J Food Sci Technol (May–June 2012) 49(3):335–341
DOI 10.1007/s13197-011-0283-6

ORIGINAL ARTICLE

Development of shelf stable protein rich composite cereal bar

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Revised: 23 July 2010 / Accepted: 6 August 2010 / Published online: 11 February 2011

Abstract Protein rich composite cereal bar based on cereal ingredients was prepared using semi automatic tablet making machine, packed in poly propylene (PP), paper aluminium foil polyethylene (PFP), metallised polyester (MP) followed by vacuum packing in metallized polyester films. Proximate composition, mineral contents as well as changes in peroxide value (PV), free fatty acid value (FFA), thiobarbituric acid value (TBA), browning, fatty acid profile, vitamins, effect of water activity on lipid peroxidation, fortification with vitamins and minerals, microbiological as well as sensory parameters during storage under ambient (15–34°C) and 37°C temperature conditions were studied. Composite cereal bar remained shelf stable for 3 months in PP and 6 months in PFP, MP and MP plus vacuum packing under ambient and 37°C temperature conditions.

Keywords Protein rich · Composite · Cereal · Packaging · Hard texture · Shelf stability

Diets based on whole grains are increasing day by day due to various health benefits associated with them as they are good source of dietary fibre, antioxidants, vitamins etc., but protein quality of cereals are not good as they are deficient in essential amino acid, lysine. However, the use of legumes / pulses in the diet improves the overall protein quality of cereals as they are rich in essential amino acid lysine. On the other hand, cereal proteins complement legume protein in the essential amino acid methionine (Iqbal et al. 2006). The addition of 10–15% defatted soy flour, soy concentrates and isolates to wheat flour not only significantly improve the quality of protein but also enhances their quantity considerably (Mizrahi et al. 1967). Tsen (1976) prepared protein rich biscuits from wheat flour fortified with soy, cotton seed, pea nut or corn germ flour. Chauhan (1982) utilized 50–50% of defatted soy flour to improve the nutritional quality of cereal protein. Defatted soy flour has been used to develop various nutritious protein rich products such as snacks, baby foods, chapati, beverage and bread (Rathod and Williams 1970; Tsen et al. 1973; Sushma et al. 1979; Chauhan and Bairns 1985; Singh and Singh 1989; Chauhan and Kumari 1990). Effect of protein isolates (Pea and soy bean) have been studied on the functional and rheological properties of protein enriched gluten free composite flour (Marco and Rosell 2008).

The nutritious energy bars have gained more importance and popularity in the global market during recent years and today the market is offering wide variety of bars under different names. Indigenously made bars like Horlicks multi cereal nutri bar, Rite bite choco delite bars, low fat bar, sugarless bar, woman bar, fruit choco bars etc are gelling popular among Indian consumers. The various varieties of bars available in the global market with good organoleptic properties and consumer appeal are referred by names such as chewy cereal granola bars, organic bar, choco bar, muffin bar, fruit filled bars and so on. These bars are generally packed in metallised polyester films and have a limited shelf life of 3 to 4 months.

For the preparation of protein rich composite cereal bar, cereals like wheat, corn and barley were used in combination with soy concentrates and isolates. The beneficial effects of incorporation of barely into processed foods have been well documented. The functional ingredient β-glucan present in barley has been associated with the properties of lowering blood cholesterol (Behall et al. 2004; Fadel et al.

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1987; Newman et al. 1989) and glycemic index (Braaten et al. 1991; Cavellero et al. 2002; Wood et al. 1990). Barley is a rich source of tocols including tocopherols and tocotrienols known to reduce serum cholesterol through their antioxidant action (Quereshi et al. 1986, 1991). The various other ingredients which are used in the preparation of composite cereal bar include cocoa butter, cocoa powder, corn syrup, glucose syrup, soy lecithin and sugar.

The main objective of this study was to develop a protein rich composite cereal bar with balanced nutrition as well as to study the changes occurring in chemical parameters and sensory attributes in order to assess the shelf- stability of the product.

Materials and methods

Good quality wheat (*Triticum aestivum*), wheat semolina, corn (*Zea mays)* were procured from local market and Barley grains (*Hordeum vulgare)* was procured from Punjab agricultural university, Ludhiana. Glucose syrup and corn syrup were procured from M/s India sweet company pvt Ltd, Mumbai, and cocoa butter from M/s Campco India, Mangalore. Soy concentrate, soy isolate and soy lecithin were procured from M/s Ruchi soy industries Ltd, Mumbai. All chemicals used were of analytical reagent grade and procured from reputed companies and used as such.

Moisture, total protein, total fat, total ash were estimated by AOAC (1984) methods. Total sugar was estimated by the method described by Khan et al. (2008). Peroxide value and free fatty acid values were determined by AOCS (1973) methods. Thiobarbituric acid value was estimated as per the method of Tarledgis et al. (1960). Fatty acid profile was determined as per AOCS (1990) methods while vitamin B_1 and B_2 contents by AOAC (1997) methods. Vitamin C content in bars was estimated by the method of Ranganna (1986) and microbiological analysis was carried out as per the method of Harrigan and McCance (1976).

To study the effect of water activity on the lipid peroxidation of composite cereal bar, 100 g sample of bar was stored in desiccators for 45 days at ambient temperature (15–34°C) containing phosphorous pentoxide to obtain 0.0 water activity and saturated salt solutions of magnesium chloride, sodium bromide and sodium nitrite to obtain water activities (a_w) of 0.33, 0.57 and 0.73 respectively. Initially and periodically, stored bar samples were analysed for moisture, PV and FFA values.

Statistical analysis All the reported values are the mean of three replicates and statistical analysis was carried out by using statistical software (Statistica, Ver 7.1 Series 1205). Experimental results were subjected to two way analysis of varience at ($p \leq 0.05$) significance levels using Duncan's multiple range tests. Correlation between chemical parameters and over all acceptability were studied at ($p<0.05$) significance levels.

Processing methods and preparation of composite cereal bar

1. Good quality corn were roasted to 220°C to have proper puffing of corn and powdered coarsely.
2. Barley grains with husk were cleaned and washed thoroughly. Dried in the hot air oven at 80°C for 2 h. After drying, barley grains were roasted up to 140°C and ground in an ultra centrifugal mill fitted with 1 mm sieve.
3. 75 g of wheat flour, 63 g of puffed corn flour and 63 g of wheat semolina were roasted in an aluminium pan up to a temperature of 140°C in a low flame to get roasted aroma of the mixed ingredients. The mixture was cooled and 100 g of roasted barley flour with husk, 325 g of soy protein concentrate, 225 g of soy protein isolate and 150 g of cocoa powder were added and mixed well.
4. 550 g of cocoa butter was melted and to this, 50 g of soy lecithin was added and mixed.

Preparation of a binder 700g of sugar was dissolved in 1400 ml of water. Filtered through the muslin cloth to remove any impurities. To this solution, 100 g of corn syrup, 100 g of glucose syrup were added and heated to a temperature of 105–110°C to have a thick consistent syrup of 80° brix.

Preparation of composite cereal bar To the hot binder syrup, melted cocoa butter with lecithin and the above roasted cereal ingredients were added and mixed well. The mixture was cooled to 55–60°C and fed in to a rectangular mould and pressed with a pressure of 6000 pounds to obtain bars.

Packing of bars Composite cereal bar was packed in polypropylene (PP), paper-aluminium foil polyethylene laminate (PFP) and matallised polyester (MP) films. Alternatively, the above bars were vacuum packed in metallised polyester films and stored under ambient (15–34°C) and 37°C temperature conditions.

Sensory evaluation and storage Sensory evaluation was carried out in composite cereal bar by trained panel of judges (20 nos.) on a 9 point Hedonic scale grading 9 for excellent and 1 for highly disliked samples (Sharma et al. 2006).

Results and discussion

Recipe for the preparation of the above bar was optimized by using 1–5% puffed corn flour, 1–5% wheat flour, 1–5%

Table 1 Changes in vitamin C (mg/100 g), vitamin B_1 (mg/100 g) and vitamin B_2 (mg/100 g) contents of fortified Composite cereal bar during storage at ambient temperature (15–34°C) and 37°C

	Packaging materials	Initial	After fortification	Room temperature		37°C	
				Storage period (months)			
				6M	9M	6M	9M
Vitamin C	PP	4.1	26.2^{a}	16.1^{bw}	11.2^{cx}	12.2^{bw}	8.4^{cw}
	PFP			17.2^{bx}	13.2^{cy}	14.4^{bx}	9.3^{cx}
	MP			18.0^{by}	13.3^{cy}	15.0^{by}	10.1^{cy}
	MP (Vac)			20.9^{bz}	17.9^{cz}	16.1^{bz}	12.0^{cz}
Vitamin B_1	PP	0.05	0.79^{a}	0.32^{bx}	0.22^{cx}	0.26^{bx}	0.17^{cx}
	PFP			0.39^{by}	0.26^{cxy}	0.30^{bxy}	0.19^{cxy}
	MP			0.41^{by}	0.28^{cy}	0.33^{by}	0.21^{cy}
	MP (Vac)			0.67^{bz}	0.43^{cz}	0.56^{bz}	0.33^{cz}
Vitamin B_2	PP	0.08	0.92^{a}	0.64^{bx}	0.49^{cx}	0.55^{bx}	0.38^{cx}
	PFP			0.67^{bx}	0.52^{cx}	0.58^{bx}	0.40^{cx}
	MP			0.68^{bx}	0.50^{cx}	0.58^{bx}	0.41^{cx}
	MP (Vac)			0.77^{by}	0.69^{cy}	0.68^{by}	0.53^{cy}

Mean values with different superscripts (a–c) in rows and (w–z) in columns are significantly different ($p \leq 0.05$)

Values are mean±standard deviation of three measurements

wheat semolina, 2–6% husked barley flour, 10–15% soy concentrate, 7–12% soy isolate, 4–8% cocoa powder, 18–25% cocoa butter, 1–4% soy lecithin and binder solution which contains 2–6% corn syrup, 2–6% glucose syrup and 20–30% sugar. Sensory attributes like colour, aroma, taste, texture and overall acceptability scores on 9 point Hedonic scale revealed that composite cereal bar by using 2.5% puffed corn flour, 3% wheat flour, 4% barley flour, 2.5% wheat semolina, 13% soy concentrate, 9% soy isolate, 6% cocoa powder, 22% cocoa butter, 4% corn syrup, 4% glucose syrup, 28% sugar and 2% lecithin received an overall acceptability score of 7.9 and highly liked by the taste panel members.

It is interesting to observe that use of cocoa butter in binder solution gave better mouth feel to the composite cereal bar as compared to hydrogenated fat, hence cocoa butter was used in the preparation of a protein rich composite cereal bar. The ingredient for binder solution was corn syrup, glucose syrup and sugar along with water. Heating of sugar in water at more than 90^{0}C also resulted in hard texture to the bar which was not liked by the taste panel members. The roasting of wheat flour, husked barley flour and semolina gave pleasant roasted flavour due to strecker degradation and used in the process of making composite cereal bar.

Composite cereal bar had 7.2% moisture, 18.8% total protein, 24.3% total fat, 30.6% total sugar, 1.7% total ash, 0.46% crude fibre and 16.9% carbohydrate (by difference). Cereal bar provides 484 Kcal of energy/100 gbar which is computed from proximate composition of the bar by taking the value of 4, 4 and 9 Kcal for carbohydrate, protein and fat respectively.

From the Table 1, it is evident that initially bar contained 4.1 mg/100 g of vitamin C, 0.05 mg/100 g of Vitamin B_1 and 0.08 mg/100 g of Vitamin B_2 respectively. After fortification, the values of Vitamin C, Vitamin B_1 and Vitamin B_2 increased to meet 50% requirement of RDA as per ICMR recommendations. After 9 months of storage at ambient temperature, the losses in Vitamin C, B_1 and B_2 were highest in PP (57%, 72% and 47%) followed by PFP (50%, 67% and 43%), MP (49%, 65% and 46%) and least in samples packed under vacuum in MP (32%, 46% and 25%). Relatively, losses were found to be higher in samples stored at 37°C than the one at ambient temperature.

Composite cereal bar initially contained 8.9 ppm of calcium, 8.2 ppm of iron and 2.8 ppm of zinc. After fortification to meet 50% RDA, mineral contents were increased to 4181.0, 119.0 and 77.8 ppm of calcium, iron and zinc respectively.

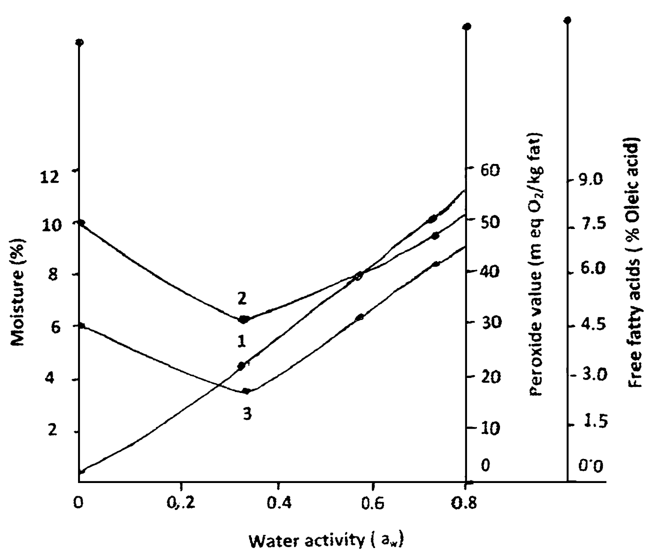

Fig. 1 Effect of water activity on moisture (1), peroxide value (PV, 2) and free fatty acid (FFA,3) contents of composite cereal bar after 45 days of storage at ambient temperature (15–34°C)

Table 2 Changes in moisture (%), peroxide value (meq O_2/kg oil), free fatty acids (%) Oleic acid), thiobarbituric acid value (mg MA/kg sample) and browning index (OD) in Composite cereal bar stored at ambient temperature (15–34°C)

Attributes	Packaging materials	Storage period (months)			
		0M	3M	6M	9M
Moisture	PP	7.5^{a}	7.8^{bx}	8.1^{cx}	8.9^{dx}
	PFP		7.6^{aby}	7.7^{by}	7.7^{by}
	MP		7.5^{ay}	7.7^{by}	7.7^{by}
	MP Vac		7.5^{ay}	7.6^{ay}	7.6^{ay}
Peroxide value	PP	0.90^{a}	13.9^{bw}	20.2^{cw}	30.9^{dw}
	PFP		12.1^{bx}	16.1^{cx}	25.2^{dx}
	MP		10.1^{by}	14.2^{cy}	23.1^{dy}
	MP Vac		9.0^{bz}	11.7^{cz}	19.2^{dz}
Free fatty acid value	PP	1.9^{a}	2.9^{bx}	4.1^{cx}	4.9^{dx}
	PFP		2.8^{by}	3.7^{cy}	4.3^{dy}
	MP		2.7^{by}	3.6^{cy}	4.2^{dy}
	MP Vac		2.6^{by}	3.1^{cz}	3.7^{dz}
Thiobarbituric acid value	PP	0.19^{a}	0.24^{bx}	0.34^{cx}	0.41^{dx}
	PFP		0.22^{bxy}	0.29^{cy}	0.36^{dy}
	MP		0.21^{ay}	0.27^{by}	0.34^{cy}
	MP Vac		0.18^{az}	0.21^{az}	0.28^{bz}
Browning index	PP	0.05^{a}	0.11^{bx}	0.13^{cx}	0.17^{dx}
	PFP		0.09^{by}	0.11^{cy}	0.15^{dy}
	MP		0.08^{by}	0.10^{cy}	0.14^{dy}
	MP Vac		0.06^{az}	0.08^{bz}	0.11^{cz}

Mean values with different superscripts (a–d) in rows and (w–z) in columns are significantly different ($p \leq 0.05$)

Values are mean±standard deviation of three measurements

Table 3 Changes in moisture (%), peroxide value (meq O_2/kg oil), free fatty acids (%) Oleic acid), thiobarbituric acid value (mg MA/kg sample) and browning index (OD) in composite cereal bar stored at 37°C

Attributes	Packaging materials	Storage period (months)			
		Initial	3M	6M	9M
Moisture	PP	7.5^{a}	7.6^{ax}	8.0^{bx}	8.6^{cx}
	PFP		7.5^{ax}	7.6^{aby}	7.7^{by}
	MP		7.5^{ax}	7.6^{aby}	7.7^{by}
	MP Vac		7.5^{ax}	7.6^{ay}	7.6^{ay}
Peroxide value	PP	0.90^{a}	19.0^{bw}	26.2^{cx}	34.6^{dw}
	PFP		15.9^{bx}	24.2^{cy}	29.4^{dx}
	MP		14.5^{by}	24.1^{cy}	28.1^{dy}
	MP Vac		13.2^{bz}	22.3^{cz}	25.3^{dz}
Free fatty acid value	PP	1.9^{a}	3.6^{bx}	4.9^{cx}	5.2^{dx}
	PFP		3.4^{bxy}	4.2^{cy}	4.9^{dy}
	MP		3.2^{byz}	4.1^{cy}	4.8^{dy}
	MP Vac		3.1^{bz}	3.7^{cz}	4.2^{dz}
Thiobarbituric acid value	PP	$0.19^{a.}$	0.26^{bx}	0.38^{cx}	0.51^{dx}
	PFP		0.24^{bxy}	0.31^{cy}	0.45^{dy}
	MP		0.23^{by}	0.29^{cy}	0.44^{dy}
	MP Vac.		$0.20^{az.}$	$0.23^{bz.}$	$0.36^{cz.}$
Browning index	PP	0.05^{a}	0.12^{bx}	0.15^{cx}	0.19^{dx}
	PFP		0.11^{bxy}	0.13^{cy}	0.17^{dy}
	MP		0.10^{by}	0.13^{cy}	0.16^{dy}
	MP Vac		0.07^{bz}	0.11^{cz}	0.14^{dz}

Mean values with different superscripts (a–d) in rows and (w–z) in columns are significantly different ($p \leq 0.05$)

Values are mean±standard deviation of three measurements

Table 4 Changes in fatty acid profile of Composite cereal bar during storage at ambient temperature (15–34°C)

Fatty acids (%)	Storage period (months)								
	Initial	PP		PFP		MP		MP(Vac)	
		6M	9M	6M	9M	6M	9M	6M	9M
Myristic	0.23^{a}	0.32^{b}	0.35^{b}	0.26^{a}	0.32^{b}	0.26^{a}	0.33^{b}	0.25^{a}	0.29^{c}
Palmitic	27.4^{a}	27.9^{ab}	28.2^{b}	27.9^{ab}	28.1^{b}	27.8^{ab}	28.1^{b}	27.8^{a}	27.9^{a}
Palmitoleic	0.28^{a}	0.22^{b}	0.16^{c}	0.23^{b}	0.18^{c}	0.23^{b}	0.19^{c}	0.26^{a}	0.21^{b}
Stearic	31.7^{a}	32.4^{a}	32.8^{b}	32.2^{a}	32.6^{b}	32.1^{a}	32.5^{a}	32.0^{a}	32.2^{a}
Oleic	32.6^{a}	31.8^{a}	31.4^{b}	32.1^{a}	31.8^{a}	32.2^{a}	31.9^{a}	32.5^{a}	32.2^{a}
Linoleic	6.1^{a}	5.4^{b}	5.2^{b}	5.7^{a}	5.6^{a}	5.8^{a}	5.7^{a}	5.9^{a}	5.8^{a}
Linolenic	0.88^{a}	0.72^{b}	0.65^{c}	0.82^{d}	0.72^{b}	0.82^{d}	0.74^{b}	0.84^{d}	0.78^{e}
SFA	59.3^{a}	60.6^{b}	61.4^{c}	60.4^{b}	61.0^{bc}	60.2^{b}	60.9^{c}	60.1^{b}	60.4^{b}
MUFA	32.9^{a}	32.0^{bc}	31.6^{b}	32.3^{c}	32.0^{c}	32.4^{c}	32.1^{c}	32.8^{a}	32.4^{c}
PUFA	7.0^{a}	6.1^{b}	5.9^{b}	6.6^{c}	6.3^{bc}	6.6^{c}	6.4^{c}	6.7^{c}	6.6^{c}

Mean values with different superscripts (a–e) in rows are significantly different ($p \leq 0.05$)

Values are mean±standard deviation of three measurements

Effect of water activity Sorption isotherm of composite cereal bar and changes in moisture, PV and FFA values during storage under different water activity conditions for 45 days are given in Fig. 1. The composite cereal bar equilibrated to 0.40, 4.2, 8.0 and 10.6% moisture level at 0.0, 0.33, 0.57 and 0.73 water activities respectively. The peroxide value and free fatty acid values were found lowest at 0.33 a_w as compared to 0.0, 0.57 and 0.73 a_w. The results are in conformity with the published literature (Labuza 1978; Semwal et al. 2001).

Changes in chemical parameters Changes in lipid peroxidation during storage of composite cereal bar was monitored by estimating peroxide value, free fatty acid value, thiobarbituric acid value and browning index and reported in Tables 2 and 3. After 9 months of storage, it was observed that there were slight but significant ($p \leq 0.05$) increase in moisture content irrespective of packaging material but difference between PFP and MP stored samples were not significant. Chemical changes in composite cereal bar were found least but significant ($p \leq 0.05$) in samples packed under vacuum in MP and stored at ambient temperature followed by MP, PFP and PP packed samples. After 9 months of storage, PV varied from 0.90 to 30.9 meq O_2/kg fat, FFA from 1.9 to 4.9% oleic acid, TBA from 0.19 to 0.41 mg malonaldehyde (MA) /kg sample and browning index from 0.05 to 0.17 in PP packed samples. As expected, changes in chemical parameters were more pronounced at 37°C than at ambient temperature.

Changes in fatty acid profile Seven fatty acids namely myristic, palmitic, palmitoleic, stearic, oleic, linoleic and linolenic acids were identified in composite cereal bar (Tables 4 and 5). The major fatty acid present in fat extracted from cereal bar was oleic (32.6%) followed by stearic (31.7%), palmitic (27.4%) and linoleic (6.1%) acids, but linolenic, palmitoleic and myristic acids were present less than 1%. During storage of composite cereal bar, there

Table 5 Changes in fatty acid profile of Composite cereal bar during storage at 37°C

Fatty acids (%)	Storage period (months)								
	Initial	PP		PFP		MP		MP(Vac)	
		6M	9M	6M	9M	6M	9M	6M	9M
Myristic	0.23^{a}	0.38^{b}	0.47^{c}	0.31^{d}	0.41^{b}	0.31^{d}	0.39^{b}	0.29^{d}	0.38^{b}
Palmitic	27.4^{a}	28.3^{b}	28.7^{b}	28.1^{b}	28.4^{b}	28.0^{ab}	28.4^{b}	28.0^{ab}	28.1^{ab}
Palmitoleic	0.28^{a}	0.16^{b}	0.10^{c}	0.20^{d}	0.16^{b}	0.21^{d}	0.17^{b}	0.22^{d}	0.19^{bd}
Stearic	31.7^{a}	32.6^{ab}	33.0^{b}	32.4^{ab}	32.7^{b}	32.3^{ab}	32.7^{b}	32.1^{ab}	32.3^{ab}
Oleic	32.6^{a}	31.5^{b}	31.0^{b}	31.8^{b}	31.6^{b}	31.9^{ab}	31.7^{b}	32.4^{a}	32.1^{a}
Linoleic	6.1^{a}	5.3^{b}	5.1^{b}	5.6^{ab}	5.4^{b}	5.6^{ab}	5.4^{b}	5.7^{ab}	5.6^{ab}
Linolenic	0.88^{a}	0.65^{b}	0.53^{c}	0.73^{d}	0.64^{b}	0.75^{de}	0.66^{b}	0.80^{e}	0.72^{d}
SFA	59.3^{a}	61.3^{b}	62.2^{c}	60.8^{b}	61.5^{b}	60.6^{c}	61.5^{b}	60.4^{c}	60.8^{bc}
MUFA	32.9^{a}	31.7^{bc}	31.1^{b}	32.0^{c}	31.8^{c}	32.1^{c}	31.9^{c}	32.6^{ac}	32.3^{ac}
PUFA	7.0^{a}	6.0^{bc}	5.6^{b}	6.3^{c}	6.0^{bc}	6.4^{c}	6.1^{bc}	6.5^{c}	6.3^{c}

Mean values with different superscripts (a–e) in rows are significantly different ($p \leq 0.05$)

Values are mean±standard deviation of three measurements was a significant decrease ($p \leq 0.05$) in PUFA and MUFA contents in different packaging materials with concomitant increase in SFA. After 9 months of storage at 37°C, 1.4 and 1.8, 1.0 and 1.1, 0.9 and 1.0 and 0.7 and 0.6 units of PUFA and MUFA were lost ($p \leq 0.05$) in PP, PFP, MP and MP vacuum packed samples but difference between PFP and MP were not significant. The corresponding values for fatty acids at ambient temperature followed the same pattern but decrease was much smaller.

Changes in sensory attributes Changes in sensory attributes like colour, aroma, taste, texture and overall acceptability on a 9—point Hedonic scale at ambient temperature and 37°C are given in Tables 6 and 7, where 9 was given for excellent in all respects and 1 for highly disliked samples. From the data, it was observed that there was a gradual but significant ($p \leq 0.05$) decrease in all the sensory parameters during storage. Comparatively texture of the bar was deteriorated much faster and it ranged from 7.7 to 5.2 and 5.0 on a 9 point Hedonic scale at ambient temperature and 37°C respectively. Texture of the bar become harder during storage and influenced the overall acceptability scores adversely and hence shelf-life. Simon et al. (2009) reported that the shelf-life of a protein bar often limited by the development of a hard or tough texture that consumer find unpalatable. Similar results were obtained in the present studies. The development of hard texture during storage may be attributed to thiol–disulphide interchange reactions during storage which lead to protein cross linking aggregation and network formation. The hard texture development in protein rich bar may also be due to the migration of moisture as well as formation of most ordered secondary structure and lower

Table 6 Changes in sensory scores of Composite cereal bar during storage at ambient temperature (15–34°C)

Attributes	Packaging materials	Storage period (months)			
		Initial	3M	6M	9M
Colour	PP	7.7^{a}	7.5^{bx}	7.3^{cx}	7.1^{dx}
	PFP		7.6^{axy}	7.4^{bxy}	7.1^{cx}
	MP		7.7^{ay}	7.5^{by}	7.2^{cx}
	MP Vac		7.7^{ay}	7.5^{by}	7.2^{cx}
Aroma	PP	7.6^{a}	7.4^{bx}	7.2^{cx}	7.1^{cx}
	PFP		7.5^{axy}	7.3^{bxy}	7.2^{bxy}
	MP		7.5^{axy}	7.3^{bxy}	7.2^{bxy}
	MP Vac		7.6^{ay}	7.4^{by}	7.3^{by}
Taste	PP	7.8^{a}	7.4^{bx}	7.3^{bcx}	7.2^{cx}
	PFP		7.5^{bxy}	7.5^{by}	7.3^{cxy}
	MP		7.6^{by}	7.5^{by}	7.3^{cxy}
	MP Vac		7.6^{by}	7.6^{by}	7.4^{cy}
Texture	PP	7.7^{a}	7.4^{bx}	6.1^{cx}	5.2^{dx}
	PFP		7.4^{bx}	6.8^{cy}	5.7^{dy}
	MP		7.4^{bx}	6.7^{cy}	5.7^{dy}
	MP Vac		7.5^{bx}	6.8^{cy}	6.0^{dz}
Over all acceptability	PP	7.9^{a}	7.4^{bx}	6.1^{cx}	6.0^{cx}
	PFP		7.5^{bxy}	7.2^{cy}	6.5^{dy}
	MP		7.5^{bxy}	7.3^{cy}	6.5^{dy}
	MP Vac		7.6^{by}	7.5^{cz}	7.2^{cz}

Mean values with different superscripts (a–d) in rows and (x–z) in columns are significantly different ($p \leq 0.05$).

Values are mean±standard deviation of three measurements

Table 7 Changes in sensory scores of Composite cereal bar during storage at 37⁰C

Attributes	Packaging materials	Storage period (months)			
		Initial	3M	6M	9M
Colour	PP	7.7^{a}	7.4^{bx}	7.3^{bx}	6.9^{cx}
	PFP		7.5^{bxy}	7.3^{cx}	6.9^{dx}
	MP		7.5^{bxy}	7.4^{bx}	6.9^{cx}
	MP Vac		7.6^{ay}	7.4^{bx}	7.1^{cy}
Aroma	PP	7.6^{a}	7.3^{bx}	7.1^{cx}	6.7^{dx}
	PFP		7.4^{bxy}	7.2^{cxy}	6.8^{dxy}
	MP		7.4^{bxy}	7.2^{cxy}	6.8^{dxy}
	MP Vac		7.5^{ay}	7.3^{by}	6.9^{cy}
Taste	PP	7.8^{a}	7.4^{bx}	7.2^{cx}	7.1^{cx}
	PFP		7.4^{bx}	7.3^{bcxy}	7.2^{cxy}
	MP		7.4^{bx}	7.3^{bcxy}	7.2^{cxy}
	MP Vac		7.5^{bx}	7.4^{bcy}	7.3^{cy}
Texture	PP	7.7^{a}	7.2^{bx}	5.5^{cx}	5.0^{dx}
	PFP		7.3^{bxy}	6.3^{cy}	5.2^{dyz}
	MP		7.3^{bxy}	6.3^{cy}	5.2^{dyz}
	MP Vac		7.4^{by}	6.7^{cz}	5.1^{dxz}
Over all acceptability	PP	7.9^{a}	7.3^{bx}	5.9^{cx}	5.0^{dx}
	PFP		7.4^{bxy}	7.1^{cyz}	5.5^{dy}
	MP		7.4^{bxy}	7.0^{cy}	5.6^{dy}
	MP Vac		7.5^{by}	7.2^{cz}	5.9^{dz}

Mean values with different superscripts (a–d) in rows and (x–z) in columns are significantly different ($p \leq 0.05$)

Values are mean±standard deviation of three measurements

Table 8 Microbiological profile (CFU/g) of Composite cereal bar during storage at ambient temperature (15–34°C) and 37°C

Storage period	Storage temperature	Standard plate count	Coliforms	Yeast & molds
Initial	–	6×10^{1}	ND	ND
6M	RT	4×10^{1}	ND	ND
	37°C	1.1×10^{2}	ND	ND
9M	RT	ND	ND	ND
	37°C	ND	ND	ND

surface hydrophobicity of protein particles (Simon et al. 2009). Besides this, maillard reactions between reducing sugars and reactive lysine residue play a part in the hardening of a protein bar (Gerard 2002). Initially composite cereal bar had an overall acceptability score of 7.9 on 9 a point Hedonic scale, hence an over all acceptability score of 7.0 was taken as a cut off for accepting the shelf-life of the bar. Based on this criterion, composite cereal bar remained shelf stable for 3 months in PP and 6 months in PFP, MP and MP vacuum packing at ambient temperature and 37°C. The increase in chemical parameters like PV, FFA, TBA and browning index negatively correlated to overall acceptability scores ($r \geq 0.92$).

During 9 months of storage as shown in the Table 8, composite cereal bar remained microbiologically stable and acceptable.

Conclusion

It is evident from the foregoing discussion that a nutritious bar can be prepared by using wheat semolina, corn flour, wheat flour, soy concentrate, soy isolate, cocoa powder and a binder containing corn syrup, glucose syrup, sugar and soy lecithin with a shelf life of 6 months. The metallised polyester film with vacuum was found most suitable for packing bars w.r.t its stability and acceptability. Development of hard texture during storage is the limiting factor for shelf life, though the product remained chemically and microbiologically safe and stable during entire storage.

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