CHAPTER-5

Cereal-legume milling by-products based snack products formulation

"Nourishment is not just "nutrition." Nourishment is the nutrients in the food, the taste, the aroma, the ambiance of the room, the conversation at the table, the love and inspiration in the cooking, and the joy of the entire eating experience."

Marc David

5.1. Introduction:

Plant-based products are nowadays becoming more popular than other conventional foods due to their health beneficial aspects (Helkar *et al.,* 2016). Professionals are also becoming reliant upon the plant-origins to find out potent future food sources. Due to lack of proper scientific knowledge and a gap of communication between common people and experts, plenty of nutrient-rich sources remain untapped. Besides cereals and legume grains, presence of higher amount of fibre in the by-products of these grains can make them eligible potential food source for enhanced digestion (Zeng & Lazarova, 2014). Our present interest is to utilize legume (chickpea and moong bean) by-products as functional food sources along with the cereal (rice and wheat) by-products to understand their contribution towards food formulation.

Among most consumed snack foods, snack bar is quite popular worldwide among all age groups (Suhem *et al.,* 2015). Roasted product viz., *papad* and traditional dairy-based confectionery product viz., barfi are also known as popular snack options, especially in India. Most of the confectionery products available in market, are generally rich in calorie but low in protein and micronutrients. Therefore, the chickpea husk and moong bean husk were considered along with cereal by-products to develop nutrient-rich value added products.

In the following section, we will discuss about the nutrient composition of plant by-product-based formulated Snack bar (Bran Bar), Dairy-Based confectionery product (Gram Pak), and Roasted Product (*Papad*) was estimated along with the evaluation of sensory parameters and storage stability of the prepared products.

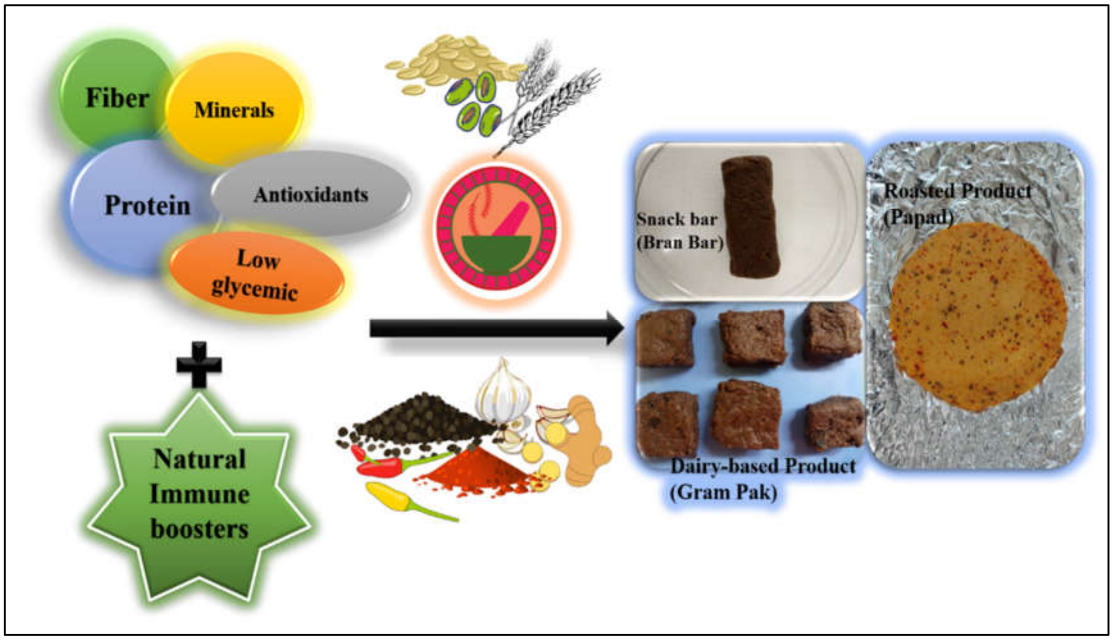

Figure 5. 1: Milling by-product based Nutrient dense value added products containing natural immune boosters

5.2. Processing of the selected milling by-products

Chickpea husk, broken rice, rice bran, and wheat bran were utilized to formulate Bran Bar and Gram Pak. The selected ingredients for *Papad* was chickpea husk, moong bean husk and broken rice. Physico-chemical composition of the raw ingredients had been discussed in Chapter 3. Further development of value added functional snack products using milling by-product flours and their characterization had been discussed.

5.3. Formulation of value added food products- Bran Bar, Gram Pak, *Papad*

Our main focus is to use the chickpea husk and moong bean husk in nutrient rich product formulation along with cereal by-products. Hence, Bran Bar and Gram Pak variants (BB0, GP0) without chickpea husk were considered as 'control' and for *Papad* variant (PD0) without moong bean husk was indicated as 'control'.

5.3.1. Bran Bar:

For the development of Bran Bar, at first by-product-flours were used to formulate composite flour according to different combinations (BB0, BB1, BB2, BB3, BB4) given in Table 5.1. The composite flour was roasted for a while on low flame (approximately 95ºC) in a heavy bottom pan for 10 minutes and kept in a glass bowl. 20g Ghee (Clarified butter) was melted first and added to the roasted flour followed by proper mixing to avoid lumps of flour and ghee. 10g Chopped raisins, 15g powdered jaggery, 5g cardamom powder, and 1ml vanilla essence were added to the mixture and mixed well. The glass bowl containing the mixture was kept in microwave oven and heated at 800 W for 2 minutes followed by proper mixing of the ingredients. This step was repeated until the ingredients started to bind. The whole process of the microwave cooking took 10-15 minutes. A thick layer of the mixture was spread over flat tray to cool down at room temperature (35±2ºC). Later the layer was cut at desired shape (18mm x 18mm x 10mm). The sample was stored at room temperature packed in a polyethylene bag for further analyses (**Figure 5.2**).

Ingredients	**BB0 (g) (Control)**	**BB1 (g)**	**BB2 (g)**	**BB3 (g)**	**BB4 (g)**
Rice bran	14.92 (28.33%)	13.75 (27.06%)	12.29 (24.22%)	7.99 (15.99%)	6.17 (11.64%)
Wheat bran	19.75 (37.50%)	16.47 (32.41%)	14.65 (28.87%)	11.04 (22.12%)	9.05 (17.07%)
Broken rice	18 (34.18%)	15.59 (30.68%)	12.04 (23.73%)	10.29 (20.60%)	8.65 (16.31%)
Chickpea husk	0.00 (0%)	5.01 (9.86%)	11.76 (23.18%)	20.62 (41.29%)	29.15 (54.98%)

Table 5. 1: Ingredient composition to formulate variants of Bran Bar (BB) (Percentage composition of formulated composite flour)

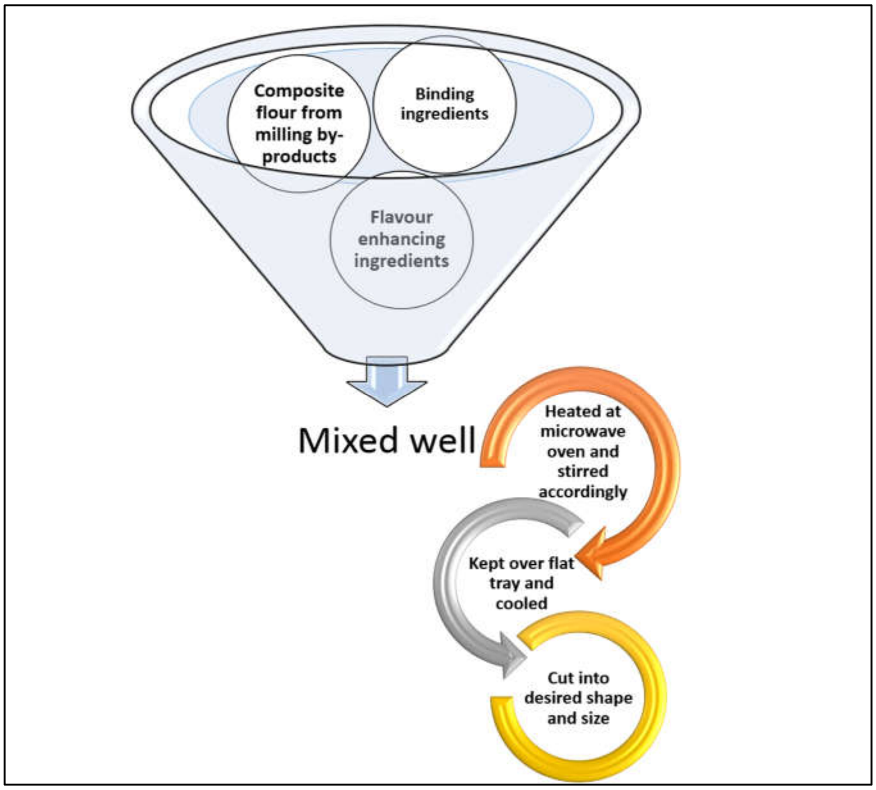

Figure 5. 2: Formulation procedure of Value added milling by-product based Bran Bar (BB)

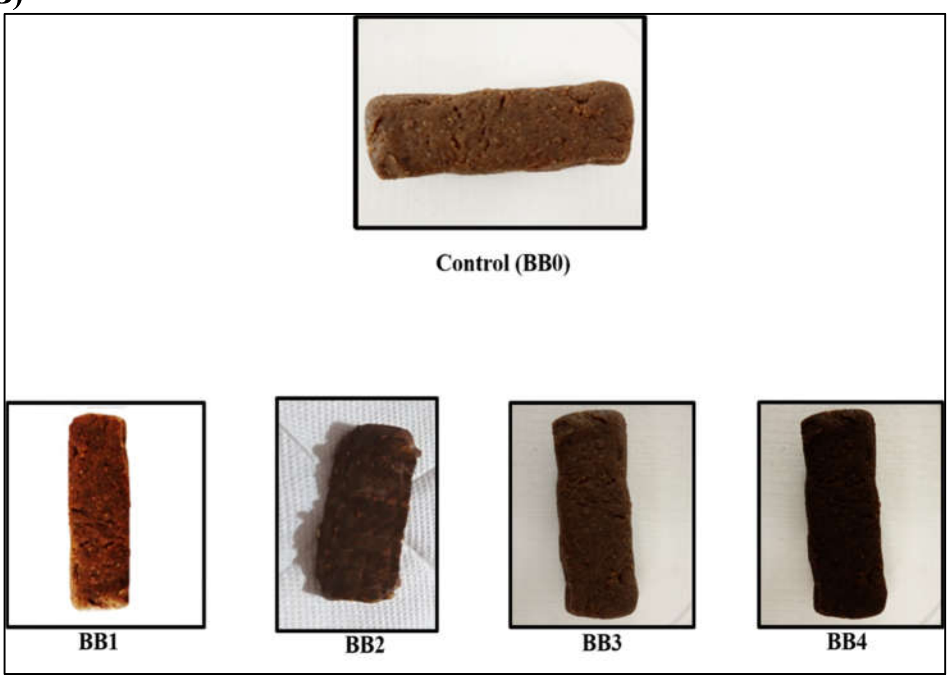

Figure 5. 3: Formulated Nutrient dense milling by-product based Bran Bar variants (BB0, BB1, BB2, BB3, BB4) comprising different percentages of milling by-products

5.3.2. Gram Pak (Dairy-based confectionary)

Milk was inoculated with yoghurt and developed acidity to 0.20% to prepare Lactic culture (Rekha *et al.,* 2017). This inoculated milk was mixed with composite flour following different combinations portrayed in the Table 5.2. A required amount of all purpose wheat flour was added to the mixture to get a perfect slurry. Ghee (shortening), jaggery, cardamom powder, and Choco powder were added as required according to the taste along with blanched Banana peel and mixed properly. The mixture was cooked at the highest power mode (800 W) in the microwave oven for 2min. and stirred for 1 min to get a consistency. This step was repeated until the ingredients started to bind (Figure 5.4). The mixture was placed over a greased tray and cooled down to room temperature to cut into desired shape and size.

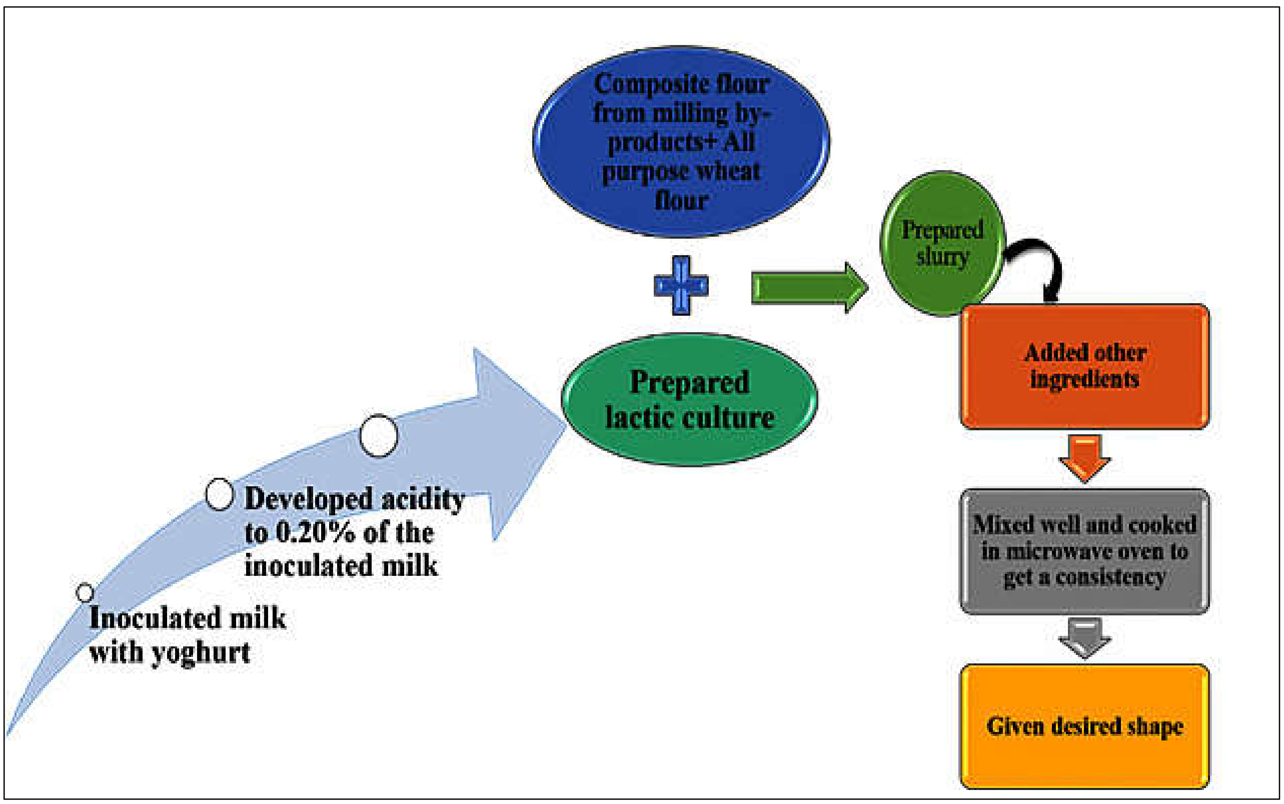

Figure 5. 4: Processing of milling by-products to formulate value added products Gram Pak (GP)

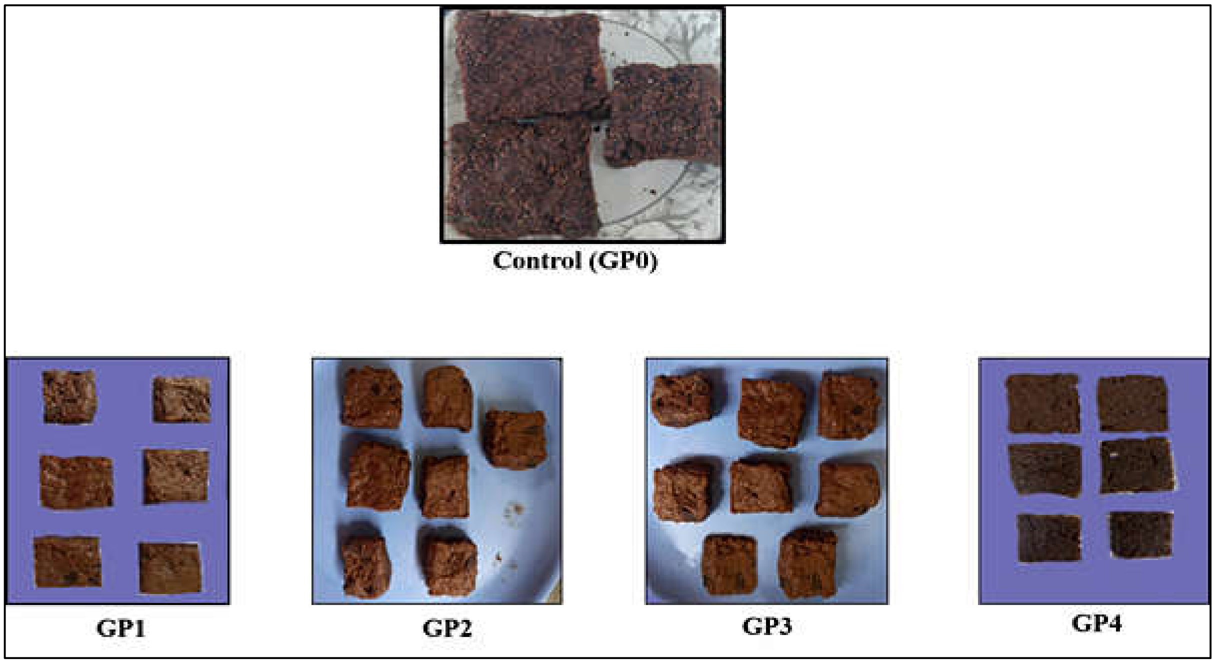

Figure 5. 5: Formulation of variants of Gram Pak (GP0, GP1, GP2, GP3, GP4) containing different percentages of milling by-products

Ingredients	GP0 (g) (Control)	GP1 (g)	GP2 (g)	GP3 (g)	GP4 (g)
Rice bran	18.22 (35.26%)	16.05 (31.98%)	14.19 (26.94%)	11.43 (21.97%)	8.07 (15.33%)
Broken rice	14.41 (27.88%)	12.80 (25.50%)	10.01 (19%)	8.06 (15.49%)	6.23 (11.84%)
Wheat bran	19.05 (36.86%)	15.16 (30.21%)	14.92 (28.32%)	10.89 (20.93%)	8.79 (16.70%)
Chickpea husk	0.00 (0%)	6.18 (12.31%)	13.56 (25.74%)	21.65 (41.61%)	29.54 (56.13%)

Table 5. 2: Ingredient composition to formulate variants of nutrient dense Gram Pak (GP)

5.3.3. *Papad* (Roasted Product)

Cumin, turmeric powder, chili powder, ginger, garlic, and salt were added as required according to the taste to the composite flour formulated according to different percentages given in the Table 5.3. Required amount of water was added and kneaded to form a dough. The dough was covered with muslin cloth and kept for 2 hrs. aside at room temperature

(35±2ºC). Later on, balls, made from the dough were shaped like tortillas (*Figure 5.6*) and kept in hot air oven at 60°C. These dried *papads* were cooled down and stored for shelf life evaluation. *Papad* can be consumed by roasting or deep frying. Papad was roasted in microwave oven for 1 min at the highest power and subjected for further analysis.

Ingredients	PD0 (g) (Control)	PD1 (g)	PD2 (g)	PD3 (g)	PD4 (g)
Chickpea husk	10.02 (27.07%)	8.75 (23.05%)	6.29 (15.17%)	4.23 (9.86%)	2.17 (4.68%)
Broken rice	27.00 (72.93%)	23.09 (60.83%)	22.12 (53.34%)	17.49 (40.77%)	14.59 (31.47%)
Moong husk	0.00 (0%)	6.12 (16.12%)	13.06 (31.49%)	21.18 (49.37%)	29.60 (63.85%)

Table 5. 3: Ingredient composition to formulate variants of value added product- *Papad* (PD)

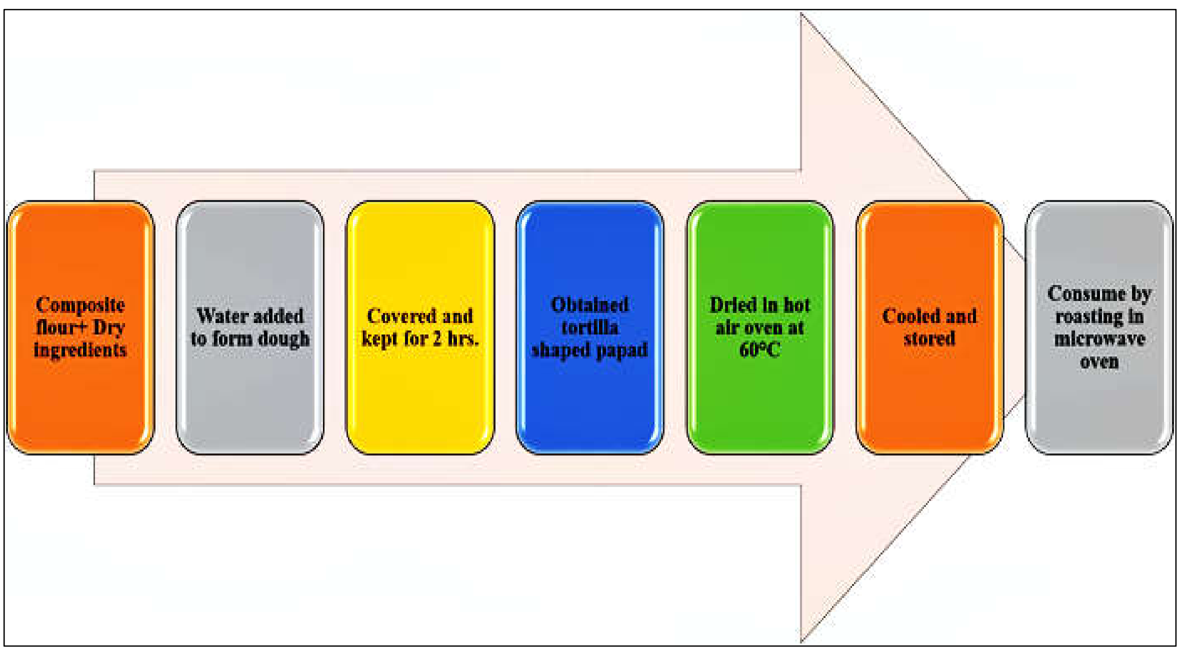

Figure 5. 6: Processing of milling by-products to develop nutrient rich product- *Papad* (PD)

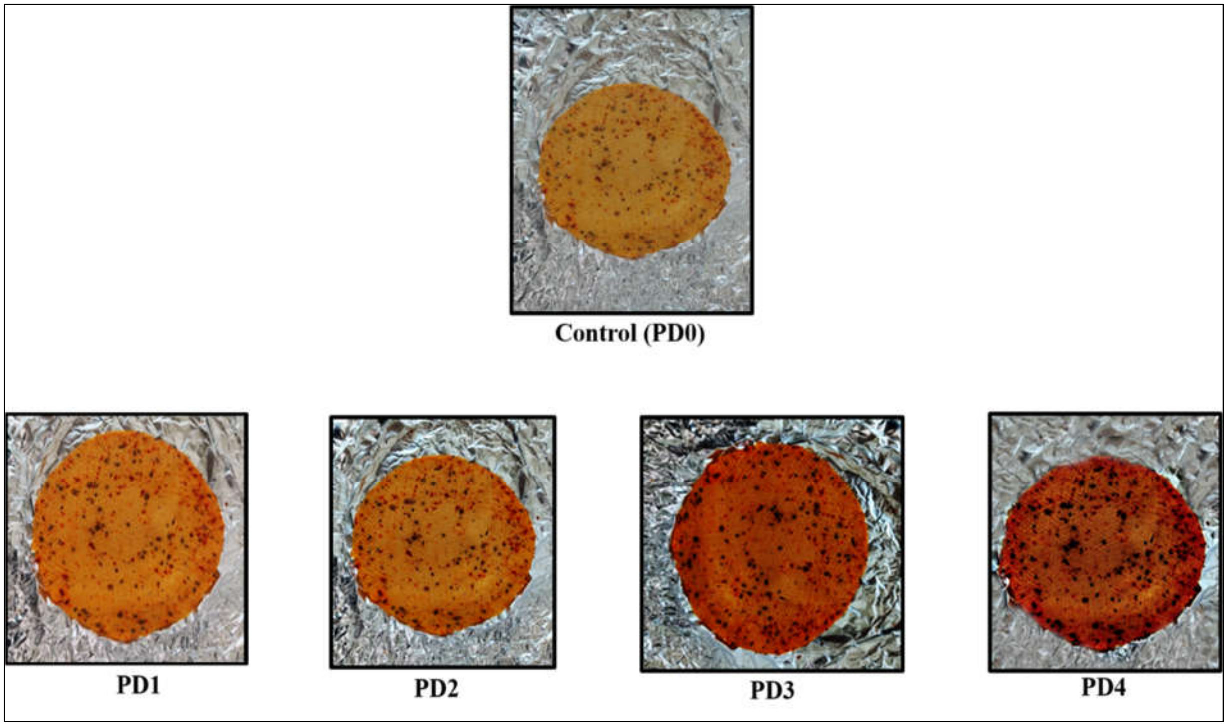

Figure 5. 7: Formulation of variants of *Papad* (PD0, PD1, PD2, PD3, PD4) using different composition percentages of milling by-products

5.4. Result and discussions

After the formulation of the value added products, we here analysed the sensory profiling and characterization of the products followed by the study of shelf life of product.

5.4.1. Detailed study of the nutritional attribute of the formulated products

5.4.1.1. Proximate compositions

Substitution with cereal bran and legume husk showed enhanced nutritional attributes of formulated Bran bar (BB), Gram Pak (GP), and *Papad* (PD) (Table 5.4). Enhanced protein level accompanied by a significant increase in fibre was observed with the increased percentage of legume husk in the composite flour formulation. Crude protein content in all the variants of the products ranged in between (18.05±0.72) % to (19.25±0.72) %. The moisture content of GP was bit higher, around 7%. BB exhibited moisture around 6%. But PD showed lesser moisture (4%).

Proximate composition	BB0	BB1	BB2	BB3	BB4
Moisture	6.21 ± 0.01^{c}	6.24 ± 0.08^{b}	6.29 ± 0.08^{b}	6.41 ± 0.09^{a}	6.71 ± 0.09^{a}
Crude protein	18.05 ± 0.72^{c}	18.14 ± 0.80^{b}	18.29 ± 0.91^{b}	18.41 ± 0.99^{a}	19.01 ± 0.99^{a}
Crude fat	4.64 ± 0.03^{c}	4.75 ± 0.03^{b}	4.78 ± 0.04^{b}	4.89 ± 0.06^{a}	5.01 ± 0.04^{b}
Crude fibre	3.46 ± 0.01^{c}	4.55 ± 0.05^{b}	4.81 ± 0.06^{b}	5.16 ± 0.11^{a}	5.37 ± 0.11^{a}
Ash	6.22 ± 0.09^{c}	6.61 ± 0.11^{b}	6.72 ± 0.12^{b}	6.85 ± 0.12^{a}	6.90 ± 0.12^{a}
Total carbohydrate	64.88 ± 2.01^{a}	64.26 ± 1.15^{b}	63.92 ± 2.11^{b}	63.44 ± 2.08^{c}	62.37 ± 0.09^{d}

Table 5. 4: Proximate composition of formulated Product- Bran Bar (BB) per 100g (%, dry matter basis) [Significantly different, *p* < 0.05 (Statistical analysis has been done row wise)]

Based upon moisture, it can be indicated that PD possess higher shelf life than BB and GP. Lesser carbohydrate level with an increased proportion of husk flour addition was also estimated. Developed products using milling by-products of cereal showed low carbohydrate in a study by Choi et al. (2015). Crude fat was less in the products (4% to 5%), lesser than the most of the products available in market. Choi et al. (2015) also found low fat in the products formulated from milling by-products. Instead of consumption of the junk foods available in the market, ingestion of such products might prevent the risk of various disorders.

Proximate composition	GP0	GP1	GP2	GP3	GP4
Moisture	7.34 ± 0.01^{c}	7.50 ± 0.08^{b}	7.69 ± 0.08^{b}	7.75 ± 0.09^{a}	7.81 ± 0.08^{b}
Crude protein	18.35 ± 0.72^{c}	18.54 ± 0.80^{b}	18.69 ± 0.91^{b}	18.81 ± 0.99^{a}	18.94 ± 0.80^{b}
Crude fat	5.34 ± 0.03^{c}	5.45 ± 0.03^{b}	5.53 ± 0.04^{b}	5.61 ± 0.06^{a}	5.72 ± 0.03^{b}
Crude fibre	3.56 ± 0.01^{c}	4.09 ± 0.05^{b}	4.21 ± 0.06^{b}	4.36 ± 0.11^{a}	4.49 ± 0.05^{b}
Ash	6.22 ± 0.09^{c}	6.46 ± 0.11^{b}	6.61 ± 0.12^{b}	6.72±0.12a	6.86 ± 0.11^{b}
Total carbohydrate	62.75 ± 2.11^{a}	62.05 ± 2.55^{b}	61.48 ± 2.61^{b}	61.11 ± 2.68^{c}	60.67 ± 2.55^{b}

Table 5. 5: Proximate composition of formulated Product- Gram Pak (GP) per 100g (%, dry matter basis) [Significantly different, *p* < 0.05 (Statistical analysis has been done row wise)]

Proximate composition	PD0	PD1	PD2	PD3	PD4
Moisture	4.24 ± 0.01^{c}	4.29 ± 0.08^{b}	4.37 ± 0.08^{b}	4.51 ± 0.09^{a}	4.55 ± 0.01^{c}
Crude protein	17.64 ± 0.72^{c}	18.75 ± 0.80^{b}	18.91 ± 0.91^{b}	19.11 ± 0.99^{a}	19.25 ± 0.72^{c}
Crude fat	4.64 ± 0.03^{c}	4.69 ± 0.03^{b}	4.75 ± 0.04^{b}	4.80 ± 0.06^{a}	4.87 ± 0.03^{c}
Crude fibre	4.26 ± 0.01^{c}	4.38 ± 0.05^{b}	4.66 ± 0.06^{b}	4.96 ± 0.11^{a}	5.27 ± 0.01^{c}
Ash	6.32 ± 0.09^{c}	6.61 ± 0.11^{b}	6.79 ± 0.12^{b}	6.87±0.12a	7.10 ± 0.09^{c}
Total carbohydrate	67.16 ± 2.11^{a}	65.66 ± 2.55^{b}	65.18 ± 2.61^{b}	64.71 ± 2.68^{c}	64.23 ± 2.11^{a}

Table 5. 6: Proximate composition of formulated Product- *Papad* (PD) per 100g (%, dry matter basis) [Significantly different, $p < 0.05$ (Statistical analysis has been done row wise)]

5.4.1.2. Sugar and starch

Although, BB0 and GP0 showed the higher total soluble sugar level, increasing percentage of legume husk in the variants exhibited decreasing sugar content (3.5 g/100 g). Same pattern was observed in case of reducing sugar present in the products. However, negligible alterations were recorded in the sugar level of different PD variants. All the products showed presence of starch in the range of 25-26 g/100 g (Table 5.5). Presence of broken rice in the formulation can be the reason of starch availability in the products (Virdi *et al.,* 2019).

5.4.1.3. Minerals

Ash (%) was significantly higher in BB, GP, and PD ranging from 6%-7%. Generally, market snack foods show lower ash content that is 1-2%. The ranges of iron (14-17 mg/100g), calcium (112-115 mg/100g), and phosphorus (185-195 mg/100g) level were found considerably higher in these variants. The improved proximate nutrients along with significant mineral availability (phosphorus, iron, calcium) (Table 5.7) of BB, GP, and PD can also point toward to the fact that formulated products using these selected by-products possess ample amount of essential micronutrients. Jaggery, moong bean husk, and rice bran (Sohail *et al.,* 2017) in the formulation is believed to be the major reason of improved iron availability in the products. Among all the products, the variants of PD showed higher mineral availability. Micronutrients are necessary factors for the functioning of living (Frossard *et al.,* 2000). These by-products-based formulated products in the current chapter could be a part of the preventive measures for the micronutrient deficiencies worldwide.

Nutrients	BB0	BB1	BB2	BB3	BB4
Non-Reducing sugar (g/100 g)	1.22±0.21[a]	1.11±0.23[b]	1.02±0.21[b]	0.93±0.19[c]	0.81±0.12[c]
Reducing sugar (g/100 g)	2.91±0.06[a]	2.88±0.05[b]	2.75±0.08[c]	2.69±0.01[d]	2.61±0.01[d]
Total soluble sugar (g/100 g)	4.13±0.02[a]	3.99±0.01[b]	3.77±0.05[b]	3.62±0.01[c]	3.42±0.01[c]
Starch (g/100 g)	25.12±0.01[d]	25.29±0.06[c]	25.90±0.05[b]	26.21±0.05[a]	26.33±0.05[a]
Iron (mg/100g)	14.06±0.07[c]	14.77±0.09[b]	14.89±0.08[b]	15.07±0.05[a]	15.27±0.09[b]
Calcium (mg/100g)	101.01±3.65[d]	112±4.23[c]	119.01±4.03[b]	120.86±4.36[a]	124.03±4.23[c]
Phosphorus (mg/100g)	180.65±0.11[c]	185.12±0.19[b]	191.08±0.20[b]	196.42±0.22[a]	198.62±0.19[b]
Trypsin inhibitor activity (TIU/mg)	1.02±1.99[d]	1.14±2.01[c]	1.25±2.01[b]	1.37±2.06[a]	1.42±2.01[b]
Phytic acid (mg/100 g)	211.03±0.09[d]	241.40±1.25[c]	253.01±1.32[b]	271.25±1.38[a]	299.01±0.09[d]
Total phenolic content (mg GAE/ g)	3.01±0.01[c]	3.29±0.01[b]	3.51±0.05[b]	3.64±0.05[a]	3.71±0.01[c]
DPPH Radical Scavenging Activity (%)	42.23±0.01[c]	45.04±0.02[b]	45.29±0.05[b]	46.02±0.06[a]	46.22±0.02[b]
In vitro digestibility of Starch (mg maltose released/ g)	28.03±0.05[c]	28.25±0.07[b]	28.41±0.07[b]	28.59±0.07[a]	28.70±0.07[a]
In vitro digestibility of Protein (%)	64.01±0.09[c]	69.25±0.11[b]	70.89±0.15[b]	73.12±0.16[a]	75.19±0.12[b]
Soluble dietary fibre(g/ 100g)	3.89±0.11[d]	4.31 ±0.12[c]	4.96±0.12[b]	5.12±0.12[a]	5.61 ±0.12[c]
Insoluble dietary fibre (g/ 100g)	10.05±0.05[d]	11.08±0.09[c]	11.75±0.11[b]	12.01±0.11[a]	12.35±0.05[d]
Total dietary fibre (g/ 100g)	13.94±0.01[d]	15.39±0.01[c]	16.71±0.06[b]	17.13 ±0.06[a]	17.96±0.06[a]

Table 5. 7: Analysed nutrient composition of formulated product- Bran Bar (BB) per 100g [Significantly different, $p < 0.05$ (Statistical analysis has been done row wise)]

Nutrients	GP0	GP1	GP2	GP3	GP4
Non-Reducing sugar (g/100 g)	1.06±0.21[a]	0.98±0.23[b]	0.91±0.21[b]	0.84±0.19[c]	0.80±0.09[d]
Reducing sugar (g/100 g)	2.75±0.06[a]	2.71±0.05[b]	2.59±0.08[c]	2.55±0.01[d]	2.51±0.05[b]
Total soluble sugar (g/100 g)	3.81±0.02[a]	3.69±0.01[b]	3.50±0.05[b]	3.39±0.01[c]	3.31±0.05[b]
Starch (g/100 g)	26.22±0.01[d]	25.95±0.06[c]	25.28±0.05[b]	25.01±0.05[a]	24.91±0.05[a]
Iron (mg/100g)	15.61±0.07[c]	16.22±0.09[a]	16.59±0.08[b]	16.77±0.05[d]	16.91±0.05[d]
Calcium (mg/100g)	110.91±3.65[d]	114.15±4.23[c]	114.86±4.03[b]	115.06±4.36[a]	115.47±3.65[d]
Phosphorus (mg/100g)	193.05±0.11[c]	193.65±0.19[b]	194.08±0.20[b]	194.62±0.22[a]	194.95±0.22[a]
Trypsin inhibitor activity (TIU/mg)	1.45±1.99[d]	1.58±2.01[c]	1.75±2.01[b]	1.86±2.06[a]	1.99±1.99[d]
Phytic acid (mg/100 g)	271.55±0.09[d]	285.43±1.25[c]	291.61±1.32[b]	311.05±1.38[a]	319.40±1.25[c]
Total phenolic content (mg GAE/ g)	2.56±0.01[c]	2.68±0.01[b]	3.05±0.05[b]	3.21±0.05[a]	3.38±0.05[a]
DPPH Radical Scavenging Activity (%)	39.93±0.01[c]	45.04±0.02[b]	45.39±0.05[b]	46.62±0.06[a]	46.97±0.06[a]
In vitro digestibility of Starch (mg maltose released/ g)	29.03±0.05[c]	29.55±0.07[b]	29.98±0.07[b]	30.12±0.07[a]	30.45±0.07[b]
In vitro digestibility of Protein (%)	64.25±0.09[c]	65.93±0.11[b]	66.54±0.15[b]	67.12±0.16[a]	68.25±0.15[b]
Soluble dietary fibre(g/ 100g)	3.09±0.11[d]	3.31 ±0.12[c]	3.85±0.12[b]	4.13±0.12[a]	4.2±0.12[a]
Insoluble dietary fibre (g/ 100g)	9.89±0.05[d]	10.69±0.09[c]	10.58±0.11[b]	11.01±0.11[a]	11.55±0.05[d]
Total dietary fibre (g/ 100g)	12.98±0.01[d]	14.00±0.01[c]	14.43±0.06[b]	15.14±0.06[a]	15.75±0.06[a]

Table 5. 8: Analysed nutrient composition of formulated product- Gram Pak (GP) per 100g [Significantly different, $p < 0.05$ (Statistical analysis has been done row wise)]

5.4.1.4. Antinutrient factors

Trypsin inhibitor activity was found around 1.40 TIU/mg along with 290 mg/100g of phytic acid content (Table 5.5). According to the recent studies, antinutrient, within a healthy range, acts as antioxidant and enhance the health status (Kumar *et al.,* 2021). Although chickpea husk contains higher amount of antinutrient (Niño-Medina *et al.,* 2019), estimated data disclosed negligible antinutrient in the products indicating the fact that use of various processing treatments can lower the antinutrient activity. Although heating affects vary moderately upon phytic acid content, trypsin inhibitor activity significantly decreased (Shi *et al.,* 2018). Soaking and blanching of the by-products and use of microwave heating for the formulation also enhanced the reduction of the antinutrient activity of the products (Suhag *et al.,* 2021).

5.4.1.5. Phenolic compounds and antioxidant properties

Phenolic content was around 3 mg GAE/g and for DPPH RSA (%) it was 45% (Table 5.5). Enhanced antioxidant activity of the products might also occur due to various heating and processing techniques during preparation (Higuchi *et al.,* 2014). Ginger, garlic, turmeric, cumin seed, cardamom are also widely known for their contribution in enhanced antioxidant level of formulated foods (Emelike *et al.,* 2020). Consumption of such functional foods as snacks can be a boon to the diet upholding the taste with health.

5.4.1.6. In vitro protein and starch digestibility

PD and GP variants showed higher in vitro digestibility of starch (30-31 mg maltose released/g) (Table 5.5). However, variants of BB (around 75%) showed better in vitro protein digestibility. According to the available data, legume based foods show better in vitro digestibility (Singh Sibian & Singh Riar, 2020).

5.4.1.7. Dietary fibre

Use of composite flour disclosed soluble dietary fibre rich value added product formulation (around 5 g/ 100g). Generally commercial products show fibre somewhat like 1 g/ 100g. Insoluble dietary fibre (g/ 100g) level was also elevated in these recipes. Total dietary fibre of the formulated products was 15-17g/100g (Table 5.5).

Nutrients	PD0	PD1	PD2	PD3	PD4
Non-Reducing sugar (g/100 g)	0.97±0.21[a]	0.99±0.23[b]	0.98±0.21[b]	1.01±0.19[c]	1.00±0.21[b]
Reducing sugar (g/100 g)	2.58±0.06[a]	2.59±0.05[b]	2.60±0.08[c]	2.60±0.01[d]	2.59±0.06[a]
Total soluble sugar (g/100 g)	3.55±0.02[a]	3.58±0.01[b]	3.58±0.05[b]	3.61±0.01[c]	3.59±0.05[b]
Starch (g/100 g)	25.22±0.01[d]	25.20±0.06[c]	25.26±0.05[b]	25.28±0.05[a]	25.29±0.05[b]
Iron (mg/100g)	16.91±0.07[c]	16.92±0.09[b]	16.90±0.08[b]	16.91±0.05[a]	16.92±0.05[a]
Calcium (mg/100g)	115.41±3.65[d]	115.50±4.23[c]	115.66±4.03[b]	115.69±4.36[a]	115.77±3.65[d]
Phosphorus (mg/100g)	195.05±0.11[c]	195.12±0.19[b]	195.15±0.20[b]	195.20±0.22[a]	195.24±0.11[c]
Trypsin inhibitor activity (TIU/mg)	1.42±1.99[d]	1.40±2.01[c]	1.39±2.01[b]	1.41±2.06[a]	1.40±2.07[a]
Phytic acid (mg/100 g)	290.03±0.09[d]	289.98±1.25[c]	291.05±1.32[b]	291.16±1.38[a]	291.21±1.32[b]
Total phenolic content (mg GAE/ g)	3.09±0.01[c]	2.99±0.01[b]	3.01±0.05[b]	3.10±0.05[a]	3.18±0.05[a]
DPPH Radical Scavenging Activity (%)	45.23±0.01[c]	45.04±0.02[b]	45.19±0.05[b]	45.22±0.06[a]	45.29±0.02[b]
In vitro digestibility of Starch (mg maltose released/ g of product starch)	31.01±0.05[c]	30.95±0.07[b]	30.92±0.07[b]	30.91±0.07[a]	31.00±0.07[a]
In vitro digestibility of Protein (%)	70.21±0.09[c]	69.93±0.11[b]	69.99±0.15[b]	70.12±0.16[a]	70.25±0.09[c]
Soluble dietary fibre(g/ 100g)	4.99±0.11[d]	4.51 ±0.12[c]	4.85±0.12[b]	4.92±0.12[a]	4.98±0.11[d]
Insoluble dietary fibre (g/ 100g)	9.05±0.05[d]	8.87±0.09[c]	8.98±0.11[b]	9.01±0.11[a]	9.07±0.09[c]
Total dietary fibre (g/ 100g)	14.04±0.01[d]	13.38±0.01[c]	13.83±0.06[b]	13.93±0.06[a]	14.05±0.01[d]

Table 5. 9: Analysed nutrient composition of formulated product- *Papad* (PD) per 100g [Significantly different, $p < 0.05$ (Statistical analysis has been done row wise)]

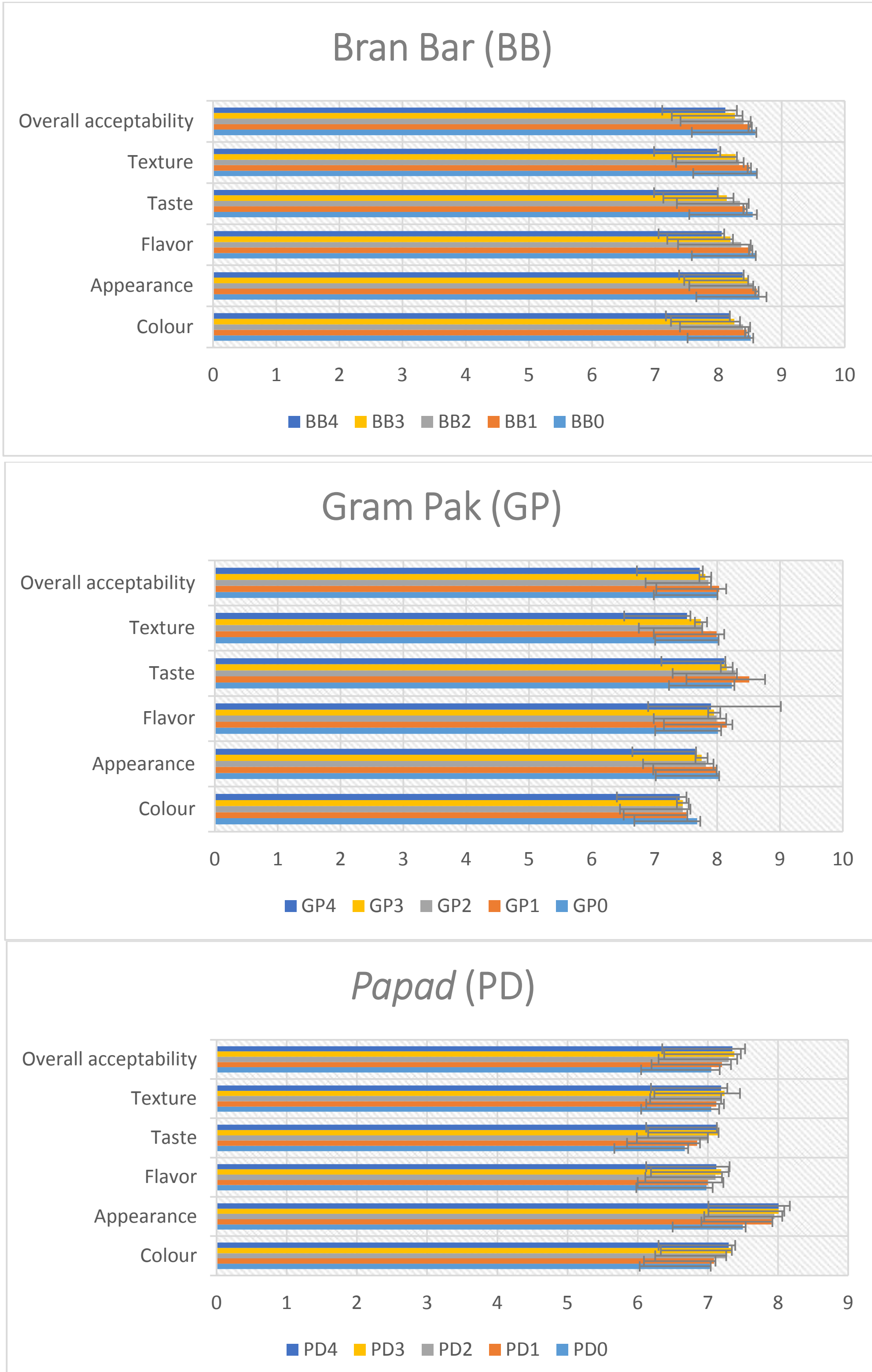

Figure 5. 8: Sensory evaluation of prepared value added products (Bran Bar, Gram Pak, *Papad*)

5.4.2. Sensory evaluation of prepared products

Satisfactory acceptability for all the formulated products were perceived (Figure 5.8). No such significant difference was observed in the sensory score of the products except colour. The variants of BB showed acceptability in the range of 8.5 to 8.1, whereas that range of GP and PD was 8.03 to 7.72 and 7.20 to 7.35 respectively. For microbial count analysis and shelf life evaluation, based upon the sensory profile and overall acceptability, GP1 (8.50±0.01), BB1 (8.03±0.02), and P3 (7.38±0.09) were chosen as most acceptable products.

5.4.3. Microbiological safety of food

The *Total Plate Count and yeast and mold count* were 1 X 10^2 CFU/g in all formulations under evaluation. No Coliform count was recorded**.** All formulations of freshly prepared foods retained their quality.

Dilutions		10^{-1}	10^{-2}
Bran Bar (BB1)	Total Plate Count	1 X 10^2	Absent
	Yeast and Mold Count	1 X 10^2	Absent
	Coliform Count	Absent	Absent
Gram Pak (GP1)	Total Plate Count	1 X 10^2	Absent
	Yeast and Mold Count	1 X 10^2	Absent
	Coliform Count	Absent	Absent
Papad (PD3)	Total Plate Count	1 X 10^2	Absent
	Yeast and Mold Count	1 X 10^2	Absent
	Coliform Count	Absent	Absent

Table 5. 10: Microbial load analysis of freshly formulated products- Bran Bar (BB1), Gram Pak (GP1), and *Papad* (PD3)

5.4.4. Shelf life of the prepared food products

According to the sensory scores, BB1, GP1, PD3 were chosen as the mot preferred products and stored for 90 days to study storage stability. BB1, PD3 were intact until 90^{th} day (Figure 5.9) from the manufactured date except GP1. It showed spoilage after 19^{th} day of the storage. Generally, milk based confectionery products show storage stability up to 10-15 days. Being a milk based product, GP1 showed relatively longer shelf life. As banana peel possesses antimicrobial activity (Vu *et al.,* 2018), use of banana peel in this formulation might contribute to the longer shelf life of Gram Pak.

BB1 showed 2.64±0.01 meq peroxide/1000g and 14.20±0.03 meq peroxide/1000g peroxide value on initial day and 90th day of the storage duration. Other products viz., PD3 also followed the same trend, except GP1 as it showed spoilage on 19th day of the storage. Free fatty acid value was in the range 0.3 to 0.7 mg KOH/100g in these products (Table 5.11). Data indicated higher shelf life of BB1 and PD3 than GP1.

0th day	15th day	30th day	45th day	60th day	75th day	90th day
Bran bar (BB1)- Peroxide value (meq peroxide/1000g)						
2.64±0.01^{e}	3.85±0.08^{b}	7.01±0.04^{c}	8.78±0.11^{a}	10.79±0.01^{e}	12.98±0.04^{c}	14.20±0.03^{d}
Bran bar (BB1)- Free fatty acid (mg KOH/100g)						
0.35±0.08^{b}	0.40±0.10^{a}	0.48±0.12^{a}	0.52±0.11^{a}	0.65±0.16^{c}	0.69±0.08^{b}	0.71±0.02^{d}
Gram Pak (GP1)- Peroxide value (meq peroxide/1000g)						
2.41±0.09^{a}	4.45±0.01^{b}	Showed spoilage after 19th day				
Gram Pak (GP1)- Free fatty acid (mg KOH/100g)						
0.33±0.08^{b}	0.41±0.11^{a}	Showed spoilage after 19th day				
Papad (PD3)- Peroxide value (meq peroxide/1000g)						
1.44±0.01^{c}	2.79±0.01^{c}	6.59±0.04^{b}	8.55±0.01^{c}	10.29±0.01^{c}	12.79±0.11^{a}	14.01±0.03^{b}
Papad (PD3)- Free fatty acid (mg KOH/100g)						
0.37±0.01^{e}	0.39±0.11^{b}	0.46±0.09^{c}	0.51±0.08^{c}	0.62±0.11^{b}	0.64±0.18^{a}	0.67±0.05^{d}

Table 5. 11: Shelf life determination of formulated products. [Significantly different, $p < 0.05$ (Statistical analysis has been done row wise)]

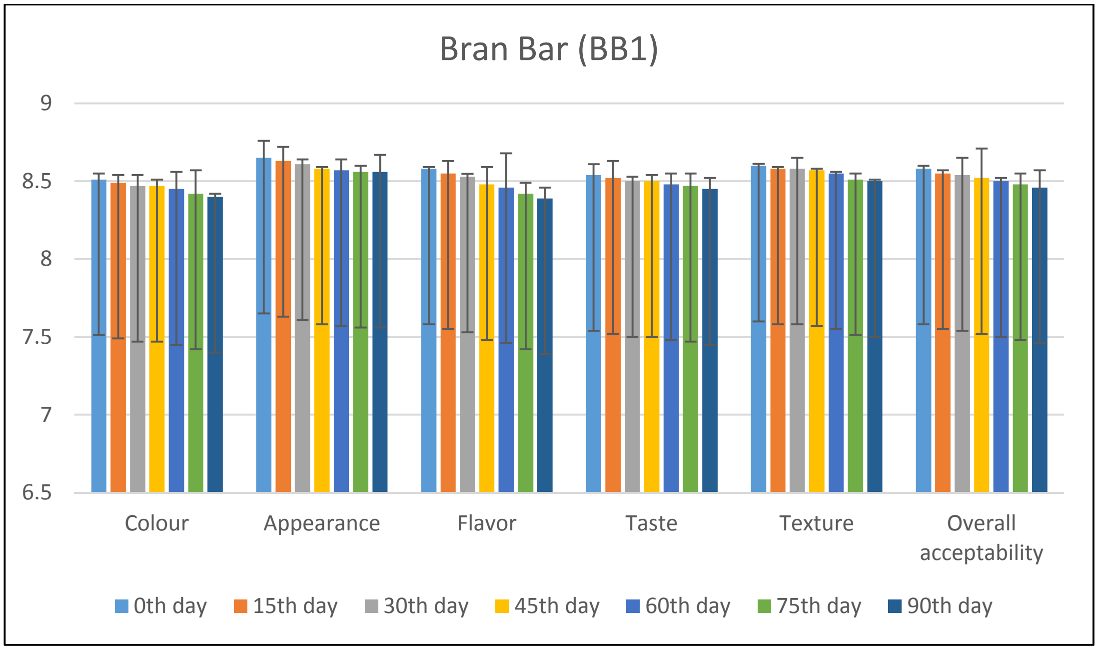

Figure 5. 9: The sensory parameters of Product (Bran Bar) incorporated with composite flour during the storage of 90 days.

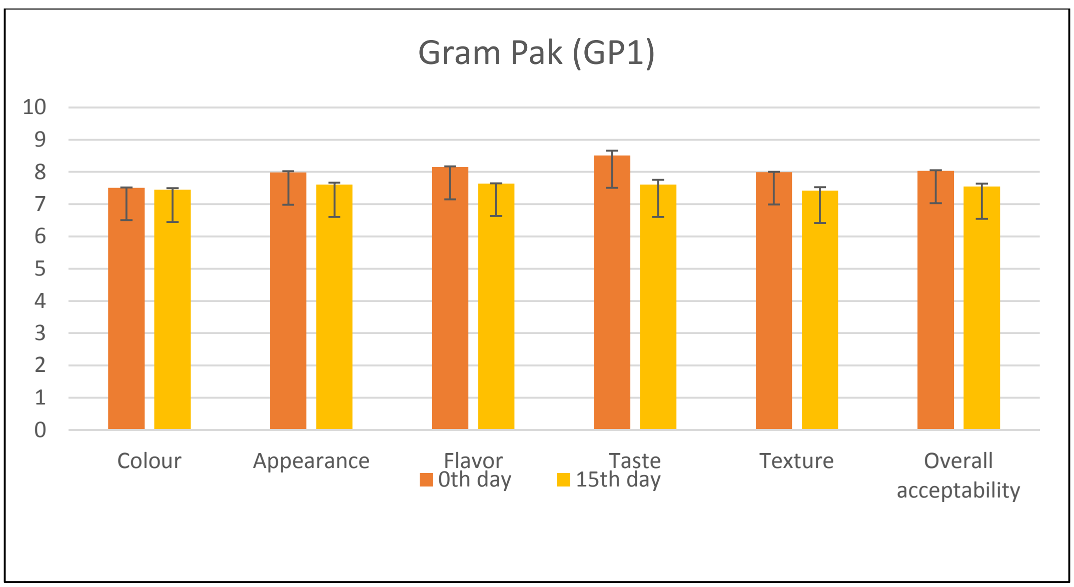

Figure 5. 10: The sensory parameters of Product (Gram Pak) incorporated with composite flour during the storage of 90 days.

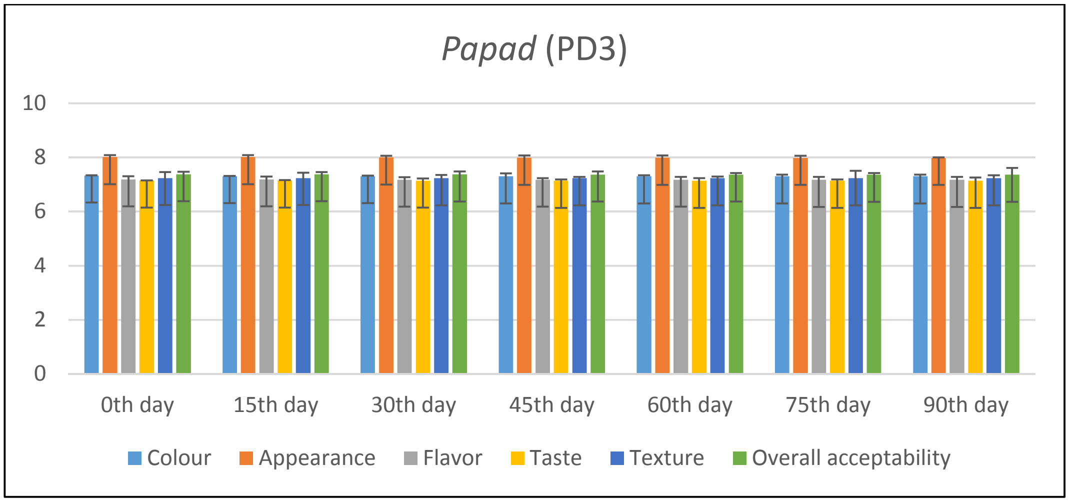

Figure 5. 11: The effect of storage on hedonic quality characteristics analysis of Product (*Papad*) incorporated with composite flour.

Formulation of these nutrient dense value added products using milling by-products followed by the estimation of nutrient composition, shelf life, and sensory parameters indicated probable use of the milling by-products in the development of snack bar, confectionary and snack products. Further, the processing technology of milling by-products to formulate these novel products was transferred to community for better understanding and utilization of agricultural by-products in food formulation. Popularization of these products (discussed in Chapter 3) had been done in collaboration with KrishiVigyan Kendra, Mahendergarh.

Chemical preservative free value added dairy based product had been developed using milling by-products of chickpea, wheat and rice incorporated with banana peel. Proximate composition of the developed product, Gram Pak (GP) showed rich nutrient status. Dairy based confectionary generally shows spoilage after 5-7 days in room temperature. Hence, along with nutrient enhancement to improve shelf life of the developed product, food irradiation was carried out using gamma source viz., ^{137}Cs. The product was kept at different storage conditions to observe the shelf life. At room temperature GP showed spoilage after 5 days of the manufacturing date. Whereas, at 4°C storage condition, it showed spoilage after 19th day. Irradiated GP which was stored at room temperature showed spoilage after 10th day without effecting the sensory qualities of the product (Figure 5.10). The enhanced shelf life of the irradiated product depicted maintenance of food security and feasible transportation of such product in cost-effective way avoiding microbial contamination.

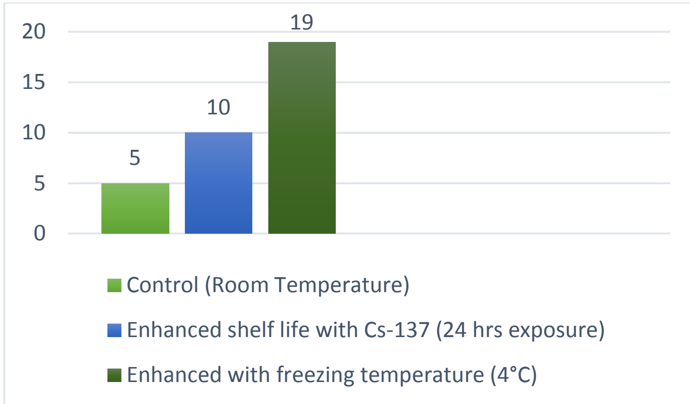

Figure 5. 12: Shelf life of Gram Pak processed and stored at different conditions

Gram Pak was exposed to gamma source for different time durations. The radiation counts observed after irradiating Gram Pak to the gamma radiations had been tabulated; Observations were recorded until the counts obtained from samples and background become same. Graphical representation of these counts for individual samples has been portrayed.

Radiation Counts in Gram Pak										
Exposure	Day1	Day2	Day3	Day4	Day5	Day6	Day7	Day8	Day9	Day10
22 hrs.	518	463	380	299	235	187	112	53	18	0
37 hrs.	409	329	251	183	102	87	49	19	0	0
48 hrs.	351	272	219	156	101	81	50	12	0	0

Table 5. 12: Observed Radiation Counts in irradiated Gram Pak stored at room temperature

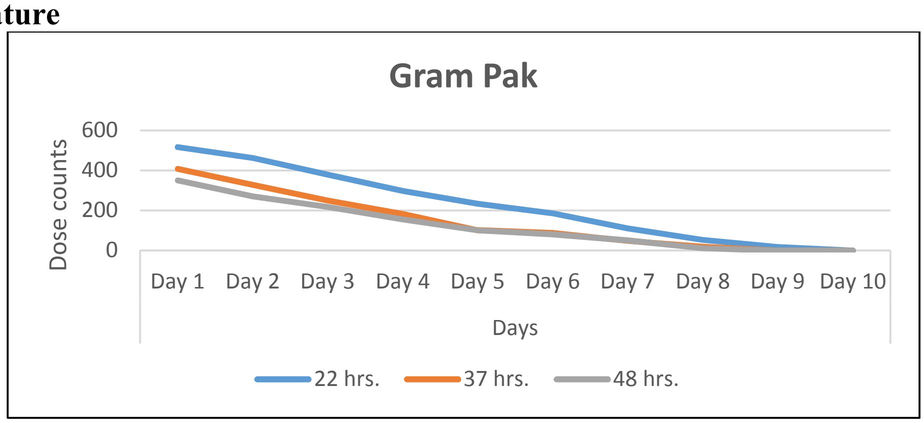

Figure 5. 13: Graphical Representation of Observed radiation counts in Gram Pak

Nutrient analysis of the irradiated products had been checked to study the effect of radiation on chemical composition. The analysis had been done when the dose count of the irradiated products became zero to check the edibility of the products. Even after becoming zero dose count of radiation, products showed visual microbial spoilage few days later. Hence it was necessary to check the quality of the products in between the time period of zero dose count to visual microbial growth.

Moisture (%)	**Ash (%)**	**Crude fat (%)**	**Crude protein (%)**	**Crude fibre (%)**	**Total carbohydrate (%)**
7.02±0.35	6.19±0.17	5.29±0.17	18.34±0.13	3.56±0.01	59.60±1.94

Table 5. 13: Nutrient composition of irradiated Gram Pak (GP) after showing count zero

Products	**Free fatty acid value (mg KOH/100g)**	**Peroxide value (meq peroxide/1000g)**
Gram Pak (After showing zero count)	0.35±0.01	2.43±0.09

Table 5. 14: Free fatty acid and Peroxide value of Gram Pak (GP) after irradiation to study storage stability

5.5. Summary

Using various processing technologies and culinary treatments to enhance nutrient status, we have studied the role of milling by-products as innovative ingredient for value added food formulation. Proximate composition, dietary fibre, mineral availability, antioxidant activity (DPPH RSA, phenol content), antinutrient, in vitro digestibility of the formulated products (Gram Pak, Bran Bar, *Papad*) were evaluated. GP showed higher moisture content which was around 7% and PD showed the lowest moisture, around 4%. Total phenolic contents present in BB, GP, and PD were in the range of 3-3.71 mg GAE/g, 2.56-3.38 mg GAE/g, and 3.09-3.18 mg GAE/g respectively. Among all the products, BB showed the highest level of dietary fibre which was around 17 g/100g. We analysed microbial load count of the freshly formulated products. Total Plate Count, yeast and mold counts were detected according to the standard methods and nominal microbial count was observed. Increased values of peroxide and free fatty acid were recorded with passing days during the storage of 90 days. Hence, the valuation of such milling by-products using conventional domestic culinary treatments can expand the use of these by-products in food industries as potential plant-based food ingredients to formulate functional food products without affecting the sensory attributes.