C was added and mixed well. The contents were incubated at 37ºC in water bath for 90 minutes. It was removed and allowed to cool to room temperature and absorbance was read at 720 nm against a suitable blank. Standard curve was plotted using one to eight µg P.

**3.4.4 *In vitro* digestibility**

**3.4.4.1 *In vitro* starch digestibility**

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

**Reagents**

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

ii. 0.2 M Disodium hydrogen phosphate: 35.39 g disodium hydrogen phosphate was dissolved in distilled water to make one litre solution.

iii. 0.2 M Potassium dihydrogen phosphate: 27.28 g potassium dihydrogen phosphate was dissolved in distilled water to make one litre solution.

iv. 0.2 M Phosphate buffer (pH 6.9): 50 ml of 0.2 M Potassium dihydrogen phosphate was added to 46.8 ml of 0.2 M disodium hydrogen phosphate to make a volume up to 200 ml.

v. Dinitrosalicylic reagent: 3, 5-dinitrosalicylic acid (10 g), sodium potassium tartrate (300 g) and sodium hydroxide (16 g) were dissolved in carbon dioxide free water and volume was made to 1 litre. The reagent was protected from carbon dioxide and was stored in brown bottle.

vi. Standard maltose solution: 100 mg Maltose monohydrate was dissolved in distilled water to make a volume up to 100 ml.

**Estimation**

Fifty mg defatted sample was weighed and dispersed in 1.0 ml of 0.2 M phosphate buffer (pH 6.9); 0.5 ml of pancreatic amylase was added to sample suspension. The suspension was incubated in water bath at $37^0$C for 2 hours with occasional shaking of test tubes. After incubation, 2 ml of dinitrosalicylic reagent was added quickly and the mixture was heated for 5 minutes in a boiling water bath. After cooling, the solution was made to 25 ml with distilled water and filtered through an ordinary filter. The absorbance was measured at 550 nm.

A blank was run simultaneously by incubating the sample without enzyme. Dinitrosalicylic reagent was added before addition of the enzyme solution. Maltose was used as standard and values were expressed as mg maltose released/g defatted sample. Standard curve was prepared by taking 0.2 to 1.0 mg maltose released per gram sample from a standard maltose solution. The starch digestibility was calculated as:

$$\textit{In vitro}\text{ starch digestibility} = \frac{\text{Concentration from graph (mg)}}{\text{Weight of sample (g)}}$$

#### 3.4.4.2 *In vitro* protein digestibility

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

**Reagents**

i. Pepsin reagent: 0.1 M $KH_2PO_4$ (pH 2.0) containing 0.2 % pepsin; 13.6 g potassium dihydrogen phosphate was dissolved in 1 litre of water, pH of the solution was adjusted to 2.0 and then 2 g pepsin was dissolved in the buffer.
ii. TCA (50 %): 50 g Trichloroacetic acid was dissolved in water and volume was made to 100 ml.

**Procedure**

Two hundred fifty mg of sample was transferred to a centrifuge tube and a 20 ml of pepsin reagent was added. The tube was stoppered and arranged in a shaker-incubator maintaining the water temperature at 37°C for 3 hours. Then centrifuge tube was removed and allowed to cool. 5 ml of TCA (50 %) was added in the above solution and the contents were centrifuged at 10,000 rpm for 10 minutes 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 microkjeldahl method (AOAC, 2000). Protein digestibility was calculated by the following formula:

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

### 3.4.5 Extraction of samples for antioxidant activity

Finely ground flour of wheat, chickpea, pearl millet and pomegranate peel powder were extracted with 80% methanol for determination of antioxidant activity using following procedure:

Five gram of weighted sample was taken in 100ml conical flask. Added 15ml 80% methanol and acidified to pH 2.0 with 6N HCl by shaking at room temperature for 30 minutes. The supernatant was decanted and re-extracted the residue for complete removal of phenolic and antioxidant compounds. The procedure was repeated for two times. Pooled the three supernatants and centrifuged at 6000 rpm for 15 minutes and filtered through whatman No-1 filter paper. Volume was made up to 50ml in the solvent. Then the samples were transferred to microcentrifuge tube and stored at -20$^0$C for total phenolic content, total flavonoids and total antioxidant capacity determination.

#### 3.4.5.1 Total phenol

The concentration of total phenol of the methanolic extracts was determined by the Folin–Ciocalteau colorimetric method (Singleton *et al.* , 1999). Phenols present in plant extract reacted with specific redox reagent (Folin–Ciocalteau reagent) to form blue chromophore constituted by a phosphotungsticphosphomolybdenum complex which was measured at 750 nm.

**Reagents:**

1. Gallic acid (GA) standard solution(100 mg%):
   Stock solution: 100 mg GA dissolved in 100ml distilled water (D/W).
   Working solution: Took 1 ml stock solution and volume made up to 20ml with D/W.
2. Folin-Ciocalteu (FC) reagent (50%): 1:1 dilution with D/W.
3. Sodium carbonate (7.5%): Dissolved 7.5 g $Na_2CO_3$ in 100ml D/W.

**Procedure**:

**Sample**: Different known sample aliquots were taken and made the volume up to 1.5ml with D/W. To this 0.5ml of Folin–Ciocalteau reagent was added. After that 10ml of 7.5% $Na_2CO_3$ was added and incubated at 37$^0$C for 60 minutes. Read the resulting blue colored complex at 750 nm. The results were expressed in mg Gallic acid equivalents/100g (mg GAE/100g).

**Standard curve**: Standard series of known concentration of Gallic acid (5µg to 20µg) were made. For that 0.1, 0.2, 0.3, 0.4 ml aliquots were taken and treated in the same way as sample. Absorbance was recorded at 750 nm and a calibration curve of absorbance versus concentration was plotted.

**Blank**: 1.5ml of D/W was taken and treated in the same way as sample.

**Calculation**:

$$\text{TPC (mgGAE/100g)} = \frac{\text{Standard Conc.}}{\text{Standard O.D}} \times \frac{\text{Sample O.D}}{\text{Aliquot taken (ml)}} \times \frac{\text{Volume made (ml)}}{\text{Sample taken (g)}} \times \frac{100}{1000} \times \text{Dilution factor}$$

#### 3.4.5.2 Total flavonoids

The amount of flavonoids content in methanolic extracts was determined by aluminium chloride colorimetric method (Zhishen *et al.* , 1999). The natural flavonoids compounds present in the sample extracts reacts with sodium nitrite; the pink colored flavonoids-aluminium complex developed using aluminium chloride in alkaline condition which was measured at 510 nm.

**Reagent:**

1. Routine standard solution (10 mg %): Dissolved 10 mg Rutine in 100 ml methanol.
2. Sodium nitrite (5 g %): Dissolved 5 g $NaNO_2$ in 100 ml D/W.
3. Aluminium chloride (10 g %): Dissolved 10 g $AlCl_3.6H_2O$ in 100 ml D/W.
4. Sodium Hydroxide (1N): Dissolved 4 g NaOH in 100 ml D/W.

**Procedure**:

**Sample**: Different known sample aliquots were taken and volume was made up to 5 ml with distilled water. Then 0.5 ml of 5% $NaNO_2$ was added in test tubes and mixed after 5 minute, 0.6 ml of 10% $AlCl_3$was added and again mixed. After 6 minute, 2 ml of 1N NaOH was added and mixed. Then 2.1 ml D/W was added to make volume up to 10ml. The absorbance of resulting pink color was read at 510 nm against blank.

**Blank:** Five ml of distilled water was taken and treated same as sample.

**Standard curve**: Standard series of known concentration of Rutine (50-200 µg) were made. For that 0.5, 1.0, 1.5, 2.0 ml aliquots were taken and made the volume up to 5 ml with D/W and treated same as sample. Absorbance was recorded at 510 nm and a calibration curve of absorbance versus concentration was plotted.

**Calculation**:

$$\underset{\text{(mgRE/100g)}}{\text{TFC}} = \frac{\text{Standard Conc.}}{\text{Standard O.D}} \times \frac{\text{Sample O.D}}{\text{Aliquot taken (ml)}} \times \frac{\text{Volume made (ml)}}{\text{Sample taken (g)}} \times \frac{100}{1000} \times \text{Dilution factor}$$

**3.4.5.3 Antioxidant activity by DPPH**

The antioxidant activity of the extracts, on the basis of the scavenging activity of the stable DPPH free radical, was determined by the method followed by Brand-Williams *et al.* (1995) as previously described by Tadhani *et al.* (2009).

**Reagent**:

1. Trolox standard solution (10 mg%): 10 mg of trolox dissolved in100 ml D/W.
2. DPPH solution: Dissolved 15.77 mg of DPPH in 200ml of methanol and set the O.D. 1.0 at 517nm.
3. Methanol

**Procedure:**

**Sample**: Different known sample aliquots were taken and volume was made up to 1 ml with methanol. Three ml of DPPH reagent was added to it and mixed the contents properly and incubated for 20 minutes at $37^0$C. Read the absorbance of the resulting oxidized solution at 517nm against methanol as blank.

**Control**: one ml of methanol was taken and treated same as sample.

**Standard curve**: Standard series of known concentration of Trolox (10-40µg) were made. For that 0.1, 0.2, 0.3, 0.4 ml aliquot were taken and made volume 1.0 ml with methanol and treated same as sample. Absorbance was recorded at 517 nm and a calibration curve of absorbance versus concentration was plotted.

**Calculation**:

The percent inhibition of activity = [(Ac – Ae)/Ac] x 100 (where, Ac = absorbance of control; Ae = absorbance of extract).

$$\text{DPPH(mgTE/100)} = \frac{\text{Standard Conc.}}{Y} \times \frac{X}{\text{Aliquot taken (ml)}} \times \frac{\text{Volume made (ml)}}{\text{Sample taken (g)}} \times \frac{100}{1000} \times \text{Dilution factor}$$

Where

X = Sample percent inhibition

Y = Standard percent inhibition

**3.5 Nutritional evaluation of pomegranate peel powder**

**3.5.1 Proximate composition**

Methods given under heading 3.4.1 were followed.

**3.5.2 Dietary fibre**

Methods given under heading 3.4.2 were followed.

**3.5.3 Total minerals (Calcium, iron, magnesium, zinc and phosphorus)**

Methods given under heading 3.4.3 were followed.

**3.5.4 *In vitro* digestibility**

**3.5.4.1 *In vitro* starch**

Methods given under heading 3.4.4.1 were followed.

**3.5.4.2 *In vitro* protein**

Methods given under heading 3.4.4.2 were followed.

**3.5.5 Extraction of samples for antioxidant activity:**

Methods given under heading 3.4.5 were followed.

**3.5.5.1 Total phenols**

Methods given under heading 3.4.5.1 were followed.

**3.5.5.2 Total flavonoids**

Methods given under heading 3.4.5.2 were followed.

**3.5.5.3 Antioxidant activity by DPPH**

Methods given under heading 3.4.5.3 were followed.

**3.6 Development of baked products from wheat, chickpea and pearl millet flour blends and pomegranate peel powder**

### 3.6.1 The proportion of ingredients used for preparation of biscuits

| Supple-mentation level (%) | Refined flour (g) | Wheat flour (g) | Chickpea flour (g) | Pearl millet flour (g) | Pomegranate peel powder (g) | Ghee (g) | Sugar (g) | Milk (g) | CMC | Sodium bicarbonate (g) | Ammonia |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control (100%WF) | - | 100 | - | - | - | 40 | 60 | 40 | a pinch | 0.5 | a pinch |
| Type-I | - | 64 | 15 | 15 | 6 | 40 | 60 | 40 | a pinch | 0.5 | a pinch |
| Type-II | - | 62 | 15 | 15 | 8 | 40 | 60 | 40 | a pinch | 0.5 | a pinch |
| Type-III | - | 60 | 15 | 15 | 10 | 40 | 60 | 40 | a pinch | 0.5 | a pinch |
| Type-IV | - | 58 | 15 | 15 | 12 | 40 | 60 | 40 | a pinch | 0.5 | a pinch |

Type-I (64:15:15:6), Type-II (62:15:15:8) Type-III (60:15:15:10) Type-IV (58:15:15:12)
WF = Wheat Flour, CF = Chickpea Flour, PMF = Pearl Millet Flour and PPP = Pomegranate Peel Powder

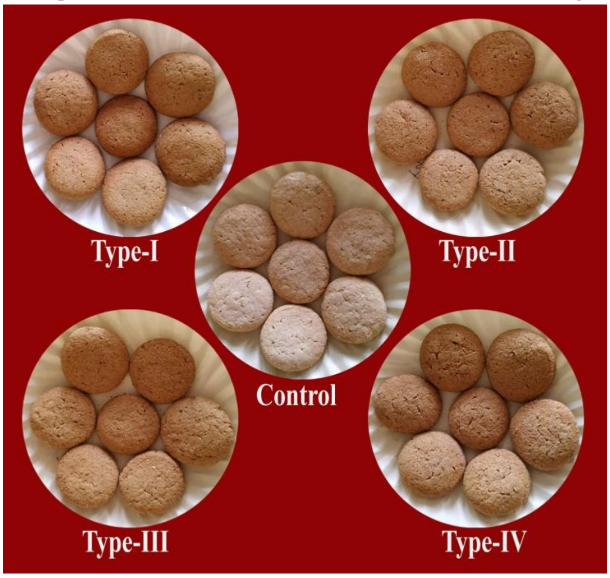


**Plate 5: Pomegranate peel powder supplemented biscuits**

Control: Wheat flour (100%)

Type I (WF:CF:PMF:PPP::64:15:15:6) Type II (WF:CF:PMF:PPP::62:15:15:8) Type III (WF:CF:PMF:PPP::60:15:15:10) Type IV (WF:CF:PMF:PPP::58:15:15:12)

### Method

- Sieved the wheat flour, chickpea flour, pearl millet flour and pomegranate peel powder.
- Then ghee and sugar were creamed.
- Sodium bicarbonate, ammonia and baking powder were added and mixed well with creamed ghee and sugar.
- In the above mixture sieved flour was added and dough was prepared with addition of milk.
- Dough was rolled into sheet.
- Biscuits were cut into the desired shape.
- Biscuits were baked at 160°C till brown colour.

### 3.6.2 The proportion of ingredients used for preparation of cake-rusk

| Supplementation level (%) | Refined flour (g) | Wheat flour (g) | Chickpea flour (g) | Pearl millet flour (g) | Pomegranate peel powder(g) | Butter (g) | Sugar (g) | Egg (No.) | Baking powder (tsp) | Vanilla essence |
|---|---|---|---|---|---|---|---|---|---|---|
| 100 % RF | 100 | - | - | - | - | 100 | 100 | 3 | 1 | Few drops |
| Type-I | - | 64 | 15 | 15 | 6 | 100 | 100 | 3 | 1 | Few drops |
| Type-II | - | 62 | 15 | 15 | 8 | 100 | 100 | 3 | 1 | Few drops |
| Type-III | - | 60 | 15 | 15 | 10 | 100 | 100 | 3 | 1 | Few drops |
| Type-IV | - | 58 | 15 | 15 | 12 | 100 | 100 | 3 | 1 | Few drops |

Type-I (64:15:15:6), Type-II (62:15:15:8) Type-III (60:15:15:10) Type-IV (58:15:15:12)
RF = Refined Flour, WF = Wheat Flour, CF = Chickpea Flour, PMF = Pearl Millet Flour and PPP = Pomegranate Peel Powder

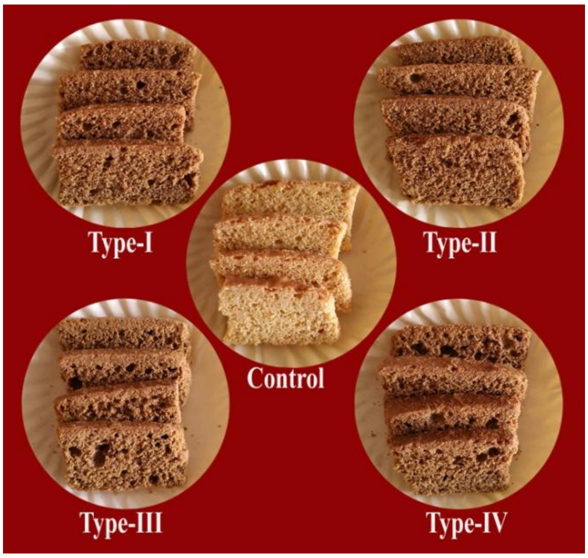


**Plate 6: Pomegranate peel powder supplemented cake-rusk**

Control: Refined flour (100%)

Type I (WF:CF:PMF:PPP::64:15:15:6) Type II (WF:CF:PMF:PPP::62:15:15:8) Type III (WF:CF:PMF:PPP::60:15:15:10) Type IV (WF:CF:PMF:PPP::58:15:15:12)

**Method**

- Wheat flour, chickpea flour, pearl millet flour and pomegranate peel powder and baking powder were sieved twice.
- Creamed sugar and butter together till light and fluffy.
- Beat eggs separately and mixed well in sugar and butter mixture. Vanilla essence was also added.
- Sieved flour was added and folded in above mixture and batter was prepared.
- The batter was poured in greased pan and baked, in preheated oven, at 160 $^0$ C for 35-40 minutes.
- After baking, cool down the cake at room temperature cut into ¼ inch thick slices and bake again in a preheated oven at 120-130 $^0$ C, till light brown.

### 3.7 Organoleptic evaluation of baked products

Baked products *i.e.*, biscuits and cake rusk were subjected to sensory evaluation with respect to color, appearance, aroma, texture, taste and overall acceptability by a panel of 10 semi trained judges, using 9 point hedonic scale (Annexure-I).

### 3.8 Nutritional evaluation of baked products

Methods mentioned in point 3.4 were followed to assess the nutritional composition of baked products.

### 3.9 Shelf life studies of baked products

#### 3.9.1 Organoleptic evaluation

Organoleptic evaluation of stored products was periodically carried out an interval of 15 days by a panel of ten semi trained judges for colour, appearance, aroma, texture, taste and overall acceptability using a nine-point Hedonic Rating Scale.

### 3.10 Statistical analysis

Mean, standard error and CD (critical difference) were calculated for analysis of data (Sheoran & Pannu 1999).

# CHAPTER-IV

## RESULTS

The present study was conducted to assess the physicochemical properties and nutrient composition of wheat variety C-306, chickpea flour (HC-5), pearl millet (86-M86) flour and pomegranate peel powder. Cake rusk and biscuits were prepared from wheat, chickpea and pearl millet flour and pomegranate peel powder and evaluated for their sensory characteristics, nutritional composition and keeping quality. The results so obtained during the course of investigation were subjected to suitable statistical analysis, tabulated and have been presented systematically under the following headings and sub-headings:

4.1 Physicochemical properties of wheat grains, wheat flour, chickpea grains, chickpea flour, pearl millet grains, pearl millet flour and pomegranate peel powder

 4.1.1 Physical properties of wheat, chickpea and pearl millet grains

 4.1.2 Physicochemical properties of wheat, chickpea, pearl millet flour and pomegranate peel powder

4.2 Nutritional composition of wheat, chickpea and pearl millet flour and pomegranate peel powder

4.3 Development of baked products utilizing wheat, chickpea and pearl millet flour and pomegranate peel powder

 4.3.1 Organoleptic acceptability of baked products *i.e.* biscuits and cake-rusk

 4.3.2 Nutritional composition of biscuits and cake-rusk

4.4 Shelf life studies of baked products

 4.4.1 Organoleptic evaluation

### 4.1 Physicochemical properties of wheat grains, wheat flour, chickpea grains, chickpea flour, pearl millet grains, pearl millet flour and pomegranate peel powder

The findings on physicochemical properties of wheat grains, wheat flour, chickpea grain, chickpea flour, pearl millet grain, pearl millet flour and pomegranate peel powder are presented in Tables 4.1 and 4.2.

#### 4.1.1 Physical properties of wheat, chickpea and pearl millet grains

The colour of wheat, chickpea and pearl millet grains was light golden yellow, dark brown and dark grey, respectively. The grain hardness and 1000 kernel weight of wheat, chickpea and pearl millet grains were 6.28 Kg/grain and 44.39g, 18.65 Kg/grain and 158.79g and 2.63 Kg/grain and 10.81g, respectively.

**Table 4.1: Physical properties of wheat grains, chickpea grains and pearl millet grains**

| Properties | Wheat grains | Chickpea grains | Pearl millet grains |
|---|---|---|---|
| Grain colour | Light golden yellow | Dark brown | Dark grey |
| Grain hardness (Kg/grain)* | 6.28±0.04 | 18.65±0.18 | 2.63±0.06 |
| 1000 Kernel weight (g)** | 44.39±0.12 | 158.79±0.14 | 10.81±0.10 |

* Values are mean ± SE of ten independent determinations
** Values are mean ± SE of four independent determinations

### 4.1.2 Physicochemical properties of wheat, chickpea and pearl millet flour and pomegranate peel powder

#### 4.1.2.1 Colour

The colour of wheat, chickpea and pearl millet flour was creamish white, pale yellow and light greyish, respectively while that of pomegranate peel powder was cocoa brown.

**Table 4.2: Physicochemical properties of wheat, chickpea and pearl millet flour and pomegranate peel powder**

| Properties | Wheat flour | Chickpea flour | Pearl millet Flour | Pomegranate peel powder |
|---|---|---|---|---|
| **Colour** | Creamish White | Pale yellow | Light Greyish | Brown |
| **Water absorption capacity (g/g)** | 1.32±0.08 | 0.92±0.15 | 1.52±0.04 | 3.28±0.08 |
| **Sedimentation value (ml)** | 35.43±0.08 | 14.01±0.23 | 15.23±0.06 | 12.51±0.04 |
| **Wet gluten (%)** | 26.45±0.11 | - | - | - |
| **Dry gluten (%)** | 7.72±0.15 | - | - | - |
| **Oil absorption capacity (g/g)** | 1.27±0.04 | 1.02±0.04 | 1.15±0.06 | 2.62±0.17 |
| **Gelation capacity (g/100ml)** | 10.22±0.02 | 9.58±0.09 | 8.72±0.15 | 6.72±0.10 |
| **Bulk density (g/ml)** | 0.79±0.05 | 0.63±0.17 | 0.61±0.11 | 0.54±0.05 |
| **Swelling power (g/g)** | 7.28±0.07 | 6.53±0.12 | 8.23±0.02 | 5.58±0.02 |

Values are mean ± SE of three independent determinations

#### 4.1.2.2 Water absorption capacity

Water absorption capacity of wheat, chickpea and pearl millet flour was 1.32, 0.92, and 1.52g/g, respectively. Pomegranate peel powder showed maximum (3.28g/g) water absorption capacity and chickpea flour showed minimum (0.92g/g) water absorption capacity.

#### 4.1.2.3 Sedimentation value

The sedimentation value of wheat, chickpea and pearl millet flour was 35.43, 14.01 and 15.23 ml, respectively while that of pomegranate peel powder was 12.51 ml.

#### 4.1.2.4 Wet and dry gluten content

Gluten content is a direct indicator of flour strength and determines the suitability of flour for making good quality bakery products. Wheat flour had 26.45 and 7.72 per cent of wet and dry gluten, respectively. It was found that chickpea flour, pearl millet flour and pomegranate peel powder had no gluten content.

#### 4.1.2.5 Oil absorption capacity

Oil absorption capacity of wheat flour, chickpea flour, pearl millet flour and pomegranate peel powder were 1.27, 1.02, 1.15 and 2.62 g/g, respectively. It was found that oil absorption capacity was highest in pomegranate peel powder *i.e.* 2.62 g/g and lowest in wheat flour which was 1.02 g/g.

#### 4.1.2.6 Gelation capacity

Gelation capacity of wheat flour (10.22 g/100ml) was found to be highest while pomegranate peel powder (6.72 g/ml) had lowest gelation capacity while that of chickpea and pearl millet flour was 9.58 g and 8.72 g/100ml, respectively.

#### 4.1.2.7 Bulk density

Bulk density of wheat flour, chickpea flour, pearl millet flour and pomegranate peel powder were observed to be 0.79, 0.63, 0.61 and 0.54 g/ml, respectively. It was found that bulk density was maximum in wheat flour and minimum in pomegranate peel powder.

#### 4.1.2.8 Swelling power

Swelling power of wheat flour and chickpea flour were observed as 7.28 and 6.53 g/g, respectively. Swelling power was found highest in pearl millet flour 8.23 g/g and lowest in pomegranate peel powder 5.58 g/g, respectively.

## 4.2 Nutritional composition of wheat, chickpea and pearl millet flour and pomegranate peel powder

### 4.2.1 Proximate composition

The data of proximate composition of wheat, chickpea, pearl millet flour and pomegranate peel powder are presented in Tables 4.3. Wheat flour contained 10.21, 12.60, 2.37, 2.15 and 1.74 per cent of moisture, crude protein, fat, ash and crude fibre, respectively while chickpea and pearl millet flour contained 9.35 and 8.61, 21.71 and 11.16, 4.40 and 5.48, 2.80 and 2.27 and 3.29 and 2.05 per cent moisture, crude protein, fat, ash and crude fibre, respectively. Pomegranate peel powder contained 7.28 percent moisture, 3.42 per cent protein, 2.78 per cent fat, 4.98 per cent ash and 13.71 per cent crude fibre on dry weight basis.

**Table 4.3 Proximate composition of wheat, chickpea and pearl millet flour and pomegranate peel powder (g/100g, on dry weight basis)**

| Flour/ Powder | Moisture* | Crude protein | Fat | Ash | Crude fibre |
|---|---|---|---|---|---|
| Wheat flour | 10.21±0.05 | 12.60±0.23 | 2.37±0.04 | 2.15±0.03 | 1.74±0.09 |
| Chickpea flour | 9.35±0.09 | 21.71±0.15 | 4.40±0.11 | 2.80±0.14 | 3.29±0.04 |
| Pearl millet flour | 8.61±0.17 | 11.16±0.06 | 5.48±0.40 | 2.27±0.07 | 2.05±0.03 |
| Pomegranate peel powder | 7.28±0.08 | 3.42±0.10 | 2.78±0.05 | 4.98±0.01 | 13.71±0.11 |

Values are mean ± SE of three independent determinations
*On fresh weight basis

Among four types of flours maximum crude protein was possessed by chickpea flour and fat by pearl millet flour while pomegranate peel powder had highest content of ash and crude fibre. Fat, ash and crude fibre content of wheat flour was found to be lower than that of other types of flours and pomegranate peel powder.

### 4.2.2 Dietary fibre

The data pertaining dietary fibre of wheat, chickpea, pearl millet flour and pomegranate peel powder are presented in Tables 4.4. Total dietary fibre content in wheat, chickpea and pearl millet flour was 10.92, 13.43 and 11.51 per cent, respectively. Soluble dietary fibre content of wheat, chickpea and pearl millet flour was 3.60, 5.22 and 2.41 per cent, respectively while insoluble dietary fibre content was 7.32, 8.21 and 9.10 per cent in wheat, chickpea and pearl millet flour, respectively. Total dietary, soluble and insoluble fibre contents of pomegranate peel powder were 28.42, 13.11 and 15.31 g/100g, respectively. All types of fibres *i.e.* total, insoluble and soluble dietary fibre were found to be highest in pomegranate peel powder. Total dietary fiber was higher in chickpea flour followed by pearl millet and wheat flour. Soluble and insoluble dietary fibre were found to be highest in chickpea and pearl millet flour, respectively.

**Table 4.4: Dietary fibre content of wheat, chickpea and pearl millet flour and pomegranate peel powder (g/100g, on dry matter basis)**

| Flour/Powder | Dietary fibre | | |
|---|---|---|---|
| | Total | Soluble | Insoluble |
| Wheat flour | 10.92±0.03 | 3.60±0.08 | 7.32±0.02 |
| Chickpea flour | 13.43±0.08 | 5.22±0.05 | 8.21±0.08 |
| Pearl millet flour | 11.51±0.11 | 2.41±0.11 | 9.10±0.15 |
| Pomegranate peel powder | 28.42±0.12 | 13.11±0.04 | 15.31±0.11 |

Values are mean ± SE of three independent determinations

### 4.2.3 *In-vitro* digestibility

The data of *in-vitro* digestibility of wheat, chickpea, pearl millet flour and pomegranate peel powder are presented in Tables 4.5. *In-vitro* protein digestibility of wheat, chickpea and pearl millet flours was 62.31, 67.63 and 61.14 per cent, respectively while i*n-vitro* starch digestibility of wheat, chickpea and pearl millet flours was 36.82, 38.47 and 23.24 mg maltose released/g meal, respectively. *In-vitro* protein and starch digestibility of pomegranate peel powder was 51.29 per cent and 24.52 mg maltose released/g meal.

**Table 4.5 *In vitro* protein and starch digestibility of wheat, chickpea and pearl millet flour and pomegranate peel powder**

| Flour/Powder | Protein digestibility (%) | Starch digestibility (mg maltose released/g meal) |
|---|---|---|
| Wheat flour | 62.31±0.04 | 36.82±0.06 |
| Chickpea flour | 67.63±0.06 | 38.47±0.11 |
| Pearl millet flour | 61.14±0.02 | 23.24±0.16 |
| Pomegranate peel powder | 51.29±0.09 | 24.52±0.18 |

Values are mean ± SE of three independent determinations

### 4.2.4 Total minerals

The data concerning total minerals content of wheat, chickpea, pearl millet flour and pomegranate peel powder are presented in Tables 4.6. Wheat flour contained 44.21, 320.30, 3.80, 3.43 and 142.00 mg/100g of calcium, phosphorus, iron, zinc and magnesium, respectively. Chickpea and pearl millet flour contained calcium (81.70 and 66.72mg/100g, respectively), phosphorus (252.0 and 289.0 mg/100g, respectively), iron (5.50 and 8.62 mg/100g, respectively), zinc (3.37 and 2.77mg/100g, respectively) and magnesium (160.0 and 125.0mg/100g, respectively). Pomegranate peel powder contained 72.30, 5.60, 149.56, 0.48 and 57.23 mg/100g of calcium, iron, magnesium, zinc and phosphorus, respectively.

**Table 4.6 Total mineral content of wheat, chickpea and pearl millet flour and pomegranate peel powder (mg/100g, on dry matter basis)**

| Flour/Powder | Calcium | Phosphorus | Iron | Zinc | Magnesium |
|---|---|---|---|---|---|
| Wheat flour | 44.21±0.01 | 320.30±0.18 | 3.80±0.22 | 3.43±0.23 | 142.0±0.09 |
| Chickpea flour | 81.70±0.07 | 252.0±0.11 | 5.50±0.04 | 3.37±0.07 | 160.0±0.06 |
| Pearl millet flour | 66.72±0.04 | 289.0±0.13 | 8.62±0.08 | 2.77±0.04 | 125.0±0.10 |
| Pomegranate peel powder | 72.30±0.03 | 57.23±0.15 | 5.60±0.46 | 0.48±0.13 | 149.56±0.14 |

Values are mean ± SE of three independent determinations

### 4.2.5 Total antioxidant activity

The data pertaining total antioxidant activity of wheat, chickpea, pearl millet flour and pomegranate peel powder are presented in Tables 4.7. Total phenols content of wheat, chickpea and pearl millet flour was 86.90, 50.13 and 120.95 mgGAE/100g, respectively. It was found that total anti-oxidant activity of pomegranate peel powder (96.92 mgTE/100g) was highest than wheat (51.70 mgTE/100g), chickpea (48.35 mgTE/100g) and pearl millet flour (25.15 mgTE/100g). Total flavonoids content of pearl millet flour was higher than other type of flours (wheat and chickpea) however radical scavenging activity of wheat flour was higher than chickpea and pearl millet flour. In contrast to flour, the total phenols, flavonoids and radical scavenging activity was found highest in pomegranate peel powder (864.73 mgGAE/100g, 1372.00 mgRE/100g and 96.92 mgTE/100g, respectively).

**Table 4.7 Total anti-oxidant activity of wheat, chickpea and pearl millet flour and pomegranate peel powder (on dry matter basis)**

| Flour/Powder | Total phenols (mgGAE/100g) | Total flavonoids (mgRE/100g) | Antioxidant activity by DPPH(mgTE/100g |
|---|---|---|---|
| Wheat flour | 86.90±0.60 | 55.72±0.87 | 51.70±0.75 |
| Chickpea flour | 50.13±0.69 | 22.17±0.54 | 48.35±0.90 |
| Pearl millet flour | 120.95±0.77 | 89.87±1.20 | 25.15±1.08 |
| Pomegranate peel powder | 864.73±0.67 | 1372.00±0.79 | 96.92±1.17 |

Values are mean ± SE of three independent determinations

## 4.3 Development of baked products utilizing wheat, chickpea, pearl millet flour and pomegranate peel powder

### 4.3.1 Organoleptic acceptability of baked products *i.e.* Biscuits and cake-rusk

#### 4.3.1.1 Biscuits

Mean scores of sensory characteristics of developed value added food product biscuits is represented in Tables 4.8.

**Colour**

The colour score of 100 per cent wheat flour biscuits was 8.50 which fell in the category of 'liked very much'. The mean score of colour of all the four types of multigrain pomegranate peel powder supplemented biscuits, prepared from different ratios of wheat, chickpea, pearl millet flour and pomegranate peel powder ranged from 8.20 (Liked very much) to 5.40 (Neither liked nor disliked). It was found that biscuits prepared from 100 per cent wheat flour had higher mean score of colour (8.50) compared to other types of developed biscuits i.e Type-I (8.20), Type-II (7.70), Type-III (7.50) and Type-IV (5.40). The colour score of Type-II and Type-III multigrain pomegranate peel powder supplemented biscuits fell in the category of 'Liked very much' and 'Liked moderately' and that of Type-IV supplemented biscuits was lowest and fell in the category of 'Neither liked nor disliked'.

**Appearance**

The appearance score of 100 per cent wheat flour biscuits was 8.40 which fell in the category of 'Liked very much'. The appearance score of biscuits containing 6, 8, 10 and 12 per cent pomegranate peel powder ranged from 8.10 to 5.20, respectively. In all the four types of biscuits, Type-I multigrain pomegranate peel powder supplemented biscuits scored highest score for appearance i.e 8.10, which fell in the category of 'Liked very much' whereas Type-IV biscuits got lowest score i.e 5.20 which was found in the category of 'Neither liked nor disliked'.

**Aroma**

The mean score of aroma of biscuits prepared from wheat flour (100%) was 8.40 which fell in the category of 'Liked very much'. As the level of supplementation of pomegranate peel powder increased in multigrain biscuits (Type-I to Type-IV) aroma score fell in the category of 'Liked very much to 'Neither liked nor disliked' and was in the range of 8.20 to 5.45. Among the four types of multi grain biscuits Type-I scored highest which fell in the category of 'liked very much' and Type-IV got lowest score for aroma was fell in the category of 'Neither liked nor disliked'.

**Texture**

Mean score of texture of 100 per cent wheat flour biscuits was 8.40 which fell in the category of 'Liked very much', whereas mean score of texture of Type-I, Type-II, Type-III and Type-IV multigrain pomegranate peel powder biscuits ranged from 8.20 to 5.35, and fell in the category of 'Liked very much' to 'Neither liked nor disliked'. Mean score of texture of supplemented biscuits Type-I was 8.20 which fell in the category of 'Liked very much'. Type-IV multigrain pomegranate peel powder supplemented biscuits had score of 5.35 which fell in the category of 'Neither liked nor disliked'.

**Taste**

The mean score of taste of 100 percent wheat flour biscuits was 8.50 which fell in the category of 'Liked very much'. As the level of supplementation of pomegranate peel powder increased in wheat, chickpea and pearl millet flour biscuits the taste score fell in the category of 'Liked very much' to 'Neither liked nor disliked'. The score ranged from 8.30 to 5.40, in different types of biscuits supplemented with pomegranate peel powder at 6, 8, 10 and 12 per cent levels. Among the four types of supplemented biscuits Type-I scored highest score for taste which fell in the category of 'Liked very much' whereas, Type-IV got lowest score for taste which was found in the category of 'Neither liked nor disliked'.

**Table 4.8 Mean scores of sensory characteristics of multi grain biscuits supplemented with pomegranate peel powder**

| Biscuits | Colour | Appearance | Aroma | Texture | Taste | Overall acceptability |
|---|---|---|---|---|---|---|
| Control (WF 100%) | 8.50±0.16 | 8.40±0.16 | 8.40±0.18 | 8.40±0.14 | 8.50±0.16 | 8.40±0.16 |
| Type-I | 8.20±0.27 | 8.10±0.29 | 8.20±0.18 | 8.20±0.16 | 8.30±0.18 | 8.20±0.18 |
| Type-II | 7.70±0.15 | 7.50±0.16 | 7.70±0.19 | 7.80±0.20 | 7.70±0.26 | 7.68±0.13 |
| Type-III | 7.50±0.16 | 7.20±0.21 | 7.40±0.31 | 7.40±0.22 | 7.40±0.28 | 7.38±0.14 |
| Type-IV | 5.40±0.20 | 5.20±0.29 | 5.45±0.26 | 5.35±0.19 | 5.40±0.14 | 5.35±0.14 |

Values are mean ± SE of ten observations

Type-I (WF:CF:PMF:PPP::64:15:15:6) Type-II (WF:CF:PMF:PPP::62:15:15:8)

Type-III (WF:CF:PMF:PPP::60:15:15:10) Type-IV (WF:CF:PMF:PPP::58:15:15:12)

WF: Wheat flour CF: Chickpea flour PMF: Pearl millet flour PPP: Pomegranate peel powder

**Overall acceptability**

The mean score of overall acceptability of wheat flour biscuits was 8.40 which fell in the category of 'Liked very much' whereas Type-I, Type-II, Type-III and Type-IV biscuits got mean score of 8.20, 7.68, 7.38 and 5.35, respectively. Type-IV biscuits scored lowest overall acceptability mean score i.e 5.35 which was found in the category of 'Neither liked nor disliked'. Type-I multigrain pomegranate peel powder biscuits had highest overall acceptability mean score of 8.20 (Liked very much) among all four types of biscuits.

**4.3.1.2 Cake-rusk**

Mean scores of sensory characteristics of developed value added food product cake–rusk is shown in Tables 4.9.

**Colour**

The mean score of colour of cake-rusk prepared from refined flour was 8.40 which was in the category of 'Liked very much', whereas, mean score of all four types of multigrain pomegranate peel powder cake-rusk ranged from 8.20 to 5.10. It was found that cake-rusk prepared from 100 per cent refined flour had highest mean score of colour (8.40) followed by Type-I (8.20), Type-II (7.60), Type-III (7.40) and Type-IV (5.10) cake-rusk. The scores of multigrain biscuits fell in the category of 'Liked very much' to 'Neither liked nor disliked'.

**Appearance**

The appearance score of the 100 per cent refined flour cake-rusk was 8.30 and fell in the category of 'Liked very much'. The appearance score of all four types of multigrain pomegranate peel powder supplemented cake-rusk ranged from 8.00 to 5.20. It was found that the cake-rusk prepared from 100 per cent refined flour had higher mean score of appearance (8.30) as compared to other types of multigrain cake-rusk i.e Type-I (8.00), Type-II (7.40), Type-III (7.25) and Type-IV (5.20). The mean score of Type-I cake-rusk fell in the category of 'Liked very much', whereas that of Type-II and Type-III biscuits was fell in the category of 'Liked moderately'. The mean score of appearance of Type-IV (5.20) value added cake-rusk was in the category of 'Neither liked nor disliked'.

**Table 4.9 Mean scores of sensory characteristics of multi grain cake -rusk supplemented with pomegranate peel powder**

| Cake-rusk | Colour | Appearance | Aroma | Texture | Taste | Overall acceptability |
|---|---|---|---|---|---|---|
| Control (RF 100%) | 8.40±0.20 | 8.30±0.13 | 8.30±0.16 | 8.40±0.22 | 8.40±0.22 | 8.34±0.23 |
| Type-I | 8.20±0.13 | 8.00±0.18 | 8.10±0.18 | 8.20±0.18 | 8.30±0.16 | 8.16±0.12 |
| Type-II | 7.60±0.16 | 7.40±0.21 | 7.60±0.22 | 7.70±0.20 | 7.60±0.23 | 7.58±0.27 |
| Type-III | 7.40±0.21 | 7.25±0.26 | 7.40±0.26 | 7.40±0.23 | 7.40±0.21 | 7.37±0.22 |
| Type-IV | 5.10±.022 | 5.20±0.23 | 5.25±0.18 | 5.30±0.13 | 5.45±0.27 | 5.26±0.18 |

Values are mean ± SE of ten observations

Type-I (WF:CF:PMF:PPP::64:15:15:6) Type-II (WF:CF:PMF:PPP::62:15:15:8)

Type-III (WF:CF:PMF:PPP::60:15:15:10) Type-IV (WF:CF:PMF:PPP::58:15:15:12)

WF: Wheat flour CF: Chickpea flour PMF: Pearl millet flour PPP: Pomegranate peel powder

RF: Refined flour

**Aroma**

The aroma score of the cake-rusk prepared from 100 per cent refined flour was 8.30 which was found in the category of 'Liked very much'. The aroma scores of cake-rusks containing 6, 8, 10 and 12 per cent pomegranate peel powder were in the range of 8.10 to 5.25. In all the four types of cake-rusk Type-I cake-rusk scored highest score for aroma i.e 8.10 which fell in the category of 'Liked very much' whereas Type-IV supplemented cake-rusk got lowest score i.e 5.25 which was found in the category of 'Neither liked nor disliked'.

**Texture**

The mean score of texture of cake-rusk prepared from refined flour (100%) was 8.40 which fell in the category of 'Liked very much'. As the level of supplementation of pomegranate peel powder increased in wheat, chickpea and pearl millet flour biscuit texture scores decreased and fell in the category of 'Liked very much' to 'Neither liked nor disliked'. The score ranged from 8.20 to 5.30, as the level of supplementation with pomegranate peel powder increased from 6 to 12 per cent. Among the four types of cake-rusks Type-I scored highest score for texture which fell in the category of ‘Liked very much’ whereas Type-IV got lowest score and fell in the category of ‘Neither liked nor disliked’.

**Taste**

Mean score of taste of 100 per cent refined flour cake-rusk was 8.40 which fell in the category of ‘liked very much’, whereas mean score of taste of Type-I, Type-II, Type-III and Type-IV cake-rusks ranged from 8.30 to 5.45, which fell in the category of ‘Liked very much’ to ‘Neither liked nor disliked’. Mean score of taste of Type-I cake-rusk was 8.30 which fell in the category of ‘Liked very much’ and that of, Type-IV cake-rusk was 5.45 which fell in the category of ‘Neither liked nor disliked’.

**Overall acceptability**

The mean score of overall acceptability of refined flour cake-rusk was 8.34 which fell in the category of ‘liked very much’ whereas Type-I, Type-II, Type-III and Type-IV cake-rusks got mean score of 8.16, 7.58, 7.37 and 5.26, respectively. Among different types of cake rusks multigrain Type-IV supplemented cake-rusk scored lowest overall acceptability mean score i.e 5.26, which was found in the category of ‘Neither liked nor disliked’, whereas, Type-I had highest mean score of 8.16 which fell in the category of ‘Liked very much’. All types *i.e.* Type-I, Type-II and Type-III pomegranate peel powder supplemented multigrain biscuits were acceptable except Type-IV which was ‘Neither liked nor disliked’.

**4.3.2 Nutritional composition of multi grain biscuits and cake-rusk**

**4.3.2.1 Proximate composition**

**Biscuits**

The result of proximate composition of multi grain biscuits supplemented with pomegranate peel powder is presented in Table 4.10 and Fig. 4.1. Moisture content in 100 per cent wheat flour biscuits was 2.94 per cent while that of Type-I, Type-II and Type-III multigrain biscuits were 3.04, 3.26 and 3.39 per cent, respectively. The protein and fat contents in control biscuits were 9.27 and 19.26 per cent, respectively which were significantly ($P \leq 0.05$) lower than Type-I (11.21 and 21.32 per cent, respectively), Type-II (10.82 and 21.98 per cent, respectively) and Type-III (10.42 and 22.52 per cent, respectively) multigrain biscuits. However it was observed that protein content of Type-III biscuits was significantly ($P \leq 0.05$) lower than that of Type-I and Type-II. The ash and crude fibre contents in wheat flour (control) biscuits were 1.81 and 1.08 per cent, respectively which increased significantly ($P \leq 0.05$) in all types (Type-I to Type-III) of multigrain biscuits from 2.16 to 2.85 per cent and from 2.17 to 3.42 per cent, respectively as the level of incorporation of pomegranate peel powder increased.

**Table 4.10 Proximate composition of multi grain biscuits supplemented with pomegranate peel powder (%, on dry matter basis)**

| Biscuits | Moisture* | Protein | Fat | Ash | Crude fibre |
|---|---|---|---|---|---|
| Control (WF 100%) | 2.94±0.01 | 9.27±0.02 | 19.26±0.02 | 1.81±0.02 | 1.08±0.02 |
| Type-I | 3.04±0.02 | 11.21±0.02 | 21.32±0.02 | 2.16±0.02 | 2.17±0.03 |
| Type-II | 3.26±0.01 | 10.82±0.01 | 21.98±0.01 | 2.52±0.03 | 2.92±0.04 |
| Type-III | 3.39±0.01 | 10.42±0.01 | 22.52±0.02 | 2.85±0.04 | 3.42±0.02 |
| CD ($p \leq 0.05$) | 0.06 | 0.07 | 0.78 | 0.10 | 0.10 |

Values are mean ± SE of three independent determinations
*On fresh weight basis

Type-I (WF:CF:PMF:PPP::64:15:15:6) Type-II(WF:CF:PMF:PPP::62:15:15:8)
Type-III (WF:CF:PMF:PPP::60:15:15:10)
WF: Wheat flour CF: Chickpea flour PMF: Pearl millet flour PPP: Pomegranate peel powder

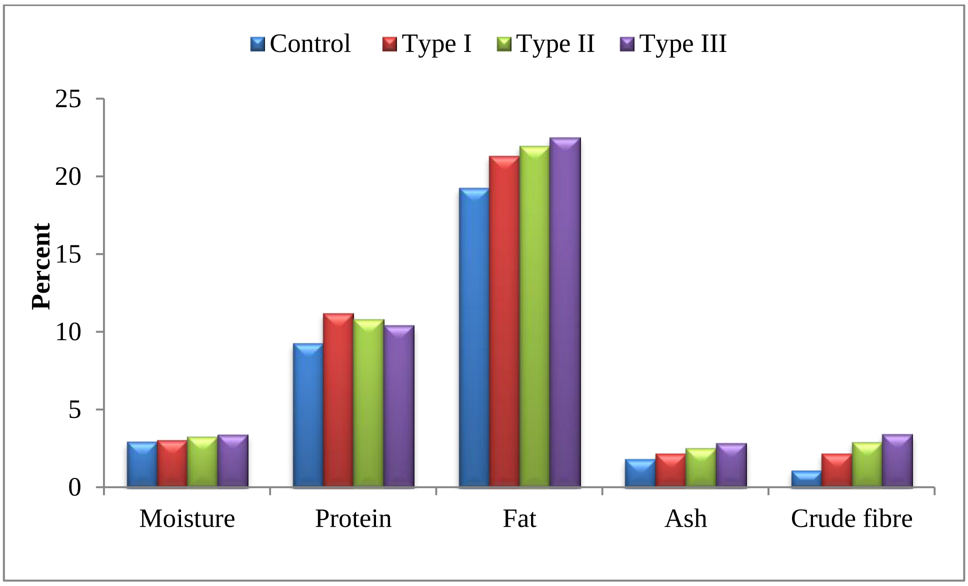


**Fig. 4.1 Proximate composition of multi grain biscuits supplemented with pomegranate peel powder (%, on dry matter basis)**

The fat, ash and crude fibre contents of Type-III biscuits were significantly higher than that of Type-II and Type-I multigrain biscuits. Similarly Type-II multigrain biscuits possessed significantly ($P \leq 0.05$) higher contents of fat, crude fibre and ash compared to Type-I multigrain biscuits. A non-significant ($P \leq 0.05$) difference was observed in fat content of Type-I and Type-II multigrain pomegranate peel powder supplemented biscuits.

**Cake-rusk**

The result of proximate composition of multi grain cake-rusk supplemented with pomegranate peel powder is presented in Table 4.11 and Fig. 4.2. Moisture content of 100 per cent refined flour cake-rusk was 3.02 per cent while the moisture content of multigrain cake-rusk *viz.* Type-I, Type-II and Type-III was 3.54, 3.72 and 3.88 per cent, respectively. The protein and fat contents in 100 per cent refined flour cake-rusk were 9.82 and 20.52 per cent, respectively. The protein and fat contents of Type-I cake-rusk were 11.23 and 21.72 per cent, respectively which were significantly (P≤0.05) higher than that of 100 per cent refined flour cake-rusk. Similarly protein content of Type-II (10.79 per cent) cake-rusk was significantly (P≤0.05) higher than that of 100 per cent refined flour cake-rusk. The protein content of Type-I cake-rusk was significantly (P≤0.05) higher than that of Type-II and Type-III cake-rusk, showing that as the level per cent of pomegranate peel powder is increased, the protein content got decreased.

**Table 4.11 Proximate composition of multi grain cake-rusk supplemented with pomegranate peel powder (%, on dry matter basis)**

| Cake-rusk | Moisture* | Protein | Fat | Ash | Crude fibre |
|---|---|---|---|---|---|
| Control (RF 100%) | 3.02±0.04 | 9.82±0.05 | 20.52±0.05 | 1.79±0.01 | 0.72±0.05 |
| Type I | 3.54±0.05 | 11.23±0.11 | 21.72±0.01 | 2.23±0.05 | 2.24±0.08 |
| Type II | 3.72±0.06 | 10.79±0.06 | 22.95±0.02 | 2.28±0.02 | 3.24±0.09 |
| Type III | 3.88±0.08 | 10.35±0.08 | 23.05±0.09 | 3.39±0.06 | 3.82±0.11 |
| CD (p≤0.05) | 0.22 | 0.28 | 0.18 | 0.15 | 0.29 |

Values are mean ± SE of three independent determinations
*On fresh weight basis

Type-I (WF:CF:PMF:PPP::64:15:15:6) Type-II (WF:CF:PMF:PPP::62:15:15:8)
Type-III (WF:CF:PMF:PPP::60:15:15:10) RF: Refined flour
WF: Wheat flour CF: Chickpea flour PMF: Pearl millet flour PPP: Pomegranate peel powder

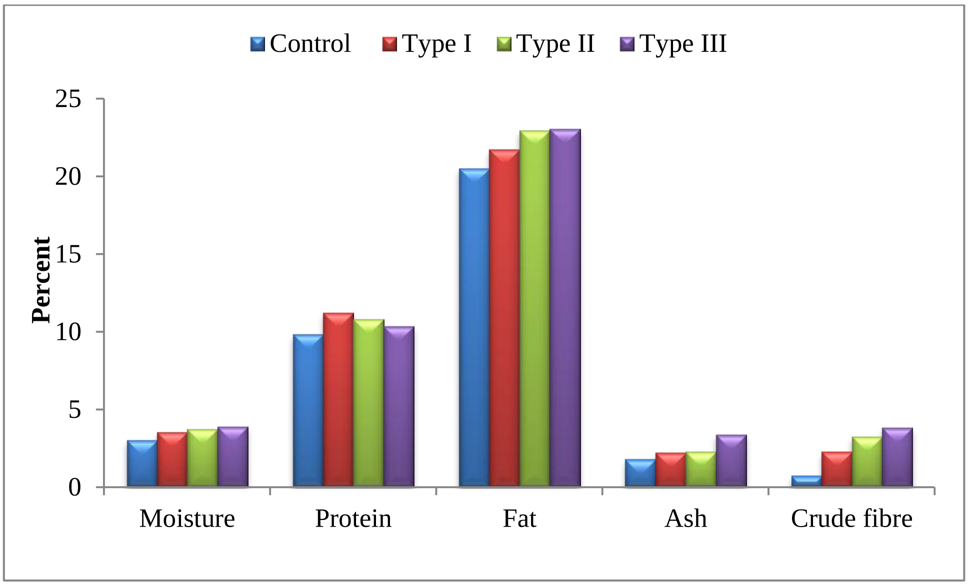


**Fig. 4.2 Proximate composition of multi grain cake-rusk supplemented with pomegranate peel powder (%, on dry matter basis)**

Fat content of Type-I, Type-II and Type-III multigrain cake-rusk were 21.72, 22.95 and 23.05 per cent, respectively which were significantly (P≤0.05) higher than that of 100 per cent refined flour cake-rusk. The ash and crude fibre contents in 100 per cent refined flour cake-rusk were 1.79 and 0.72 per cent, respectively which significantly (P≤0.05) enhanced on supplementation with chickpea flour (15 %), pearl millet flour (15 %) and pomegranate peel powder (6 to 10 per cent). As the level of supplementation of pomegranate peel powder in cake-rusk increased from 6 to 10 per cent the ash and crude fibre content of all types of multigrain cake-rusks increased significantly (P≤0.05) from 2.23 to 3.39 and 2.24 to 3.82 per cent, respectively. A non-significant (P≤0.05) difference was observed in ash content of Type-I and Type-II multigrain pomegranate peel powder supplemented cake-rusk.

#### 4.3.2.2 Dietary fibre

**Biscuits**

The result of dietary fibre content of multi grain biscuits supplemented with pomegranate peel powder is presented in Tables 4.12. Total dietary fibre content of wheat flour biscuits was 8.42 per cent. It was observed that total, soluble and insoluble dietary fibre content of multigrain biscuits supplemented with pomegranate peel powder was significantly higher than that of control. Total dietary fibre content of three types of value added biscuits were in the range of 9.40 to 10.35 per cent, respectively. Maximum total dietary fibre was observed in Type-III biscuits i.e 10.35 per cent and minimum was 9.40 per cent in Type-I biscuits. There was a significant increase in total dietary fibre content of multigrain biscuits as the level of incorporation with pomegranate peel powder increased from 6 to 10 per cent.

**Table 4.12 Dietary fibre content of multi grain biscuits supplemented with pomegranate peel powder (%, on dry matter basis)**

| Biscuits | Dietary fibre | | |
|---|---|---|---|
| | Total | Soluble | Insoluble |
| Control (WF 100%) | 8.42±0.08 | 1.70±0.14 | 6.72±0.17 |
| Type-I | 9.40±0.10 | 2.20±0.06 | 7.20±0.06 |
| Type-II | 9.88±0.20 | 2.40±0.12 | 7.48±0.11 |
| Type-III | 10.35±0.14 | 2.78±0.17 | 7.57±0.15 |
| CD (p≤0.05) | 0.46 | 0.44 | 0.44 |

Values are mean ± SE of three independent determinations

Type-I (WF:CF:PMF:PPP::64:15:15:6) Type-II (WF:CF:PMF:PPP::62:15:15:8)

Type-III (WF:CF:PMF:PPP::60:15:15:10)

WF: Wheat flour CF: Chickpea flour PMF: Pearl millet flour PPP: Pomegranate peel powder

Soluble dietary fibre content of biscuits made from wheat flour (control) was 1.70 per cent, which enhanced significantly on increasing the level of incorporation of pomegranate peel powder in wheat, chickpea and pearl millet flour. Among all the three types of multigrain biscuits, Type-III biscuits had maximum content of soluble dietary fibre *i.e.* 2.78 per cent, followed by 2.40 per cent in Type-II and 2.20 per cent in Type-I biscuits. Soluble dietary fibre content of Type-IV biscuits was significantly higher than that of Type-I. Wheat flour biscuits contained 6.72 per cent insoluble dietary fibre which was significantly (p≤0.05) lower than Type-I, Type-II and Type-III biscuits. The values of insoluble dietary fibre ranged from 7.20 to 7.57 per cent in Type-I, Type-II and Type-III biscuits and there was non-significant difference in the insoluble dietary fibre content of three types of multigrain biscuits.

**Cake-rusk**

The result of dietary fibre content of multi grain cake-rusk supplemented with pomegranate peel powder is presented in Tables 4.13. Total dietary fibre content of refined flour cake-rusk was 3.04 per cent. As the supplementation levels of pomegranate peel powder increased in wheat, chickpea and pearl millet flour, total dietary fibre content was also increased significantly ($p \leq 0.05$) in multigrain cake-rusk *viz*., Type-I, Type-II and Type-III from 9.10 to 9.78 per cent. Maximum total dietary fibre was observed in Type-III cake-rusk i.e 9.78 per cent and minimum was 9.10 per cent in Type-I biscuits.

**Table 4.13 Dietary fibre content of multi grain cake-rusk supplemented with pomegranate peel powder (%, on dry matter basis)**

| Cake-rusk | Dietary fibre | | |
|---|---|---|---|
| | **Total** | **Soluble** | **Insoluble** |
| Control (RF 100%) | 3.04±0.03 | 0.79±0.01 | 2.25±0.05 |
| Type-I | 9.10±0.05 | 2.10±0.02 | 7.00±0.06 |
| Type-II | 9.53±0.08 | 2.50±0.05 | 7.03±0.05 |
| Type-III | 9.78±0.04 | 2.73±0.06 | 7.05±0.02 |
| CD ($p \leq 0.05$) | 0.19 | 0.15 | 0.17 |

Values are mean ± SE of three independent determinations

Type-I (WF:CF:PMF:PPP::64:15:15:6) Type-II (WF:CF:PMF:PPP::62:15:15:8)

Type-III (WF:CF:PMF:PPP::60:15:15:10) RF: Refined flour

WF: Wheat flour CF: Chickpea flour PMF: Pearl millet flour PPP: Pomegranate peel powder

Soluble dietary fibre content of cake-rusk made from refined flour (control) was 0.79 per cent which increased from 2.10 to 2.73 per cent on increasing the incorporation level of pomegranate peel powder in multigrain cake-rusk. Among all the three types of value added cake-rusk, Type-III cake-rusk had maximum content of soluble dietary fibre *i.e.* 2.73 per cent, followed by 2.50 per cent in Type-II and 2.01 per cent in Type-I cake-rusk. Insoluble dietary fibre content of refined flour cake-rusk was 2.25 per cent, which was significantly ($p \leq 0.05$) lower than Type-I, Type-II and Type-III cake-rusk and as the level of incorporation of pomegranate peel powder increased from 6 to 10 per cent. The values ranged from 7.00 to 7.05, respectively for Type-I, Type-II and Type-III cake-rusk. A non-significant difference was observed in insoluble dietary fibre of Type-I, Type-II and Type-III multigrain cake-rusk.

**4.3.2.3 Total minerals**

**Biscuits**

The results of total mineral content of multi grain biscuits supplemented with pomegranate peel powder is presented in Table 4.14 and Fig 4.3. It was observed that the control biscuits contained 47.28, 167.21, 2.73, 1.10 and 75.21 mg/100g of calcium, phosphorus, iron, zinc and magnesium, respectively. Type-I biscuits possessed 63.25, 259.09, 3.20, 2.48 and 88.31 mg/100g of calcium, phosphorus, iron, zinc and magnesium, respectively. Type-II biscuits contained 64.42, 238.23, 3.44, 1.92 and 92.70 mg/100g of calcium, phosphorus, iron, zinc and magnesium, respectively while Type-III biscuits contained 65.68, 225.05, 4.20, 1.67 and 93.26 mg/100g of calcium, phosphorus, iron, zinc and magnesium, respectively. All types of multigrain pomegranate peel powder supplemented biscuits had significantly ($p \leq 0.05$) higher mineral content than control biscuits. It was observed that there was a significant increase in calcium, iron and magnesium content of multigrain biscuits as the level of supplementation with pomegranate peel powder increased from 6 to 10 per cent. However a decreasing trend was observed for zinc and phosphorus content of all types of multigrain biscuits with the increase in level of supplementation (6 to 10 %) with pomegranate peel powder.

**Table 4.14 Total mineral content of multi grain biscuits supplemented with pomegranate peel powder (mg/100g, on dry matter basis)**

| Biscuits | Calcium | Phosphorus | Iron | Zinc | Magnesium |
|---|---|---|---|---|---|
| Control (WF 100%) | 47.28±0.01 | 167.21±0.11 | 2.73±0.05 | 1.10±0.01 | 75.21±0.03 |
| Type-I | 63.25±0.04 | 259.09±0.05 | 3.20±0.02 | 2.48±0.05 | 88.31±0.04 |
| Type-II | 64.42±0.05 | 238.23±0.04 | 3.44±0.08 | 1.92±0.04 | 92.70±0.05 |
| Type-III | 65.68±0.08 | 225.05±0.01 | 4.20±0.02 | 1.67±0.02 | 93.26±0.08 |
| CD ($p \leq 0.05$) | 0.18 | 0.19 | 0.18 | 0.12 | 0.18 |

Values are mean ± SE of three independent determinations

Type-I (WF:CF:PMF:PPP::64:15:15:6) Type-II (WF:CF:PMF:PPP::62:15:15:8)

Type-III (WF:CF:PMF:PPP::60:15:15:10)

WF: Wheat flour CF: Chickpea flour PMF: Pearl millet flour PPP: Pomegranate peel powder

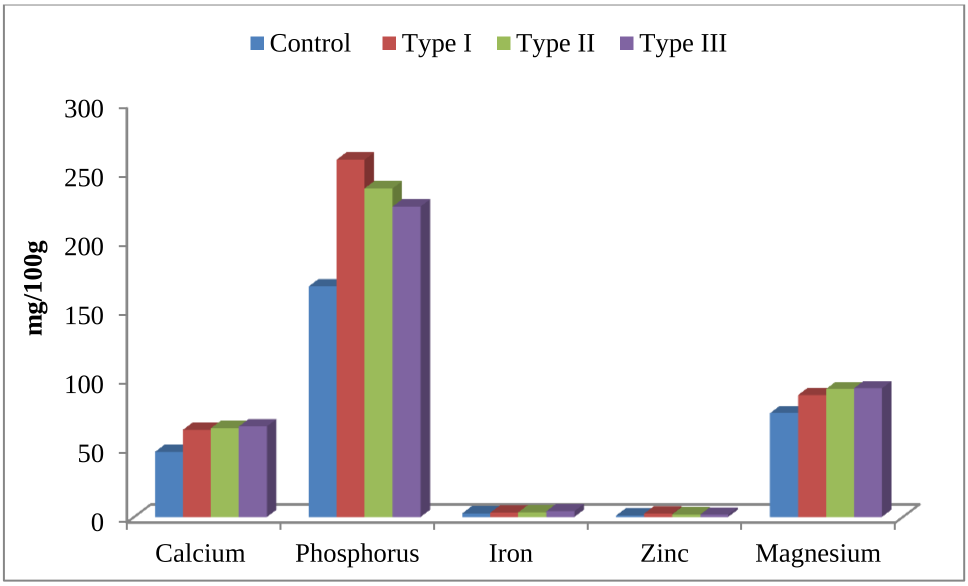


**Fig. 4.3 Total mineral content of multi grain biscuits supplemented with pomegranate peel powder (mg/100g, on dry, matter basis)**

**Cake-rusk**

The results of total mineral content of multi grain cake-rusk supplemented with pomegranate peel powder is presented in Table 4.15 and Fig 4.4. The 100 per cent refined flour cake-rusk had 22.49, 105.23, 1.03, 0.87 and 38.23 mg/100g of calcium, phosphorus, iron, zinc and magnesium, respectively which were significantly (P≤0.05) lower than Type-I, Type-II and Type-III cake-rusk. Type-I cake-rusk contained 61.35, 225.63, 2.72, 1.85 and 85.27 mg/100g of calcium, phosphorus, iron, zinc and magnesium, respectively and Type-II and Type-III cake-rusk contained 62.52, 205.24, 2.89, 1.36 and 93.41 mg/100g and 62.96, 185.53, 3.05, 1.02 and 95.96 mg/100g of calcium, phosphorus, iron, zinc and magnesium, respectively. It was observed that mineral content of value added cake-rusk were significantly (P≤0.05) higher than that of 100 per cent refined flour cake-rusk. However, as the level of pomegranate peel powder increased from 6 to 10 per cent a decreasing pattern was observed in phosphorus and zinc contents of Type-II compared to Type-I and, Type-III multigrain cake-rusk compared to Type-II. A non-significant difference was observed in the iron content of Type-I and Type-II value added cake-rusk. i.e 2.72 and 2.89 mg/100g, respectively.

**Table 4.15 Total mineral content of multi grain cake-rusk supplemented with pomegranate peel powder (mg/100g, on dry matter basis)**

| Cake rusk | Calcium | Phosphorus | Iron | Zinc | Magnesium |
|---|---|---|---|---|---|
| Control (RF 100%) | 22.49±0.01 | 105.23±0.05 | 1.03±0.02 | 0.87±0.02 | 38.23±0.01 |
| Type-I | 61.35±0.03 | 225.63±0.04 | 2.72±0.05 | 1.85±0.08 | 85.27±0.04 |
| Type-II | 62.52±0.05 | 205.24±0.12 | 2.89±0.11 | 1.36±0.07 | 93.41±0.05 |
| Type-III | 62.96±0.06 | 185.53±0.05 | 3.05±0.04 | 1.02±0.02 | 95.96±0.03 |
| CD (p≤0.05) | 0.15 | 0.25 | 0.23 | 0.19 | 0.13 |

Values are mean ± SE of three independent determinations

Type-I (WF:CF:PMF:PPP::64:15:15:6) Type-II (WF:CF:PMF:PPP::62:15:15:8)

Type-III (WF:CF:PMF:PPP::60:15:15:10) RF: Refined flour

WF: Wheat flour CF: Chickpea flour PMF: Pearl millet flour PPP: Pomegranate peel powder

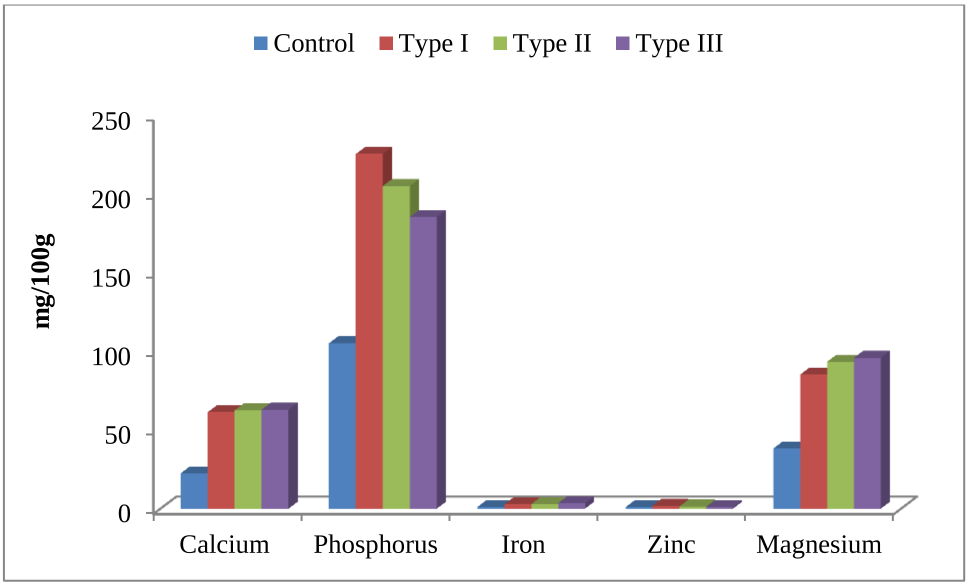


**Fig. 4.4 Total mineral content of multigrain cake-rusk supplemented with pomegranate peel powder (mg/100g, on dry matter basis)**

#### 4.3.2.4 *In-vitro* digestibility

**Biscuits**

The results of *in-vitro* protein and starch digestibility of multi grain biscuits supplemented with pomegranate peel powder is presented in Table 4.16. Biscuits made from wheat flour (control) possessed *in vitro* protein and starch digestibility of 69.08 per cent and 49.67 mg maltose released/g meal, respectively and these values were significantly ($p \leq 0.05$) higher than that of all types of multigrain pomegranate peel powder biscuits. Type-I value added biscuits had *in vitro* protein and starch digestibility of 68.42 per cent and 47.23 mg maltose released/g meal, respectively. *In vitro* protein and starch digestibility of Type-II value added biscuits was 68.30 per cent and 46.62 mg maltose released/g meal, respectively while that of Type-III biscuits was 67.85 per cent and 45.21 mg maltose released/g meal, respectively. The *in vitro* protein digestibility of Type-I and Type-II biscuits was significantly ($P \leq 0.05$) higher than that of Type-III biscuits however a non-significant difference was found in the values of Type-I and Type-II biscuits. A significant ($P \leq 0.05$) decrease was observed in the *in vitro* starch digestibility of Type-I, Type-II and Type-III multigrain pomegranate peel powder biscuits with the increase in level of supplementation with pomegranate peel powder.

**Table 4.16 *In vitro* protein and starch digestibility of multi grain biscuits supplemented with pomegranate peel powder (on dry matter basis)**

| Biscuits | Protein digestibility (%) | Starch digestibility (mg maltose release/ g meal ) |
|---|---|---|
| Control (WF 100%) | 69.08±0.01 | 49.67±0.03 |
| Type-I | 68.42±0.15 | 47.23±0.05 |
| Type-II | 68.30±0.05 | 46.62±0.08 |
| Type-III | 67.85±0.03 | 45.21±0.11 |
| CD (p≤0.05) | 0.28 | 0.26 |

Values are mean ± SE of three independent determinations

Type-I (WF:CF:PMF:PPP::64:15:15:6) Type-II (WF:CF:PMF:PPP::62:15:15:8)

Type-III (WF:CF:PMF:PPP::60:15:15:10)

WF: Wheat flour CF: Chickpea flour PMF: Pearl millet flour PPP: Pomegranate peel powder

**Cake-rusk**

The results of *in-vitro* protein and starch digestibility of multi grain cake-rusk supplemented with pomegranate peel powder is presented in Table 4.17. Cake-rusk made from refined flour (control) had 72.49 per cent *in vitro* protein digestibility and 51.37 mg maltose released/g meal *in vitro* starch digestibility and these values were significantly ($p \leq 0.05$) higher than that of all types of multigrain cake-rusk. The protein and starch digestibility of Type-I multigrain cake-rusk was 72.04 per cent and 50.04 mg maltose released/g meal, respectively. Type-II cake-rusk had protein digestibility of 71.85 per cent and starch digestibility of 49.56 mg maltose released/g meal while Type-III cake-rusk had protein digestibility of 70.51 per cent and starch digestibility of 49.21 mg maltose released/g meal. There was a significant ($p \leq 0.05$) decrease in the starch digestibility of Type-I, Type-II and Type-III cake-rusks from 50.04 to 49.21 mg maltose released/g meal as the level of substitution with pomegranate peel powder increased from 6 to 10 per cent. A significant ($p \leq 0.05$) decrease was also observed in the protein digestibility of value added cake-rusks from 72.04 to 70.51 per cent.

**Table 4.17 *In vitro* protein and starch digestibility of multi grain cake-rusk supplemented with pomegranate peel powder (on dry matter basis)**

| Cake-rusk | Protein digestibility (%) | Starch digestibility (mg maltose released/g meal) |
|---|---|---|
| Control (RF 100%) | 72.49±0.01 | 51.37±0.08 |
| Type-I | 72.04±0.03 | 50.04±0.03 |
| Type-II | 71.85±0.03 | 49.56±0.07 |
| Type-III | 70.51±0.05 | 49.21±0.06 |
| CD (p≤0.05) | 0.12 | 0.22 |

Values are mean ± SE of three independent determinations

Type-I (WF:CF:PMF:PPP::64:15:15:6) Type-II (WF:CF:PMF:PPP::62:15:15:8)

Type-III (WF:CF:PMF:PPP::60:15:15:10) RF: Refined flour

WF: Wheat flour CF: Chickpea flour PMF: Pearl millet flour PPP: Pomegranate peel powder

### 4.3.2.5 Total anti-oxidant activity

**Biscuits**

Antioxidant activity, polyphenol and flavonoids content of control and supplemented biscuits is presented in Table 4.18 and Fig 4.5. Wheat flour (control) biscuits had total polyphenol 75.78 mgGAE/100g, flavonoids 41.86mgRE/100g and radical scavenging activity of 23.15 mgTE/100g. Polyphenol, flavonoids and radical scavenging activity of all types of multigrain pomegranate peel powder biscuits were significantly ($P \leq 0.05$) higher than that of 100 per cent wheat flour biscuits. Type-I and Type-II value added biscuits contained polyphenols 106.53 and 118.98mgGAE/100g, flavonoids 107.79 and 128.89 mgRE/100g and radical scavenging activity 38.97 and 40.68 mgTE/100g, respectively while Type-III value added biscuits contained polyphenol 131.42 mgGAE/100g, flavonoids 149.94 mgRE/100g and radical scavenging activity 42.63 mgTE/100g, respectively. As the level of subsituition with pomegranate peel powder increased in Type-I, Type-II and Type-III biscuits from 6 to 10 per cent while chickpea (15%) and pearl millet (15%) content was kept constant a significant ($P \leq 0.05$) increase was observed in the level of total polyphenols, flavonoids and radical scavenging activity of multigrain pomegranate peel powder biscuits.

**Table 4.18 Total anti-oxidant activity of multi grain biscuits supplemented with pomegranate peel powder (on dry matter basis)**

| Biscuits | Total phenols (mgGAE/100gm) | Total flavonoids (mgRE/100gm) | Antioxidant activity by DPPH(mgTE/100gm) |
|---|---|---|---|
| Control (WF 100%) | 75.78±0.72 | 41.86±0.60 | 23.15±0.26 |
| Type-I | 106.53±1.32 | 107.79±0.34 | 38.97±0.20 |
| Type-II | 118.98±0.60 | 128.89±0.46 | 40.68±0.37 |
| Type-III | 131.42±0.46 | 149.94±0.71 | 42.63±0.54 |
| CD (p≤0.05) | 2.80 | 1.51 | 1.22 |

Values are mean ± SE of three independent determinations

Type-I (WF:CF:PMF:PPP::64:15:15:6) Type-II (WF:CF:PMF:PPP::62:15:15:8)

Type-III (WF:CF:PMF:PPP::60:15:15:10)

WF: Wheat flour CF: Chickpea flour PMF: Pearl millet flour PPP: Pomegranate peel powder

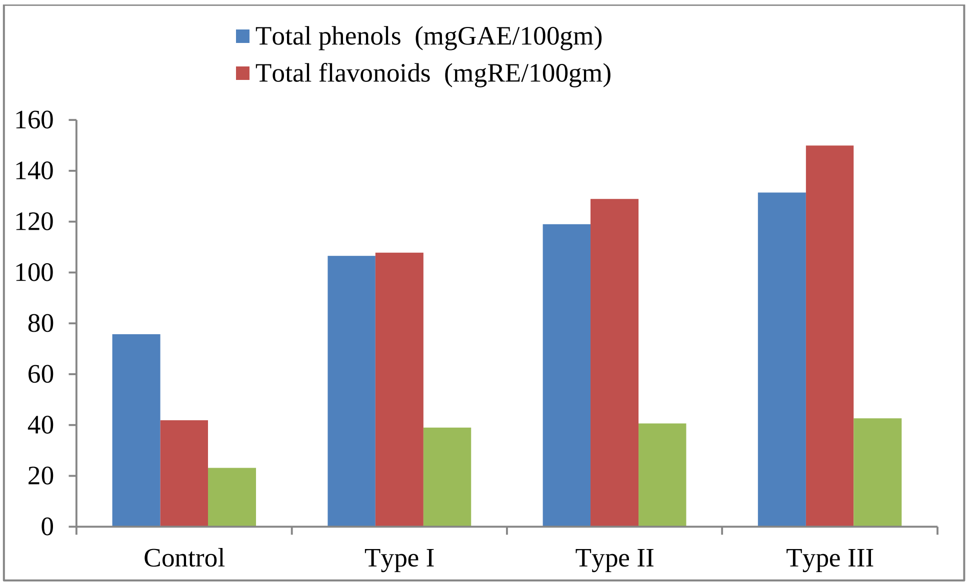


**Fig. 4.5 Total anti-oxidant activity of multigrain biscuits supplemented with pomegranate peel powder (on dry matter basis)**

**Cake-rusk**

Antioxidant activity, polyphenol and flavonoids content of control and supplemented cake-rusk is presented in Table 4.19 and Fig 4.6. Refined flour (control) cake-rusk contained polyphenol 58.19 mgGAE/100g, flavonoids 39.75 mgRE/100g and antioxidant activity 22.30 mgTE/100g. Total polyphenol, flavonoids and anti-oxidant activity of all the types of multigrain pomegranate peel powder cake-rusk were significantly (P≤0.05) higher than that of 100 per cent refined flour cake-rusk. Type-I and Type-II value added cake-rusk contained total polyphenols (104.53 and 112.75 mgGAE/100g), flavonoids (105.69 and 122.75 mgRE/100g) and radical scavenging activity (35.71 and 37.76 mgTE/100g) while Type-III cake-rusk contained total polyphenol 125.68 mgGAE/100g, flavonoids 145.84 mgRE/100g and radical scavenging activity 40.36 mgTE/100g, respectively which was highest among all types of multigrain pomegranate peel powder cake-rusk.

**Table 4.19 Total antioxidant activity of multi grain cake-rusk supplemented with pomegranate peel powder (on dry matter basis)**

| Cake-rusk | Total phenols (mgGAE/100gm) | Total flavonoids (mgRE/100gm) | Antioxidant activity by DPPH(mgTE/100gm) |
|---|---|---|---|
| Control (RF 100%) | 58.19±0.60 | 39.75±0.75 | 22.30±0.43 |
| Type-I | 104.53±0.56 | 105.69±0.92 | 35.71±0.43 |
| Type-II | 112.75±0.61 | 122.75±0.46 | 37.76±0.37 |
| Type-III | 125.68±1.17 | 145.84±0.43 | 40.36±0.26 |
| CD (p≤0.05) | 2.59 | 2.23 | 1.26 |

Values are mean ± SE of three independent determinations

Type-I (WF:CF:PMF:PPP::64:15:15:6) Type-II (WF:CF:PMF:PPP::62:15:15:8)

Type-III (WF:CF:PMF:PPP::60:15:15:10) RF: Refined flour

WF: Wheat flour CF: Chickpea flour PMF: Pearl millet flour PPP: Pomegranate peel powder

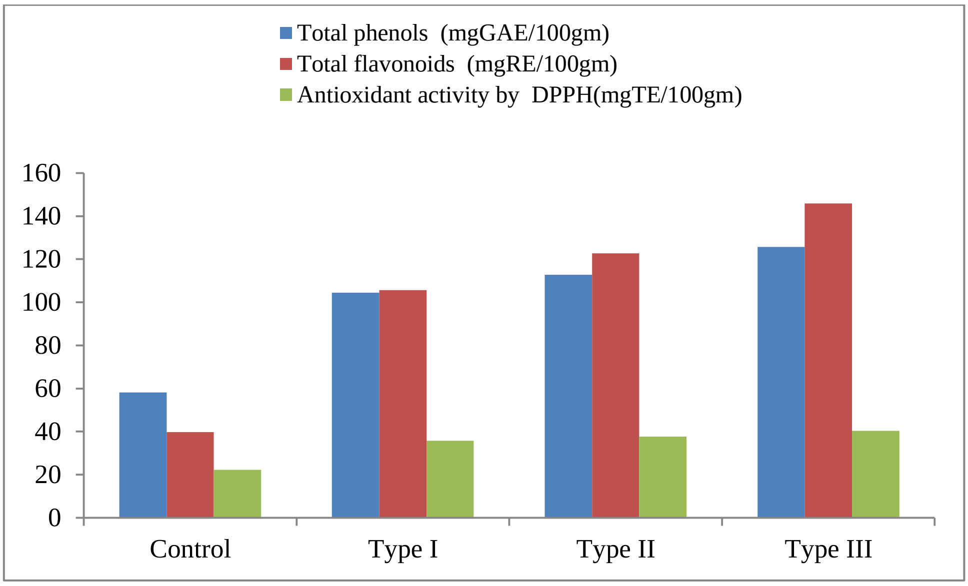


**Fig. 4.6 Total anti-oxidant activity of multi grain cake-rusk supplemented with pomegranate peel powder (on dry matter basis)**

As the level of fortification with pomegranate peel powder increased from 6 to 10 per cent, (while chickpea and pearl millet content was kept constant i.e 15 per cent each), a significant (P≤0.05) increase was observed in the level of polyphenols, flavonoids and antioxidant activity of value added cake-rusk.

## 4.4 Shelf life studies of baked products

### 4.4.1 Organoleptic evaluation

**Biscuits**

Results of all sensory characteristics (colour, appearance, aroma, texture, taste and overall acceptability) of multi grain biscuits supplemented with pomegranate peel powder is presented in Table 4.20.

**Colour**

Mean score for colour of biscuits made from 100 per cent wheat flour (control) and all types of value added biscuits was noted as 8.50, 8.20, 7.70 and 7.50, respectively on zero day of storage, which fell in the category of 'Liked very much' to 'Liked moderately'. These scores decreased with increase in storage period i.e 15, 30, 45, 60, 75 and 90 days. However, up to ninety days, biscuits made from 100 per cent wheat flour (control) and Type-I, Type-II and Type-III value added biscuits scored 7.10, 6.50, 6.50 and 6.40, respectively which fell in the category of 'liked moderately' to 'Liked slightly'.

**Appearance**

Mean score for appearance of biscuits made from 100 per cent wheat flour (control) and all type of value added biscuits was observed as 8.40, 8.10, 7.50 and 7.20, respectively on zero day of storage, which fell in the category of 'Liked very much' to 'Liked moderately'. A decreased trend was observed in the appearance score of the biscuits during the storage time of 15$^{th}$ day to 90$^{th}$ day. The appearance score of control biscuits made from wheat flour was in the range of 8.40 to 6.50 up to 90$^{th}$ days which fell in the category of 'Liked very much' to 'Liked slightly'. Similarly, mean score of appearance of Type-I, Type-II and Type-III multigrain pomegranate peel powder biscuits were in the range of 8.10 to 6.30, 7.50 to 6.40 and 7.20 to 6.35, respectively which fell in the category of 'Liked very much' to 'Liked slightly' during 90 days of storage.

**Aroma**

The aroma score of biscuits made from wheat flour, Type-I, Type-II and Type-III supplemented biscuits decreased from zero day (8.40) to 90$^{th}$ day (6.45), zero day (8.20) to 90$^{th}$ day (6.20), zero day (7.70) to 90$^{th}$ day (6.50) and zero day (7.40) to 90$^{th}$ day (6.50), respectively during storage period. The mean score of aroma of control and Type-I biscuits lied in the category of 'Liked very much' to 'Liked slightly' from zero to 90 day. Mean score of aroma of Type-II and Type-III value added biscuits was found in the category of 'Liked very much' to 'Liked slightly' and 'Liked moderately' to 'Liked slightly' during 90 days of storage.

**Texture**

Mean score of texture of wheat flour (control) biscuits on zero day was 8.40 (liked very much), which was found to decrease as the storage time increased. Up to 90$^{th}$ days of storage, mean score of texture of wheat flour (control) biscuits fell in the category of 'Liked very much' (8.10) on zero day to 'Liked slightly' (6.10) on 90$^{th}$ day, respectively. Similarly, mean score of texture of Type-I, Type-II and Type-III multigrain pomegranate peel powder supplemented biscuits on zero day was 8.20 (Liked very much), 7.80 (Liked very much) and 7.40 (Liked moderately), respectively. Mean scores of texture of three types of supplemented biscuits also decreased with increase in the storage time till 90$^{th}$ day. Texture of all types of biscuits was acceptable up to 90 day.

**Table 4.20 Effect of storage on organoleptic characteristics of multi grain biscuits supplemented with pomegranate peel powder**

| Organoleptic characteristics | Storage period days | Biscuits | | | |
|---|---|---|---|---|---|
| | | Control | Type-I | Type-II | Type-III |
| | | **Colour** | | | |
| | 0 | 8.50±0.07 | 8.20±0.11 | 7.70±0.07 | 7.50±0.05 |
| | 15 | 8.10±0.04 | 7.90±0.12 | 7.60±0.08 | 7.20±0.07 |
| | 30 | 7.80±0.10 | 7.50±0.07 | 7.50±0.10 | 7.20±0.12 |
| | 45 | 7.70±0.08 | 7.40±0.10 | 7.40±0.12 | 7.10±0.09 |
| | 60 | 7.50±0.04 | 7.40±0.09 | 7.20±0.13 | 7.10±0.15 |
| | 75 | 7.20±0.04 | 7.30±0.13 | 7.00±0.14 | 7.00±0.06 |
| | 90 | 7.10±0.07 | 6.50±0.04 | 6.50±0.07 | 6.40±0.04 |
| **Mean** | | 7.70 | 7.47 | 7.27 | 7.07 |
| | | **Appearance** | | | |
| | 0 | 8.40±0.06 | 8.10±0.08 | 7.50±0.09 | 7.20±0.14 |
| | 15 | 7.80±0.05 | 7.70±0.04 | 7.40±0.13 | 7.20±0.11 |
| | 30 | 7.60±0.03 | 7.50±0.10 | 7.30±0.08 | 7.10±0.06 |
| | 45 | 7.50±0.07 | 7.40±0.10 | 7.20±0.11 | 7.10±0.15 |
| | 60 | 7.40±0.13 | 7.30±0.05 | 7.20±0.15 | 7.00±0.14 |
| | 75 | 7.30±0.10 | 7.10±0.13 | 7.10±0.07 | 6.90±0.07 |
| | 90 | 6.50±0.12 | 6.30±0.17 | 6.40±0.05 | 6.35±0.10 |
| **Mean** | | 7.54 | 7.38 | 7.21 | 7.02 |
| | | **Aroma** | | | |
| | 0 | 8.40±0.13 | 8.20±0.04 | 7.70±0.06 | 7.40±0.09 |
| | 15 | 7.70±0.07 | 7.60±0.08 | 7.50±0.12 | 7.30±0.13 |
| | 30 | 7.60±0.10 | 7.55±0.12 | 7.40±0.15 | 7.30±0.12 |
| | 45 | 7.50±0.15 | 7.45±0.10 | 7.40±0.09 | 7.20±0.11 |
| | 60 | 7.30±0.08 | 7.20±0.16 | 7.20±0.11 | 7.00±0.08 |
| | 75 | 7.10±0.08 | 7.10±0.06 | 7.00±0.08 | 6.80±0.05 |
| | 90 | 6.45±0.11 | 6.20±0.11 | 6.50±0.13 | 6.50±0.11 |
| **Mean** | | 7.48 | 7.4 | 7.24 | 7.07 |
| | | **Texture** | | | |
| | 0 | 8.40±0.05 | 8.20±0.09 | 7.80±0.04 | 7.40±0.10 |
| | 15 | 8.10±0.14 | 7.80±0.13 | 7.50±0.14 | 7.30±0.15 |
| | 30 | 7.60±0.09 | 7.60±0.06 | 7.40±0.05 | 7.30±0.07 |
| | 45 | 7.40±0.14 | 7.50±0.12 | 7.30±0.12 | 7.15±0.14 |
| | 60 | 7.40±0.16 | 7.40±0.10 | 7.20±0.07 | 7.00±0.13 |
| | 75 | 7.30±0.09 | 7.20±0.15 | 7.00±0.13 | 6.80±0.08 |
| | 90 | 6.10±0.12 | 6.10±0.05 | 6.20±0.10 | 6.30±0.12 |
| **Mean** | | 7.47 | 7.40 | 7.20 | 7.03 |
| | | **Taste** | | | |
| | 0 | 8.50±0.10 | 8.30±0.18 | 7.70±0.10 | 7.40±0.20 |
| | 15 | 7.80±0.22 | 7.90±0.26 | 7.50±0.28 | 7.30±0.32 |
| | 30 | 7.60±0.16 | 7.50±0.12 | 7.40±0.26 | 7.20±0.14 |
| | 45 | 7.40±0.26 | 7.40±0.26 | 7.30±0.26 | 7.00±0.12 |
| | 60 | 7.40±0.32 | 7.30±0.22 | 7.21±0.16 | 7.00±0.30 |
| | 75 | 7.25±0.18 | 7.20±0.30 | 6.80±0.30 | 6.90±0.18 |
| | 90 | 6.45±0.24 | 6.40±0.12 | 6.50±0.22 | 6.50±0.24 |
| **Mean** | | 7.50 | 7.42 | 7.20 | 7.07 |
| | | **Overall Acceptability** | | | |
| | 0 | 8.40±0.12 | 8.20±0.36 | 7.68±0.26 | 7.38±0.12 |
| | 15 | 7.90±0.24 | 7.78±0.30 | 7.50±0.14 | 7.26±0.24 |
| | 30 | 7.64±0.36 | 7.53±0.14 | 7.40±0.20 | 7.22±0.30 |
| | 45 | 7.50±0.14 | 7.43±0.12 | 7.32±0.30 | 7.11±0.18 |
| | 60 | 7.40±0.20 | 7.32±0.06 | 7.20±0.10 | 7.04±0.22 |
| | 75 | 7.23±0.28 | 7.18±0.24 | 6.98±0.16 | 6.88±0.16 |
| | 90 | 6.48±0.32 | 6.50±0.16 | 6.50±0.22 | 6.45±0.26 |
| **Mean** | | 7.53 | 7.41 | 7.22 | 7.05 |

**Taste**

Wheat flour biscuits (Control) got highest mean scores of taste (8.50) at zero day, which showed decreasing trend as (8.50 to 6.45) the storage time increased i.e $15^{th}$ to $90^{th}$ day. Type-I, Type-II and Type-III multigrain pomegranate peel powder supplemented biscuits mean scores of taste were in the range of 8.30 to 6.40 ('Liked very much' to 'Liked slightly'), 7.70 to 6.50 ('Liked very much' to 'Liked slightly') and 7.40 to 6.50 ('Liked moderately' to 'Liked slightly'), respectively.

**Overall acceptability**

The mean score of overall acceptability of control biscuits made from wheat flour and all the three types of multigrain pomegranate peel powder supplemented biscuits Type-I, Type-II and Type-III was 8.40 (Liked very much), 8.20 (Liked very much), 7.68 (Liked very much) and 7.38 (Liked moderately), respectively on zero day of storage which decreased on increasing the storage time i.e. 15, 30, 45, 60, 75 and 90 days. On 90 days of storage, mean scores of overall acceptability of all the three types of value added biscuits fell in the category of 'Liked slightly'.

## Cake-rusk

Results of all sensory characteristics (colour, appearance, aroma, texture, taste and overall acceptability) of multi grain cake-rusk supplemented with pomegranate peel powder is presented in Table 4.21.

**Colour**

Mean score for colour of cake-rusk made from 100 per cent refined flour (control) and all types of multigrain pomegranate peel powder cake-rusk was noted as 8.40, 8.20, 7.60 and 7.40, respectively on zero day of storage, which fell in the category of 'Liked very much' to 'Liked moderately'. These scores decreased with increase in storage interval i.e 15, 30, 45, 60, 75 and 90 days. However, up to 90 days, cake-rusk made from 100 per cent refined flour (control) and Type-I, Type-II and Type-III multigrain pomegranate peel powder cake-rusk scored 7.00, 6.50, 6.40 and 6.30, respectively which fell in the category of 'Liked moderately' to 'Liked slightly'.

**Appearance**

Mean score for appearance of cake-rusk made from 100 per cent refined flour (control) and all types of multigrain pomegranate peel powder cake-rusk was observed as 8.30, 8.00, 7.40 and 7.25, respectively on zero day of storage, which was found in the category of 'Liked very much' to 'Liked moderately'. A decreasing trend was noted in the appearance score of the cake-rusk during the storage time of $15^{th}$ day to $90^{th}$ day. The appearance score of control cake-rusk made from refined flour ranged from 8.30 to 6.30 up to $90^{th}$ days which fell in the category of 'Liked very much' to 'Liked slightly'. Similarly, mean score of appearance of Type-I, Type-II and Type-III multigrain pomegranate peel powder cake-rusk were in the range of 8.00 to 6.50, 7.40 to 6.40 and 7.25 to 6.40, respectively and fell in the category of 'Liked very much' to 'Liked slightly'.

**Table 4.21 Effect of storage on organoleptic characteristics of multi grain cake-rusk supplemented with pomegranate peel powder**

| Organoleptic characteristics | Storage period days | Cake-rusk | | | |
|---|---|---|---|---|---|
| | | Control | Type-I | Type-II | Type-III |
| | | **Colour** | | | |
| | 0 | 8.40±0.12 | 8.20±0.18 | 7.60±0.14 | 7.40±0.20 |
| | 15 | 8.00±0.08 | 7.80±0.14 | 7.50±0.24 | 7.20±0.20 |
| | 30 | 7.70±0.12 | 7.40±0.16 | 7.40±0.16 | 7.10±0.16 |
| | 45 | 7.60±0.14 | 7.30±0.16 | 7.30±0.22 | 7.10±0.22 |
| | 60 | 7.40±0.16 | 7.30±0.20 | 7.10±0.16 | 7.00±0.14 |
| | 75 | 7.10±0.18 | 7.20±0.20 | 7.00±0.20 | 7.00±0.20 |
| | 90 | 7.00±0.20 | 6.50±0.26 | 6.40±0.14 | 6.30±0.26 |
| **Mean** | | 7.6 | 7.38 | 7.18 | 7.01 |
| | | **Appearance** | | | |
| | 0 | 8.30±0.26 | 8.00±0.14 | 7.40±0.16 | 7.25±0.18 |
| | 15 | 7.70±0.20 | 7.60±0.20 | 7.30±0.22 | 7.20±0.20 |
| | 30 | 7.50±0.14 | 7.55±0.22 | 7.20±0.18 | 7.10±0.24 |
| | 45 | 7.40±0.16 | 7.40±0.22 | 7.20±0.22 | 7.10±0.20 |
| | 60 | 7.30±0.22 | 7.30±0.22 | 7.10±0.18 | 7.00±0.24 |
| | 75 | 7.20±0.22 | 7.10±0.24 | 7.10±0.24 | 6.80±0.26 |
| | 90 | 6.30±0.20 | 6.50±0.26 | 6.40±0.20 | 6.30±0.16 |
| **Mean** | | 7.44 | 7.35 | 7.14 | 7.02 |
| | | **Aroma** | | | |
| | 0 | 8.30±0.18 | 8.10±0.22 | 7.60±0.20 | 7.40±0.10 |
| | 15 | 7.60±0.22 | 7.50±0.24 | 7.50±0.24 | 7.30±0.22 |
| | 30 | 7.60±0.16 | 7.50±0.20 | 7.40±0.18 | 7.20±0.23 |
| | 45 | 7.50±0.16 | 7.35±0.20 | 7.30±0.22 | 7.10±0.18 |
| | 60 | 7.30±0.15 | 7.20±0.22 | 7.20±0.23 | 7.00±0.16 |
| | 75 | 7.10±0.71 | 7.10±0.22 | 7.00±0.20 | 6.80±0.20 |
| | 90 | 6.40±0.20 | 6.30±0.20 | 6.45±0.16 | 6.50±0.21 |
| **Mean** | | 7.44 | 7.34 | 7.23 | 7.04 |
| | | **Texture** | | | |
| | 0 | 8.30±0.26 | 8.20±0.28 | 7.70±0.22 | 7.40±0.22 |
| | 15 | 8.10±0.24 | 7.70±0.24 | 7.50±0.23 | 7.30±0.20 |
| | 30 | 7.50±0.20 | 7.50±0.24 | 7.40±0.24 | 7.25±0.18 |
| | 45 | 7.40±0.20 | 7.50±0.20 | 7.20±0.22 | 7.15±0.14 |
| | 60 | 7.30±0.22 | 7.40±0.20 | 7.20±0.26 | 7.00±0.14 |
| | 75 | 7.30±0.21 | 7.20±0.22 | 7.00±0.24 | 6.70±0.20 |
| | 90 | 6.10±0.22 | 6.00±0.23 | 6.10±0.20 | 6.30±0.21 |
| **Mean** | | 7.43 | 7.36 | 7.16 | 7.01 |
| | | **Taste** | | | |
| | 0 | 8.40±0.22 | 8.30±0.28 | 7.60±0.08 | 7.40±0.17 |
| | 15 | 7.70±0.22 | 7.80±0.20 | 7.40±0.18 | 7.25±0.16 |
| | 30 | 7.60±0.18 | 7.50±0.22 | 7.40±0.22 | 7.20±0.17 |
| | 45 | 7.40±0.20 | 7.40±0.22 | 7.30±0.18 | 7.00±0.18 |
| | 60 | 7.40±0.22 | 7.30±0.21 | 7.21±0.20 | 7.00±0.16 |
| | 75 | 7.25±0.18 | 7.20±0.24 | 6.70±0.22 | 6.80±0.20 |
| | 90 | 6.50±0.24 | 6.30±0.28 | 6.40±0.24 | 6.50±0.20 |
| **Mean** | | 7.46 | 7.40 | 7.14 | 7.05 |
| | | **Overall Acceptability** | | | |
| | 0 | 8.34±0.18 | 8.16±0.16 | 7.58±0.16 | 7.37±0.20 |
| | 15 | 7.82±0.22 | 7.68±0.20 | 7.44±0.17 | 7.25±0.24 |
| | 30 | 7.58±0.18 | 7.49±0.26 | 7.36±0.12 | 7.17±0.22 |
| | 45 | 7.46±0.16 | 7.39±0.26 | 7.26±0.14 | 7.09±0.26 |
| | 60 | 7.34±0.16 | 7.30±0.24 | 7.14±0.16 | 7.00±0.20 |
| | 75 | 7.19±0.39 | 7.16±0.22 | 6.96±0.18 | 6.82±0.24 |
| | 90 | 6.40±0.22 | 6.38±0.22 | 6.44±0.18 | 6.50±0.16 |
| **Mean** | | 7.48 | 7.37 | 7.17 | 7.03 |

**Aroma**

The aroma score of cake-rusk made from refined flour, Type-I, Type-II and Type-III multigrain pomegranate peel powder decreased from zero day (8.30) to 90$^{th}$ day (6.40), zero day (8.10) to 90$^{th}$ day (6.30), zero day (7.60) to 90$^{th}$ day (6.45) and zero day (7.40) to 90$^{th}$ day (6.50), respectively during storage period. The mean score of aroma of control and Type-I cake-rusk lied in the category of 'Liked very much' to 'Liked slightly' from zero to 90 days. Likewise, mean score of aroma of Type-II and Type-III value added cake-rusk fell in the category of 'Liked very much' to Liked slightly' and 'Liked moderately' to 'Liked slightly' during 90 days of storage.

**Texture**

Mean score of texture of refined flour (control) cake-rusk on zero day was 8.30 (liked very much), which decreased as the storage time increased. Up to 90$^{th}$ day of storage, mean score of texture of refined flour (control) cake-rusk fell in the category of 'Liked very much' (8.10) to 'Liked slightly' (6.10), respectively. Similarly, mean score of texture of Type-I, Type-II and Type-III multigrain pomegranate peel powder supplemented cake-rusk on zero day was obtained as 8.20 (Liked very much), 7.70 (Liked very much) and 7.40 (Liked moderately), respectively. Mean scores of texture of three types of supplemented cake-rusk decreased (6.00 to 6.30) with increase in the storage time till 90$^{th}$ day. Texture of all types of cake-rusk was acceptable up to 90 days.

**Taste**

Wheat flour cake-rusk (Control) got highest mean scores of taste (8.40) at zero day, which showed decreasing trend (from 8.40 to 6.50) as the storage time increased i.e 15$^{th}$ to 90$^{th}$ day. Type-I, Type-II and Type-III multigrain pomegranate peel powder supplemented cake-rusk scored mean scores of taste in the range of 8.30 to 6.30 ('Liked very much' to 'Liked slightly'), 7.60 to 6.40 ('Liked very much' to 'Liked slightly') and 7.40 to 6.50 ('Liked moderately' to 'Liked slightly'), respectively.

**Overall acceptability**

The mean score of overall acceptability of control cake-rusk made from refined flour and all the three types of multigrain pomegranate peel powder supplemented cake-rusk Type-I, Type-II and Type-III was 8.34 (Liked very much), 8.16 (Liked very much), 7.58 (Liked very much) and 7.37 (Liked moderately) on zero day of storage which decreased on increasing the storage time *i.e.* 15, 30, 45, 60, 75 and 90 days. On 90 days of storage, mean scores of overall acceptability of all the three types of value added cake-rusk fell in the category of 'liked slightly'.

## CHAPTER-V

# DISCUSSION

This chapter presents the discussions regarding the findings of the present study. The relevant discussions have been presented under the following headings:

5.1 Physicochemical and nutritional properties of wheat grains, chickpea grains, pearl millet grains, wheat flour, chickpea flour, pearl millet flour and pomegranate peel powder

5.2 Development and organoleptic acceptability of baked products (biscuits and cake-rusk) utilizing wheat, chickpea and pearl millet flour blends and pomegranate peel powder

5.3 Nutritional composition of baked products

5.4 Shelf life studies of baked products

## 5.1 Physicochemical and nutritional properties of wheat grains, chickpea grains, pearl millet grains, wheat flour, chickpea flour, pearl millet flour and pomegranate peel powder

The physical properties of wheat variety C-306 indicated that the colour of wheat grain variety was light golden yellow. Similar report for colour of different wheat varieties were reported by other researchers (Tharshini 2016; Pandey 2015; Rakhi 2013). Grain hardness of wheat was 6.28 Kg/grain. The results of the present study authenticated with those of other workers (Tharshini 2016; Pandey 2015; Rakhi 2013) who also reported that grain hardness of wheat varieties ranged from 5.42 to 8.13 and 6.20 to 7.40Kg/grain, respectively. Thousand kernel weight of wheat C-306 was 44.39 g. Panghal *et al.* (2019) and Tharshini (2016) also analysed and reported that thousand kernel weight of different wheat grain varieties ranged from 29.6 to 53.8g. However, Pandey (2015) revealed slightly greater values for thousand kernel weight of wheat varieties i.e 41.44 to 45.46 g. Boz *et al.* (2012) reported the slightly lower values of thousand kernel weight of five wheat varieties and values ranged from 35.06 to 38.24g. Thousand kernel weight which can be used to determine the potential flour yield in wheat grain, are accepted as the main quality factors by the milling industry (Mut *et al.* 2010). The colour of grain of pearl millet variety (86-M-86) was dark grey. Similar observations for colour of different pearl millet varities were reported by Govindaraj *et al.* (2018). Grain hardness of pearl millet was 2.63 Kg/grain. The findings of the present study corroborated with those of Laminu *et al.* (2016) who also revealed that grain hardness of pearl millet variety was 3.00Kg/grain. Badau *et al.* (2007) also reported that thousand kernel weight of pearl millet was 10.81g. Khatak *et al.* (2018) and Kumari *et al.* (2018) also reported that thousand kernel weight of pearl millet varieties ranged from 7.86 to 13.47g and 6.75 to 12.97g. The findings of the present study corroborated with those of Keshavrao (2017) and Laminu *et al.* (2016) who also reported that thousand kernel weight of pearl millet varities ranged from 9.90 to 10.30g. The colour of chickpea grain variety was dark brown. Similar observations for colour of different chickpea varities were reported by Sastry *et al.* (2019) and Segev *et al.* (2010). Thousand kernel weight of chickpea grains was 158.79g. Sastry *et al.* (2019) and Tikle and Mishra (2018) reported that thousand kernel weight of different chickpea varieties ranged from 81 to 367g and 256 to 382.6g, respectively. The variations in physical properties of different grain varieties could be due to differences in their nutritional composition; differences in agro-climatic zones of production, genetic variations, harvesting time or differences in processing techniques.

The colour of wheat flour was creamish white while that of chickpea flour, pearl millet flour and pomegranate peel powder was pale yellow, light greyish and brown, respectively. Similar findings were reported by Tharshini (2016) and Kushwaha *et al.* (2013) that pomegranate peel powder was light brown in colour.

The water absorption capacity is the ability of a moist material to retain water when subjected to an external centrifugal gravity force or compression. It consists of the sum of bound water, hydrodynamic water and, mainly, physicaly trapped water (Vazquez- Ovando *et al*. 2009). It is an important property of dietary fibre from both a physiological and technological point of view. Dietary fibre holds water by adsorption and absorption phenomena and some water is also retained outside the fibre matrix (free water) (Sanchez-Zapata *et al*. 2009). Water absorption capacity of wheat flour, chickpea flour, pearl millet flour and pomegranate peel powder was 1.32, 0.92, 1.52 and 3.28 g/g, respectively. Slightly higher values for water absorption capacity of wheat flour were reported by other workers (Kumar *et al.* 2017; Tharshini 2016; Chandra *et al.* 2015). The findings of the present study are supported by those of Arab *et al.* (2010). The water absorption capacity of chickpea flour was 1.32g/g. Similar results were reported for water absorption capacity of chickpea flour by other workers (Rao 2018; Jagannadham *et al.* 2014; Xu *et al.* 2013; Arab *et al.* 2010). Water absorption capacity of pearl millet flour was 1.52g/g. Khatak *et al.* (2018) reported the higher values of the water absorption capacity of different varieties of pearl millet flour i.e 1.53 to 1.70g/g. Akinola *et al.* (2017) reported the higher values of water absorption capacity of pearl millet flour. Hasnaoui *et al.* (2014) reported that water holding capacity of pomegranate peel ranged between 2.31 and 3.53 ml/g. The pomegranate peel powder had highest water absorption capacity (3.28g/g) followed by that of pearl millet, wheat and chickpea flour. It may be due to differences in their chemical composition, hydrophilic properties and presence of polar groups i.e amino, carboxyl, hydroxyl and sulfhydryl. Pomegranate peels are rich in polar compounds, such as carbohydrates and fiber. Sedimentation value of wheat flour and pomegranate peel powder were 35.43 and 12.51 ml, respectively. Similar observations were reported by Pandey (2015) for wheat flour (38.67-30.33 ml).

Gluten content is a direct indicator of flour strength and determines the suitability of flour for making good quality bakery products. Gluten is the exclusive property of wheat flour. Wheat flour contained 26.45 and 7.72 per cent of wet and dry gluten, respectively. Panghal *et al.* (2019) and Chaudhary (2011) reported that wet and dry gluten contents in wheat flour ranged from 22 to 36 per cent and 7.5 to 14.62 per cent, respectively.

The oil absorption capacity is a technological property related to the chemical structure of the plant polysaccharides and depends on surface properties, overall charge density, thickness and hydrophobic nature of the fibre particle (Figuerola *et al*. 2005; Fernandez-Lopez *et al*. 2009). Oil absorption capacity of wheat, chickpea, pearl millet flours and pomegranate peel powder was 1.27, 1.02, 1.15 and 2.62g/g, respectively. Similar results were also reported by Rao (2018) and Samta (2018) for the oil absorption capacity of wheat flour. The findings of the present study are supported by that of Rao (2018) that the oil absorption capacity of chickpea was 0.78g/g. Jogihalli *et al.* (2017) also concluded that the oil absorption capacity of chickpea flour was 1.25g/g. Similar results were also reported by Jagannadhan et al (2014); Xu *et al.* (2013); Arab *et al.* (2010) that the oil absorption capacity of chickpea flour was 0.81g/g, 1.07 to 1.26ml/g and 1.10g/g and their results are in close agreement with the present results. Obadina *et al.* (2017) reported that the oil absorption capacity of pearl millet flour was 0.33ml/g.

Gelation capacity of wheat, chickpea and pearl millet flour was 10.22, 9.58 and 8.72g/100ml, respectively. Rao (2018) reported gelation capacity for wheat and chickpea flour to be 9.00 and 8.50 g/100ml, respectively. Kumar *et al.* (2017) and Chandra *et al.* (2015) reported similar values for the gelation capacity of wheat flour. Khatak *et al.* (2018) reported that gelation capacity of different pearl millet varieties ranged from 8.00 to 12.5 per cent. It was reported that lower the least gelation capacity, the better the gelating ability of the protein ingredient (Akintayo *et al.* 1999) and the swelling ability of the flour was enhanced (Kaushal *et al.* 2012). Swelling power of wheat flour, chickpea flour, pearl millet flour and pomegranate peel powder was 7.28, 6.53, 8.23 and 5.58g/g, respectively while bulk density of these flours were 0.79, 0.63, 0.61 and 0.54g/ml, respectively. The findings of the present study lended support to those of Rao (2018) who also reported that swelling power and bulk density of wheat and chickpea flour was 7.85 and 5.28g/g and 0.64 and 0.68g/ml, respectively. Obadina *et al.* (2017) reported that swelling power of pearl millet flour was 2.55 per cent. Akinola *et al.* (2017) also reported that the swelling power and bulk density of pearl millet flour was 1.12g/ml and 4.47g/g, respectively.

The bulk density depends upon the particle size and initial moisture content of flours. The high bulk densities of flour suggested their suitability for use in food preparations. On contrast, low bulk density would be an advantage in the formulation of complementary foods (Akpata and Akubor 1999).

Moisture content of wheat, chickpea, pearl millet flours and pomegranate peel powder was 10.21, 9.35, 8.61 and 7.28 percent, respectively. Tharshni (2016) also reported that the moisture content of wheat flour was 10.62 per cent and Pandey (2015) reported that wheat varieties had moisture content ranging from 10.60 to 11.75 per cent. Punia *et al.* (2017) assessed the different wheat varieties and concluded that the moisture content ranged from 7.79 to 9.45 per cent. Rao (2018) and Samta (2018) reported that the moisture content of wheat varieties were slightly lower than the present study *i.e.* 9.89 and 9.45 per cent, respectively. Rao (2018) supported the present study and found that the moisture content of chickpea was 8.90 per cent. Jagannadham (2014) studied the moisture content of chickpea flour and reported it to be 9.35 per cent which was slightly higher than the present study. Kumari *et al.* (2018) observed that moisture content of pearl millet flour was 9.86 per cent. Results of the present study corroborated with those of Tanvi (2018) and Rani (2017) who concluded that the moisture content of different pearl millet varieties ranged from 7.73 to 8.56 per cent and 7.27 to 8.61 per cent, respectively. Srivastava *et al.* (2014) reported 4.0 per cent moisture content in pomegranate peel powder whereas Ismail *et al.* (2014) reported that moisture content in pomegranate peel powder was 9.34 per cent.

The crude protein content of wheat flour, chickpea flour, pearl millet flour and pomegranate peel powder was 12.60, 21.71, 11.16 and 3.42 percent, respectively. The results of the present study have been supported by those of Panghal *et al.* (2019) who explored the protein content of different wheat varieties and found in range of 9.7 to 15 per cent whereas Punia *et al.* (2017) revealed that the protein content of different wheat cultivars ranged from 9.03 to 12.33 per cent. Results of the present study corroborated with those of Samta (2018) and Rao (2018) who also reported similar values for protein content (13.72 and 12.03 per cent, respectively) in wheat flour. The crude protein content of chickpea was 20.25 per cent (Rao 2018). Similar findings were reported by Jagannadham *et al.* (2014) that crude protein content in chickpea was 21.7 per cent. The crude protein content of chickpea were reported towards higher side by Arab *et al.* (2010) and Maheri-Sis *et al.* (2008) i.e 24.63 and 22.76 per cent, respectively compared to the present study. Similar findings regarding the crude protein of pearl millet were reported by Tanvi (2018) who studied different varieties of pearl millet and observed that protein content ranged from 11.76 to 10.61 per cent. Kumari *et al.* (2018) assessed the protein content of different varieties of pearl millet and found it in the range of 11.14 to 13.22 per cent whereas Obadina *et al.* (2017) reported lower values of crude protein in pearl millet i.e 7.52 per cent.

The crude fiber content of wheat flour was 1.74 per cent, chick pea flour was 3.29 percent, pearl millet was 2.05 per cent and that of pomegranate peel powder was 13.71 percent. Similar findings for the crude fibre content of wheat flour were reported by Tharshini (2016) and Arab *et al.* (2010) i.e 1.83 and 1.85 per cent, respectively. Rao (2018); Samta

(2018) and Punia *et al*. (2017) found that the crude fibre of wheat flour was 1.62, 1.58 and 0.79 to 0.93 per cent which were slightly lower than the present study. The findings of the present study regarding fibre content in chickpea flour were lower as well as higher compared to those of other workers who reported 1.85 per cent (Arab *et al.* 2010), 1.60 (Rao 2018) and 6.49 to 9.94 per cent (Maheri-Sis *et al.* 2008) crude fibre. Kumari *et al.* (2018) and Tanvi (2018) supported the present study and concluded that the crude fibre of pearl millet ranged from 1.25 to 2.19 per cent and 1.92 to 2.33 per cent, respectively. The crude fibre of pearl millet was 1.08 to 1.67 per cent by Rani (2017). The findings in the present study corroborated with those of Shabtay *et al.* (2008) who also reported 14.2 per cent crude fibre in pomegranate peel powder. On the contrary Ullah *et al.* (2012) reported somewhat higher value (21 per cent) of crude fiber in pomegranate peel powder.

Ash content of wheat flour, chickpea flour, pearl millet and pomegranate peel powder were 2.15, 2.80, 2.27 and 4.98 per cent, respectively. The value of ash in wheat flour in present investigation was higher than that reported by earlier investigators (Samta 2018; Punia *et al.* 2017; Rao 2018). These variations could be due to differences in varieties , differences in sowing conditions, crop maturity at harvesting time, differences in processing treatments, etc. Saharan (2017) supported the present study and reported that the ash content of wheat flour was 2.90 per cent. Rao (2018) also reported that the ash content of chickpea flour was 2.25 per cent. Jaganndham *et al.* (2018) and Arab *et al.* (2010) reported that the ash content of wheat flour was 3.46 and 3.30 per cent, respectively which were higher than the values of present investigation. Kumari *et al.* (2018) assessed and found that ash content of different varieties of pearl millet ranged from 0.86 to 1.92 per cent whereas Rani (2017) found that the ash content of pearl millet ranged from 1.67 to 1.87 per cent. Tanvi (2018) also supported the present investigation and found that the ash content of two pearl millet varieties ranged from 2.04 to 2.69 per cent. The value of ash content of pomegranate peel powder in present study corroborated with those of several other investigators (Topkaya & Isik 2018; Shreenidhi & Kalpna 2016; Tharshini 2016; Taher-Maddah *et al.* 2012; Ullah *et al.* 2012).

Fat content of wheat flour, chickpea flour, pearl millet flour and pomegranate peel powder were 2.37, 4.40, 5.48 and 2.78 per cent, respectively. Rao (2018), Samta (2018) and Punia *et al.* (2017) supported the present study and reported that the fat content of wheat flour was 2.56, 2.00 and 2.62 to 3.48 per cent, respectively which were slightly higher than the present study. The fat content of chickpea flour was reported 4.98 per cent by Rao (2018) which supported the results of present study whereas Jaganndham *et al.* (2014) reported a higher fat content of chickpea flour than the present study. Kumari *et al.* (2018) and Tanvi (2018) supported the present study and concluded that the fat content of pearl millet ranged from 4.02 to 5.74 and 5.59 to 6.29 per cent, respectively. Tharshini (2016) reported 3.76 per cent fat content in pomegranate peel powder which was slightly higher than that found in the present study. Essa and Mohamed (2018) and Thorat *et al.* (2018) reported the lower fat content of pomegranate peel powder i.e 1.43 and 1.73 per cent, respectively compared to that of the present study.

Total dietary fibre content in wheat flour, chickpea flour, pearl millet flour and pomegranate peel powder was 10.92, 13.43, 11.51 and 28.42 per cent, respectively. Soluble dietary fibre content was 3.60, 5.22, 2.41 and 13.11 per cent in wheat, chickpea flour, pearl millet flour and pomegranate peel powder, respectively while insoluble dietary fibre content was 7.32, 8.21, 9.10 and 15.31 per cent, respectively in wheat flour, chickpea flour, pearl millet flour and pomegranate peel powder. The findings of the present study are in agreement with those of Tharshini (2016); Saharn (2017); Samta (2018). The results of the present study also corroborated with those of Topkaya & Isik (2018) and Essa & Mohamed (2018) who also reported that pomegranate peel powder contained total dietary fibre content 43.49 and 56.22 g/100g, respectively.

*In- vitro* starch digestibility of wheat, chickpea, pearl millet and pomegranate peel powder was 36.82, 38.47, 23.24 and 24.52 mg maltose released/g meal, respectively while i*n-vitro* protein digestibility of wheat, chickpea, pearl millet and pomegranate peel powder was 62.31, 67.63, 61.14 and 51.29 per cent, respectively. Similar values for starch digestibility in wheat flours have been reported by earlier investigators ( Rakhi 2013; Parmar 2014; Pandey 2015). Tanvi (2018) and Johari (2017) also lended support to the present study with regard to the starch and protein digestibility of pearl millet flour. The low digestibility of pomegranate peel powder is often attributed to the presence of anti-nutritional factors such as trypsin inhibitors, tannins, haemaglutinins and phytic acid (Tharshini 2016).

Wheat flour contained 44.21, 320.30, 3.80, 3.43 and 142.00 mg/100g of calcium, phosphorus, iron, zinc and magnesium, respectively while chickpea flour contained 81.70, 252.00, 5.50, 3.37 and 160.00 mg/100g of calcium, phosphorus, iron, zinc and magnesium, respectively, pearl millet flour contained 66.72, 289.00, 8.62, 2.77 and 125.00 mg/100g of calcium, phosphorus, iron, zinc and magnesium, respectively. Tanvi (2018) and Rani (2017) also reported similar values for mineral content in pearl millet flour. The results of the present study are also supported by those of earlier worker, Pandey (2015) who reported that wheat flour contained 54.40 to 55.45 mg/100g calcium, 354.67 to 497.33 mg/100g phosphorus, 4.98 to 5.46 mg/100g iron, 2.29 to 3.43 mg/100g zinc and 142.50 to 156.33 mg/100g magnesium. Similarly Tharshini (2016) also reported 43.33 mg/100g calcium, 323.96 mg/100g phosphorus, 4.05 mg/100g iron, 3.22 mg/100g zinc and 120.34 mg/100g magnesium in wheat flour. The pomegranate peel powder contained 72.30, 57.23, 5.60, 0.48 and 149.56 mg/100g of calcium, phosphorus, iron, zinc and magnesium, respectively. Tharshini (2016) also analysed and found that the pomegranate peel powder contained 66.67, 2.22, 156.00, 0.31 and 5.64 mg/100g of calcium, iron, magnesium, zinc and phosphorus, respectively. The findings of the present investigation are comparable to those reported by other workers (Ullah *et al.* 2012; Kushwaha *et al.* 2013; Ismail *et al.* 2014). Minor deviations reported in the mineral contents of flour and pomegranate peel powder in present study and that of several other investigators could be attributed to differences in varieties (newly released), agro-climatic conditions and differences in uptake of nutrients by crop from soil and further translocation of the grains (Marles, 2017). Arab *et al.* (2010) and Wang *et al.* (2010) reported similar values of mineral content of chickpea flour as in the present study.

Total Antioxidant activity *viz.*, total phenols, total flavonoids, radical scavenging activity of wheat flour was 86.90 mgGAE/100g, 55.72 mgRE/100g and 51.70 mgTE/100g, respectively while that of pearl millet flour was 120.95 mgGAE/100g, 89.87 mgRE/100g and 25.15 mgTE/100g, respectively. Vinita (2018) supported the present investigation that the total phenolic content of cereals ranged from 30.07 to 119.94 mgGAE/100g whereas Sreeramulu *et al*. (2009) reported that it ranged from 47.64 to 133.63 mgGAE/100g. Ragaee *et al.* (2006) concluded that the values of total phenolic content in cereals ranged from 50.00 to 412 mgGAE/100g which were towards higher side. The content of total flavonoid found in cereals in present study are supported by results of other workers i.e 17.74 to 88.88 mgRE/100g (Vinita 2018), 10.57 to 118.90 mgRE/100g (Thummakomma & Meda 2017) and 11 to 75 mgRE/100g (Ivanisova *et al.* 2012). The result of present study regarding the radical scavenging activity are in close agreement with those of other workers i.e 23.11 to 89.29mgTE/100g (Vinita 2018) and 24 to 139 mgTE/100g (Sreeramulu *et al.* 2009). Total Antioxidant activity *viz.*, total polyphenol, total flavonoids and radical scavenging activity of chickpea flour was 50.13 mgGAE/100g, 22.17 mgRE/100g and 48.35 mgTE/100g, respectively. Results of Vinita (2018) supported the present investigation that the total phenolic content of pulses flour ranged from 33.09 to 99.57 mgGAE/100g whereas Sreeramulu *et al*. (2009) reported that it ranged from 62.35 to 418 mgGAE/100g. The results of present study are in agreement with those of other workers namely, Thummakoma & Meda (2017); Karthiga & Jaganathan (2013) and Kaur & Sadana (2013). Similar values for the content of total flavonoid in pulses were also reported by the other workers i.e 21.16 to 65.73 mgRE/100g (Vinita 2018), 49.02 to 108.13 mgRE/100g (Thummakomma & Meda 2017) and 29 to 167 mg/100g (Renuka & Thakur 2014). Similarly radical scavenging activity was found in the range of 21.08 to 107.14, 23.97 to 45.23 and 26 to 107 mgTE/100g by Vinita (2018), Thummakomma & Meda (2017) and Sreeramulu *et al.* (2009), respectively. The phenolic, flavonoids and radical scavenging activity of pomegranate peel powder was 864.73 mgGAE/100g, 1372 mgRE/100g and 96.92 mgTE/100g. The present study was supported by Tharshini (2016) who also reported total phenols as 854.85 mgGAE/100g.

## 5.2 Development and organoleptic acceptability of baked products (biscuits and cake-rusk) utilizing wheat, chickpea and pearl millet flour blends and pomegranate peel powder

Baked products i.e biscuits and cake-rusk were prepared from wheat, chickpea, pearl millet flour blends and pomegranate peel powder. Chickpea and pearl millet flour ratio was kept constant (i.e 15 per cent each) while wheat flour was substituted by pomegranate peel powder at 6, 8, 10 and 12 per cent levels in biscuits and cake-rusk .

The mean score of overall acceptability of the 100 per cent wheat flour biscuits was 8.40 which fell in the category of 'Liked very much' whereas that of chickpea, pearl millet flour blends and pomegranate peel powder supplemented biscuits varied from 8.20 (Liked very much) to 5.35 (Neither liked nor disliked). Similarly Topkaya & Isik (2018), Tharshini (2016), Srivastva *et al.* (2014), Ismail *et al.* (2014) and Mehder (2013) also reported that pomegranate peel supplementation resulted in reduction in organoleptic acceptability scores of muffins, nankhtai, biscuits, cookies and pan bread compared to control, but all the products were acceptable.

The mean score of overall acceptability of the control cake-rusk was 8.34 which fell in the category of 'Liked very much'. The overall acceptability scores of value added cake-rusk at 64:15:15:6, 62:15:15:8, 60:15:15:10 and 58:15:15:12 levels fell in the category of 'Liked very much' to 'Neither liked nor disliked'. The results of the present study are in agreement with those of Topkaya & Isik (2018), Tharshini (2016), Srivastva *et al.* (2014), Ismail *et al.* (2014) and Mehder (2013) who also reported that increase in the level of incorporation of pomegranate peel powder caused reduction in the sensory characteristics of the value added products. However, Vaijapurkar *et al.* (2014) reported that value added biscuits prepared from wheat flour, pearl millet flour and 3 per cent pomegranate peel powder were more acceptable compared to control.

## 5.3 Nutritional composition of baked products

### Proximate composition

The protein content of Type-I biscuits was significantly ($P \leq 0.05$) higher than that of wheat flour (control) biscuits. Similarly protein content of Type-II and Type-III biscuits was significantly ($P \leq 0.05$) higher than that of control biscuits. Protein content of Type-III biscuits was significantly lower than that of Type-I and Type-II. Fat content of Type-I, Type- II and Type-III biscuits were significantly ($P \leq 0.05$) higher than that of 100 per cent control biscuits. A non-significant ($P \leq 0.05$) difference was observed in fat content of Type-I and Type-II multigrain pomegranate peel powder biscuits. The crude fibre and ash contents in wheat flour biscuits were 1.08 and 1.81 per cent, respectively which significantly ($P \leq 0.05$) increased on supplementation with chickpea flour (15%), pearl millet flour (15%) and increase in level of supplementation with pomegranate peel powder (from 6 to 10 per cent). The proximate composition of Type-I, Type- II and Type-III biscuits was superior than that of control biscuits. Value added cake-rusk was also found to possess higher proximate composition as compared to control cake-rusk. This increase may be due to higher contents of fat, crude fibre and ash content in chickpea flour, pearl millet flour and pomegranate peel powder and also higher content of protein in chickpea flour. As the level of substitution of wheat flour with pomegranate peel powder increased fat, crude fibre and ash contents of Type-I, Type-II and Type-III value added baked products also improved. However the protein content of value added products reduced in Type-I to Type-III with the increase of pomegranate peel powder addition due to lower protein content in pomegranate peel powder compared to other flours. The protein content of Type-I cake-rusk and biscuits were significantly ($P \leq 0.05$) higher than that of Type-II and Type-III. These results are in agreement with those of earlier workers (Essa & Mohamed 2018; Topkaya and Isik 2018; Tharshini 2016; Ismail *et al.* 2014; Srivastva *et al.* 2014), who found that proximate composition of multi grain products supplemented with pomegranate peel powder were higher than that of control products developed from one type of grain flour.

**Dietary fibre**

Total, soluble and insoluble dietary fibre contents of all types of supplemented biscuits were higher than that of wheat flour biscuits which was taken as control and this increase was due to incorporation of chickpea and pearl millet flour at 15 per cent level and also addition of pomegranate peel powder (6 to 10%). Similarly total, soluble and insoluble dietary fibre contents of control cake-rusk made from 100 per cent refined flour was significantly ($P \leq 0.05$) lower than that of multi grain pomegranate peel powder supplemented cake-rusk. As the level of incorporation with pomegranate peel powder raised from 6 to 10 per cent in cake-rusk there was a significant ($P \leq 0.05$) increase in total and soluble dietary fibre contents. The total, soluble and insoluble dietary fibre contents were found maximum in Type-III bakery products. The results of present investigation are in close agreement with those of Essa & Mohamed (2018), Topkaya & Isik (2018); Tharshini (2016). The differences in dietary fibre contents of different types of value added baked products were due to differences in level of supplementation with pomegranate peel powder while chickpea flour and pearl millet flour were kept constant at 15 per cent level.

**Total minerals**

Total mineral contents of all type of value added biscuits were significantly ($P \leq 0.05$) higher than that of wheat flour biscuits due to addition of chickpea flour, pearl millet flour and pomegranate peel powder. . However, as the level of pomegranate peel powder increased from 6 to 10 per cent in Type-I, Type-II and Type-III biscuits a decreasing pattern was observed in phosphorus and zinc contents of multigrain biscuits compared to Type-I. Similarly multigrain pomegranate peel powder supplemented cake-rusk had significantly

(P≤0.05) higher total mineral content than control cake-rusk (100 % refined flour). There was a significant (P≤0.05) increase in the calcium and iron content of all types of value added bakery products. There was a significant (P≤0.05) decrease in the phosphorus and zinc content of Type-I, Type-II and Type-III multigrain pomegranate peel powder supplemented cake-rusk as the level of supplementation with pomegranate peel powder increased from 6 to 10 per cent. Similar findings were also reported by other investigators (Topkaya & Isik 2018; Tharshini 2016; Srivastava 2014; Rana 2015; Pandey & Sangwan 2016a; Pandey & Sangwan 2016c) that value added products possessed higher mineral contents compared to control. The increase in mineral contents of value added baked products might be due to high content of calcium, magnesium and iron in chickpea and pearl millet flour as compared to cereal flour and pomegranate peel powder.

***In vitro* digestibility**

The starch and protein digestibility of control biscuits was 49.67 mg maltose released/g meal and 69.08 per cent, respectively and these values were significantly (P≤0.05) higher than that of all types of multigrain pomegranate peel powder supplemented biscuits. The *in vitro* protein digestibility of Type-I and Type-II biscuits was significantly (P≤0.05) higher than that of Type-III biscuits however a non-significant difference was found in the values of Type-I and Type-II biscuits. A significant (P≤0.05) decrease was observed in the *in vitro* starch digestibility of Type-I, Type-II and Type-III multigrain pomegranate peel powder biscuits with the increase in level of supplementation with pomegranate peel powder. Similarly the *in vitro* starch and protein digestibility of control cake-rusk was significantly (P≤0.05) higher than that of all types of value added cake-rusk. There was a significant (p≤0.05) decrease in the starch digestibility of Type-I, Type-II and Type-III cake-rusks from 50.04 to 49.21 mg maltose released/g meal as the level of substitution with pomegranate peel powder increased from 6 to 10 per cent. A significant (p≤0.05) decrease was also observed in the protein digestibility of value added cake-rusks from 72.04 to 70.51 per cent. The differences in the starch and protein digestibility of control and value added baked products might be due to differences in the starch, protein and antinutrient contents of raw flour and pomegranate peel powder used for product development. Moreover the biological utilization of protein is primarily dependent on its digestibility. The results of present investigation corroborated with those of (Tharshini 2016; Hooda 2002; Sangwan 2002; Pandey 2015).

**Total anti-oxidant activity**

Polyphenol, flavonoids and radical scavenging activity of all types of multigrain pomegranate peel powder biscuits and cake-rusk were significantly (P≤0.05) higher than that of 100 per cent wheat flour biscuits and 100 per cent refined flour cake-rusk. As the level of subsituition with pomegranate peel powder increased in Type-I, Type-II and Type-III biscuits and cake rusk from 6 to 10 per cent while chickpea (15%) and pearl millet (15%) content was kept constant a significant ($P \leq 0.05$) increase was observed in the level of total polyphenols, flavonoids and radical scavenging activity of multigrain pomegranate peel powder biscuits and cake-rusk. The differences in the total anti-oxidant activity of control and value added baked products were due to higher contents of anti-oxidants present in pomegranate peel powder. The results of present study are in agreement with those of other workers (Essa & Mohamed 2018; Topkaya & Isik 2018; Ismail *et al.* 2016; Paul & Bhattacharyya 2015).

**Shelf life studies of baked products**

Biscuits and cak-rusk prepared from wheat, chickpea flour, pearl millet flour blends and pomegranate peel powder in ratio of 64:15:15:6, 62:15:15:8 and 60:15:15:10 and control products prepared from 100 per cent wheat flour and refined flour were stored in air tight plastic bag at room temperature. It was found that all types of cake-rusk and biscuits were organoleptically acceptable upto 90 days of storage. The values for their organoleptic scores fell in the category of 'Liked very much' to 'Liked slightly'. These findings were supported by those of other researchers (Ismail *et al.* 2016; Tharshini 2016; Sangwan & Dahiya 2013; Chandel 2014; Rana 2015; Pandey 2015) who reported that the value added products developed from different composite flours could be stored upto 90 days.

# CHAPTER-VI

## SUMMARY AND CONCLUSIONS

The present study delineates information pertaining to the physic-chemical evaluation of wheat variety (C-306), chickpea (HC-5), pearl millet (86-M-86) and pomegranate peel powder and development, nutritional evaluation and shelf life study of biscuits and cake-rusk prepared from wheat, chickpea and pearl millet flour and pomegranate peel powder.

The physical properties of wheat variety C-306 indicated that the colour of wheat grain variety was light golden yellow. Grain hardness of wheat was 6.28 Kg/grain. Thousand kernel weight of wheat C-306 was 44.39 g. The colour of grain of pearl millet variety (86-M-86) was dark grey. Grain hardness of pearl millet was 2.63 Kg/grain. The colour of chickpea grain variety was dark brown. The colour of wheat flour was creamish white while that of chickpea flour, pearl millet flour and pomegranate peel powder was pale yellow, light greyish and cocoa brown, respectively. Water absorption capacity of wheat flour, chickpea flour, pearl millet flour and pomegranate peel powder was 1.32, 0.92, 1.52 and 3.28 g/g, respectively. The water absorption capacity of chickpea flour was 1.32g/g. Water absorption capacity of pearl millet flour was 1.52g/g. The pomegranate peel powder had highest water absorption capacity (3.28g/g) followed by that of pearl millet, wheat and chickpea flour. Sedimentation value of wheat flour and pomegranate peel powder were 35.43 and 12.51 ml, respectively. Wheat flour contained 26.45 and 7.72 per cent of wet and dry gluten, respectively. Oil absorption capacity of wheat, chickpea, pearl millet flours and pomegranate peel powder was 1.27, 1.02, 1.15 and 2.62g/g, respectively. Gelation capacity of wheat, chickpea and pearl millet flour was 10.22, 9.58 and 8.72g/100ml, respectively. Swelling power of wheat flour, chickpea flour, pearl millet flour and pomegranate peel powder was 7.28, 6.53, 8.23 and 5.58g/g, respectively while bulk density of these flours were 0.79, 0.63, 0.61 and 0.54g/ml, respectively.

Moisture content of wheat, chickpea, pearl millet flours and pomegranate peel powder was 10.21, 9.35, 8.61 and 7.28 percent, respectively. The crude protein content of wheat flour, chickpea flour, pearl millet flour and pomegranate peel powder was 12.60, 21.71, 11.16 and 3.42 percent, respectively. The crude fiber content of wheat flour was 1.74 per cent, chick pea flour was 3.29 percent, pearl millet was 2.05 per cent and that of pomegranate peel powder was 13.71 percent. Ash content of wheat flour, chickpea flour, pearl millet and pomegranate peel powder were 2.15, 2.80, 2.27 and 4.98 per cent, respectively. Fat content of wheat flour, chickpea flour, pearl millet flour and pomegranate peel powder were 2.37, 4.40, 5.48 and 2.78 per cent, respectively.

Total dietary fibre content in wheat flour, chickpea flour, pearl millet flour and pomegranate peel powder was 10.92, 13.43, 11.51 and 28.42 per cent, respectively. Soluble dietary fibre content was 3.60, 5.22, 2.41 and 13.11 per cent in wheat, chickpea flour, pearl millet flour and pomegranate peel powder, respectively while insoluble dietary fibre content was 7.32, 8.21, 9.10 and 15.31 per cent, respectively in wheat flour, chickpea flour, pearl millet flour and pomegranate peel powder.

*In- vitro* starch digestibility of wheat, chickpea, pearl millet and pomegranate peel powder was 36.82, 38.47, 23.24 and 24.52 mg maltose released/g meal, respectively while i*n-vitro* protein digestibility of wheat, chickpea, pearl millet and pomegranate peel powder was 62.31, 67.63, 61.14 and 51.29 per cent, respectively.

Wheat flour contained 44.21, 320.30, 3.80, 3.43 and 142.00 mg/100g of calcium, phosphorus, iron, zinc and magnesium, respectively while chickpea flour contained 81.70, 252.00, 5.50, 3.37 and 160.00 mg/100g of calcium, phosphorus, iron, zinc and magnesium, respectively, pearl millet flour contained 66.72, 289.00, 8.62, 2.77 and 125.00 mg/100g of calcium, phosphorus, iron, zinc and magnesium, respectively. The pomegranate peel powder contained 72.30, 57.23, 5.60, 0.48 and 149.56 mg/100g of calcium, phosphorus, iron, zinc and magnesium, respectively.

Total Antioxidant activity *viz.*, total phenols, total flavonoids, radical scavenging activity of wheat flour was 86.90 mgGAE/100g, 55.72 mgRE/100g and 51.70 mgTE/100g, respectively while that of pearl millet flour was 120.95 mgGAE/100g, 89.87 mgRE/100g and 25.15 mgTE/100g, respectively. Total Antioxidant activity *viz.*, total phenols, total flavonoids and radical scavenging activity of chickpea flour was 50.13 mgGAE/100g, 22.17 mgRE/100g and 48.35 mgTE/100g, respectively. The phenolic, flavonoids and radical scavenging activity of pomegranate peel powder was 864.73 mgGAE/100g, 1372 mgRE/100g and 96.92 mgTE/100g.

Baked products i.e biscuits and cake-rusk were prepared from wheat, chickpea, pearl millet flour blends and pomegranate peel powder. Chickpea and pearl millet flour ratio was kept constant (i.e 15 per cent each) while wheat flour was substituted by pomegranate peel powder at 6, 8, 10 and 12 per cent levels in biscuits and cake-rusk. The mean score of overall acceptability of the 100 per cent wheat flour biscuits was 8.40 which fell in the category of ‘Liked very much’ whereas that of chickpea, pearl millet flour blends and pomegranate peel powder supplemented biscuits varied from 8.20 (Liked very much) to 5.35 (Neither liked nor disliked). The mean score of overall acceptability of the control cake-rusk was 8.34 which fell in the category of ‘Liked very much’. The overall acceptability scores of value added cake-rusk at 64:15:15:6, 62:15:15:8, 60:15:15:10 and 58:15:15:12 levels fell in the category of ‘Liked very much’ to ‘Neither liked nor disliked’.

The protein content of Type-I biscuits was significantly (P≤0.05) higher than that of wheat flour (control) biscuits. Similarly protein content of Type-II and Type-III biscuits was significantly (P≤0.05) higher than that of control biscuits. Protein content of Type-III biscuits was significantly lower than that of Type-I and Type-II. Fat content of Type-I, Type- II and Type-III biscuits were significantly (P≤0.05) higher than that of 100 per cent control biscuits. A non-significant (P≤0.05) difference was observed in fat content of Type-I and Type-II multigrain pomegranate peel powder biscuits. The crude fibre and ash contents in wheat flour biscuits were 1.08 and 1.81 per cent, respectively which significantly (P≤0.05) increased on supplementation with chickpea flour (15%), pearl millet flour (15%) and increase in level of supplementation with pomegranate peel powder (from 6 to 10 per cent). The proximate composition of Type-I, Type- II and Type-III biscuits was superior than that of control biscuits. Value added cake-rusk was also found to possess higher proximate composition as compared to control cake-rusk. As the level of substitution of wheat flour with pomegranate peel powder increased fat, crude fibre and ash contents of Type-I, Type-II and Type-III value added baked products also improved. However the protein content of value added products reduced in Type-I to Type-III with the increase of pomegranate peel powder. The protein content of Type-I cake-rusk and biscuits were significantly (P≤0.05) higher than that of Type-II and Type-III.

Total, soluble and insoluble dietary fibre contents of all types of supplemented biscuits were higher than that of wheat flour biscuits which was taken as control and this increase was due to incorporation of chickpea and pearl millet flour at 15 per cent level and also addition of pomegranate peel powder (6 to 10%). Similarly total, soluble and insoluble dietary fibre contents of control cake-rusk made from 100 per cent refined flour was significantly (P≤0.05) lower than that of multi grain pomegranate peel powder supplemented cake-rusk. As the level of incorporation with pomegranate peel powder raised from 6 to 10 per cent in cake-rusk there was a significant (P≤0.05) increase in total and soluble dietary fibre contents. The total, soluble and insoluble dietary fibre contents were found maximum in Type-III bakery products.

Total mineral contents of all type of value added biscuits were significantly (P≤0.05) higher than that of wheat flour biscuits due to addition of chickpea flour, pearl millet flour and pomegranate peel powder. . However, as the level of pomegranate peel powder increased from 6 to 10 per cent in Type-I, Type-II and Type-III biscuits a decreasing pattern was observed in phosphorus and zinc contents of multigrain biscuits compared to Type-I. Similarly multigrain pomegranate peel powder supplemented cake-rusk had significantly (P≤0.05) higher total mineral content than control cake-rusk (100 % refined flour). There was a significant (P≤0.05) increase in the calcium and iron content of all types of value added bakery products. There was a significant (P≤0.05) decrease in the phosphorus and zinc content of Type-I, Type-II and Type-III multigrain pomegranate peel powder supplemented cake-rusk as the level of supplementation with pomegranate peel powder increased from 6 to 10 per cent.

The starch and protein digestibility of control biscuits was 49.67 mg maltose released/g meal and 69.08 per cent, respectively and these values were significantly ($P \leq 0.05$) higher than that of all types of multigrain pomegranate peel powder supplemented biscuits. The *in vitro* protein digestibility of Type-I and Type-II biscuits was significantly ($P \leq 0.05$) higher than that of Type-III biscuits however a non-significant difference was found in the values of Type-I and Type-II biscuits. A significant ($P \leq 0.05$) decrease was observed in the *in vitro* starch digestibility of Type-I, Type-II and Type-III multigrain pomegranate peel powder biscuits with the increase in level of supplementation with pomegranate peel powder. Similarly the *in vitro* starch and protein digestibility of control cake-rusk was significantly ($P \leq 0.05$) higher than that of all types of value added cake-rusk. There was a significant ($p \leq 0.05$) decrease in the starch digestibility of Type-I, Type-II and Type-III cake-rusks from 50.04 to 49.21 mg maltose released/g meal as the level of substitution with pomegranate peel powder increased from 6 to 10 per cent. A significant ($p \leq 0.05$) decrease was also observed in the protein digestibility of value added cake-rusks from 72.04 to 70.51 per cent.

Total phenols, flavonoids and radical scavenging activity of all types of multigrain pomegranate peel powder biscuits and cake-rusk were significantly ($P \leq 0.05$) higher than that of 100 per cent wheat flour biscuits and 100 per cent refined flour cake-rusk. As the level of substitution with pomegranate peel powder increased in Type-I, Type-II and Type-III biscuits and cake rusk from 6 to 10 per cent while chickpea (15%) and pearl millet (15%) content was kept constant a significant ($P \leq 0.05$) increase was observed in the level of total polyphenols, flavonoids and radical scavenging activity of multigrain pomegranate peel powder biscuits and cake-rusk. The differences in the total anti-oxidant activity of control and value added baked products were due to higher contents of anti-oxidants present in pomegranate peel powder.

Biscuits and cake-rusk prepared from wheat, chickpea flour, pearl millet flour blends and pomegranate peel powder in ratio of 64:15:15:6, 62:15:15:8 and 60:15:15:10 and control products prepared from 100 per cent wheat flour and refined flour were stored in air tight plastic bag at room temperature. It was found that all types of cake-rusk and biscuits were organoleptically acceptable upto 90 days of storage. The values for their organoleptic scores fell in the category of 'Liked very much' to 'Liked slightly'.

From the present study it may be concluded that organoleptically acceptable value added baked products namely biscuits and cake-rusk could be developed from multigrain flour and pomegranate peel powder. Hence, it is recommended that value added products developed from wheat, chickpea and pearl millet flour and pomegranate peel powder which are rich in protein, minerals and dietary fibre should be commercialized and promoted so that malnutrition and hidden hunger among the population can be eradicated. Development and consumption of such products also can help in improving the nutritional status of growing children. Further, products enriched in pomegranate peel powder can be exploited to provide health benefits especially in prevention of cardiovascular diseases, cancer, type-II diabetes, inflammation, etc. The outcome of the present research will definitely provide benefits to the industry in devising strategies for delivery of protein, mineral and fibre rich baked products in the market and common households. Also, it will help in proper utilization of pomegranate peel which would otherwise be discarded by the industries.

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## 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 | : | **Development and Nutritional Evaluation of Multi Grain Bakery Products Supplemented with Pomegranate Peel Powder** |
| 2. Full name of the degree holder | : | **Neha** |
| 3. Admission No. | : | 2017HS16M |
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| 7. Year of award of degree | : | 2019 |
| 8. Major subject | : | Foods and Nutrition |
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| 10. Number of words in the abstract | : | 483 |

***Keywords:*** Wheat, chickpea, pearl millet, physico-chemical, pomegranate peel powder, value added products, organoleptic acceptability, nutritional composition, shelf life

The present study describe information pertaining to the physico-chemical properties of wheat variety (C-306), chickpea (HC-5), pearl millet (86-M-86) and pomegranate peel powder and development, nutritional evaluation and shelf life study of biscuits and cake-rusk prepared using wheat, chickpea and pearl millet flour blend and pomegranate peel powder. The grain hardness and 1000 kernel weight of wheat variety (C-306) were 6.28 Kg/grain and 44.39g, respectively while that of chickpea and pearl millet grain was 18.65 and 2.63Kg/grain and 158.79 and 10.81 g, respectively. Water absorption capacity and sedimentation value of wheat flour were 1.32 g/g and 35.43 ml, respectively. Wheat flour had 26.45 and 7.72 per cent of wet and dry gluten, respectively. Oil absorption capacity was found highest in pomegranate peel powder and lowest in chickpea flour. Wheat flour showed highest amount of gelation capacity and bulk density while that of pomegranate peel powder was lowest. Pearl millet flour had maximum and pomegranate peel powder had minimum swelling power. Among various flour and pomegranate peel powder, chickpea flour possessed maximum crude protein, pearl millet contained maximum fat while pomegranate peel powder had highest content of ash and crude fibre. Pomegranate peel powder possessed higher fat content compared to wheat flour. Total, soluble and insoluble dietary fibre contents of pomegranate peel powder were found highest. Among all the flours, chickpea flour contained maximum content of calcium and magnesium. Wheat flour possessed highest phosphorus and zinc content. Pearl millet flour contained maximum iron content as compared to other flours. However, pomegranate peel powder possessed higher calcium, iron and magnesium contents than wheat flour. *In- vitro* protein and starch digestibility of chickpea flour was observed maximum while minimum was observed in pomegranate peel powder compared to other flours. Pearl millet flour possessed highest amount of total phenols and total flavonoids contents and wheat flour possessed maximum radical scavenging activity compared to other flours. Total phenols, total flavonoids and radical scavenging activity of pomegranate peel powder was observed highest. Value added baked products like cake-rusk and biscuits were prepared from wheat, chickpea, pearl millet flour blends and pomegranate peel powder. Chickpea and pearl millet flour ratio was kept constant (15%) while wheat flour was substituted by pomegranate peel powder at 6, 8, 10 and 12 per cent levels in cake-rusk and biscuits. Baked products containing 6, 8 and 10 per cent pomegranate peel powder were organoleptically acceptable and their scores fell in the category ‘Liked very much’ to ‘Liked moderately’. The value added products had significantly higher protein, crude fibre, mineral content and antioxidant activity than control. The sensory scores for biscuits and cake-rusk decreased gradually during storage period however biscuits and cake-rusk were found to be organoleptically acceptable up to 90 days, respectively. From the present study it is concluded that all the multi grain pomegranate peel powder supplemented products were found to have better nutritive value than control.

**(MAJOR ADVISOR)** **(SIGNATURE OF THE STUDENT)**

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- First prize in Volleyball game 19 Nov. to 20 Nov. (2014)
- Second prize in Basketball game 28 Sep. to 1 Oct. (2015)

**NEHA**

## UNDERTAKING OF THE COPY RIGHT

"I **Neha,** Admn. No. **2017HS16M** undertake that I give copy right to the CCS HAU, Hisar of my thesis entitled **"Development and Nutritional Evaluation of Multi Grain Bakery Products Supplemented with Pomegranate Peel Powder".**

I also undertake that, patent, if any, arising out of the research work conducted during the program shall be filed by me only with due permission of the competent authority of CCS HAU, Hisar.

**Signature of student**