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Effect of Packaging and Storage on Quality of Pearl Millet based Expanded Snack

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ABSTRACT

Pearl millet based ready-to-eat expanded snack was evaluated for stability during storage for 90 days in three different packages at ambient condition. The quality parameters of the product like moisture content, protein and iron contents, phytic acid, FFA and PV values, microbial counts and sensory parameters (both objective and subjective) were determined during storage. The moisture content, phytic acid, FFA and PV, microbial counts increased with increase in storage period whereas protein and iron contents, sensory parameters decreased. All the parameters indicated loss in quality. However, overall quality and acceptability of the product remained acceptable throughout the storage period. Further, the quality of product was better maintained in Al laminates than LDPE.

KEYWORDS

Storage; Packaging material; Expanded snacks; Phytic acid; FFA; PV

INTRODUCTION

The market of snack food industry including semi - processed/cooked and ready to eat foods was around INR 82.9 billion in 2004 to 2005 and is rising rapidly with a growth rate of 25% [1]. With the changing life styles and the busy schedules of working peoples, high mobility groups, change in eating habits of children, the demand for semi - processed cooked/ready to eat food has increased tremendously. According to the report (2004) of Euromonitor International, a market research company, the amount of money Indians spend on meals outside the home has more than doubled in the past decade, to about US$ 5 billion a year and is expected to double again in coming few years. Value addition of food products is expected to increase from the current 8% to 35% by the end of 2025. Indian snack food market is one of the largest snack markets in the world (www.mofpi.nic.in) [2]. Snack food consumption is becoming popular among the groups of children. Most of the snacks available in the markets are mainly of cereals based which are high in calories and low in protein contents. So, to improve nutritive value to these snack foods and/or to correct nutrient inadequacies in food supply, development and production of snack foods from raw materials rich in essential nutrients (balanced protein and micronutrient) is of concern now-a-days.

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Therefore, RTE expanded snack was developed with good nutritional quality using pearl millet, green gram and quality protein maize. Since the product is expected to pass through a long chain during distribution and consumption, evaluation of its shelf life is very important. Shelf-life studies provide important information to product developers enabling them to ensure that the consumer will get a high quality product for a significant period of time after production. The shelf-life of food depends upon several factors like the food itself, packaging, temperature, and humidity etc.

The objective of this study was to evaluate the shelf life of the pearl millet based expanded snack in different packaging materials during storage at ambient condition. The changes in different quality parameters during storage were determined too.

MATERIAL AND METHODS

An expanded ready-to-eat snack was developed for school going children (5 years - 15years) as per ICMR guidelines using the blend of pearl millet (60%), QPM (30%) and green gram (10%) through extrusion processing. The shelf life of the snack developed under optimized conditions i.e., 13% M.C., 470 RPM, 128°C was evaluated. Two different packages namely, low density polyethylene (LDPE) of thickness 30 µm thickness and Al laminated polyethylene (60 µm thickness) were used for packing of snack.

Storage study of extruded snacks

Shelf-life of the extruded snacks, packed in three different packages (Figure 1) viz. low density polyethylene (LDPE) of 30 µm thickness (represented as P1 in text) and Al laminated polyethylene of 60 µm thickness (represented as P_2 in text) was studied for 3 months duration at ambient condition (maximum temperature 31.5 ± 2.75°C, minimum temperature 18 ± 6°C and 70 ± 10% RH. The samples were withdrawn at the intervals of 15 days up to 90 days and analysed for moisture, protein, iron, phytic acid, texture, colour, FFA, peroxide value, microbial count and sensory qualities.

Figure 1: Optimized extruded snack packed in different packaging materials.

Permeability of packaging materials

Water vapour permeability of the packages was measured using the method described by Jaya and Das [3]. The water vapour permeability (kilogram per square meter per day per pascal) of the packaging materials was computed using Equation 1.

$$K_p = \frac{(dw/d\theta_p)}{(A_p P^*)} \quad (1)$$

where, $dw/d\theta_p$ is the slope of the straight line plot between the time, θ_p (day) and weight (kilograms) of the silica gel kept within the packaging materials, A_p is the surface area of the packaging material (square meter), P^* is the saturation vapour pressure of water at T°C (pascal), and T is average temperature (38°C).

Moisture content

Moisture content of the snack was determined by the hot air oven method [4]. Weighed amount (10 g) of samples were taken in a clean, dried and pre-weighed aluminum dishes. The contents were dried in an oven at 100 ± 1°C for 4 hours - 5 hours or till constant weight was obtained. Dried samples were transferred to desiccators, cooled and weighed. Percentage loss in weight was taken as moisture content of sample.

Determination of phytic acid

Phytic acid was extracted in 0.5 M nitric acid and determined colorimetrically by the method described by Davies & Reid [5].

Estimation of protein

Crude protein was estimated using UDK 152 automatic distillation & titration unit (VELP Scientifica make). One gram sample was taken in the tube and mixed in the digestion mixture properly and kept it for 30 minutes for digestion. The digested mixture was used for protein analysis. The instrument directly displayed the values of % protein in the sample.

Estimation of iron

One gram of sample was added with 5 ml of HNO_3 and left overnight for pre-digestion. The samples were digested according to the procedure given by Jackson [6] using triacid mixture of nitric acid, perchloric acid and sulphuric acid in ratio (10:1:4), until it crystallized and transparent colour of the acid was obtained. Then water was added to the transparent solution placed in the conical flask, shaken well and filtered the solution. Thereafter, added the double distilled water to make the volume up to 50 ml. The absorbance in atomic absorption spectrophotometer (ZEEnit- 700) was noted as iron and zinc contents.

Free fatty acids

FFA content was determined using AOAC (1984) method of samples. FFA value was calculated using Equation (2):

$$\text{FFA (as \% oleic acid)} = \frac{\text{Titre value} \times \text{normality of NaOH} \times 0.282 \times 100}{\text{Weight of oil in miscella}} \quad (2)$$

Peroxide value

For peroxide value, 1 g of oil extracted from snack was taken in a conical flask; 15 ml of solvent (acetic acid and chloroform 3:2) was added. Then 1 ml of potassium iodide solution was added and allowed to stand for 5 minutes. This was followed by addition of 35 ml of water and the liberated iodine was titrated with 0.1 N sodium thiosulphate solution using starch as an indicator [7] (Equation 3):

$$\text{PV meq/ kg fat} = \frac{\{\text{Sample titre - Blank titre}\} \times \text{normality of sodium thiosulphate solution} \times 1000}{\text{weight of fat taken}} \quad (3)$$

Texture

Crispness and hardness are crucial textural characteristics of extruded snack food products. The textural properties of extrudates were measured using a texture analyser (Model *TA + Di*, scientific micro systems, UK) attached with 25 kg load cell. A 2 mm cylindrical probe (P2) was used to determine the hardness. The test was carried out using test speed of 0.5 mm/s and compression distance of 90% of the product size. A force-time curve was recorded and analysed. Ten randomly collected samples were measured for each extrusion condition. Hardness was measured as the maximum force in the force-time curve whereas the crispness of the extrudates was determined by counting the number of positive peaks in the curve [8].

Microbial analysis

Sample was weighed aseptically, macerated using sterile pestle and mortar and suspended uniformly in sterile distilled water. To make 1:10 dilution, 1 ml of water sample was added to test tube containing 9 ml of appropriate media with the help of sterile pipettes and mixed thoroughly by shaking in front of flame inside the laminar flow. Subsequent dilution of 1:100 was made by transferring 1 ml suspension from 1:10 dilution tube to test tube containing 9 ml of appropriate media.

Total plate count and yeast mould count were determined as per the standard methods given in APHA [9]. Samples were incubated in duplicate plates of suitable media and incubated at recommended temperatures. The presumptive coliform test was used to detect the presence of coliforms in the sample.

Sensory evaluation

Sensory quality is the combination of different senses of perfection coming into play in choosing and eating a food. It is important to both the consumers and processor. The acceptability of samples were determined on a 9 point hedonic scale as per IS standard (9 = "like extremely", 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like nor dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much, and 1 = "dislike extremely"). All the extruded samples were subjected to sensory evaluation using untrained panel (age group 25 years to 45 years). The panel consisting of 10 judges was requested to record their ratings for different attributes like colour, taste, appearance, texture and overall acceptability. The data thus obtained were analysed statistically using ANOVA technique [10].

Statistical analysis

The data for each determination was collected in triplicate. The data were analysed using the technique of analysis of variance [11]. The effects were tested for significance at $P \leq 0.05$ using SPSS 16.0. Pairwise comparisons were made by Post-Hoc in SPSS.

3. RESULTS AND DISCUSSION

Permeability of packaging materials

The permeability of packaging materials, for water vapour, were experimentally found and used for describing the moisture uptake by the extruded snacks during storage. Cumulative moisture gain by the silica gel kept in the packaging materials at 90% relative humidity and 38°C is shown in Figure 2. The permeability (K_p) of the packaging materials was calculated using (Equation 1) and the values are shown in the Table 1. LDPE had higher water vapour permeability than Al laminates.

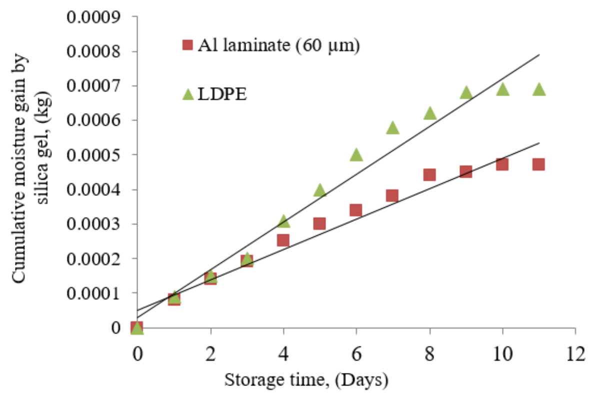

Figure 2: Cumulative moisture gain by silica gel through different packaging materials with time of storage in controlled environment.

Packaging Material	$dw/d\theta_p$ (kg water/day)	A_p (m^2)	P* (Pascal)	K_p (kg m^{-2} day^{-1} pa^{-1})
LDPE, 30 μm Thickness	7.4×10^{-5}	0.0154	6539.03	7.34×10^{-7}
Al Laminate, 60 μm Thickness	5.1×10^{-5}	0.0154	6539.03	5.06×10^{-7}

Table 1: Permeability of different packaging material.

Moisture content

Table 2 represents the effect of packaging material and storage period on the moisture content of the extruded snack.

Storage Days	Moisture Content (%)		Mean	Phytic Acid (mg/100)		Mean
	P1	P2		P1	P2	
0	3.10	3.10	3.10	378.00	378.00	378.00
15	3.20	3.10	3.15	382.00	385.00	383.50
30	3.50	3.20	3.35	391.00	388.00	389.50
45	4.00	3.50	3.75	400.00	391.00	395.50
60	4.30	3.80	4.05	428.00	399.00	413.50
75	4.80	4.00	4.40	443.00	413.00	428.00
90	5.20	4.10	4.65	458.00	425.00	441.50
Mean	4.01	3.54		411.43	397.00	
CD (*p* ≤*0.05*)	Packaging Material 0.074 Storage Days 0.138 Interaction (P × S) 0.196			Packaging Material 1.883 Storage Days 3.524 Interaction (P × S) 4.983		

Table 2: Effect of packaging materials and storage days on moisture content and phytic acid of extruded snacks.

Packaging material was found to have a significant effect on the moisture content of the snack. A consistent increase in moisture contents of snacks was recorded during the storage period. In the LDPE packed snack, the moisture content increased from 3.1% to 5.2% whereas in Al laminated packets the increase was from 3.1% to 4.1%. Snacks packed in laminate pouches absorbed less moisture during storage due to the less water vapour permeability of the aluminum foil (Table 1).

Storage period was found to have a notable effect on the moisture content of snacks. The mean moisture content of the snacks at the beginning of the storage was 3.1% which increased significantly to 4.46% after the storage period of 90 days. The interaction effect of packaging material and storage time on moisture content of the snacks was also found to be significant ($P \leq 0.05$).

Phytic acid

Phytic acid chelates important minerals, and inhibits enzymes required for digestion, including pepsin, needed for breakdown of protein in the stomach and amylase, needed for the breakdown of starch into sugar. Trypsin, needed for protein digestion is also inhibited by phytates [12]. Thus, the phytic acid has powerful anti-nutritional effects. The diet high in phytate-rich grains lead to tooth decay, nutrient deficiencies, lack of appetite and digestive problem.

The effects of packaging materials, storage period and their interaction were found to be significant on phytic acid content of extruded snacks (Table 2). The increases in the mean value of phytic acid were 8.84% in LDPE packets whereas 5% and 5.25% in case of Al laminates respectively. The increase in phytic acid might be due to increase in moisture content of the product. The enzyme phytase is sensitive to temperature and humidity and hence susceptible to degradation during storage [13]. Due to degradation of phytase, there is increase in phytic acid. However, the values of phytic acid during the storage period of 90 days remained less than 600 mg/100g, which was found to be critical limit by the author for bitter taste development in the pearl millet flour.

Protein and iron

The protein content of stored snacks showed a decreased from 13.2% to 13.1% (0.76%) during 90 days of storage. The decrease in protein content of the stored snacks might be the interaction with free fatty acids liberated from phospholipids and with lipid oxidation of the product, and cross-linking by Millard reaction as suggested by Lawal [14]. Butt *et al.* [15] studied the effect of moisture and packaging materials during storage of wheat flour and observed decrease in protein content. They attributed the decrease due to increase proteolytic activity with increase in moisture content of the samples. Akhtar *et al.* [16] studied the storage stability of chemically treated mango pulp and reported reduction in protein content through the 90 days of storage period.

The effect of packaging materials, storage period and their interaction were found to be significant on protein and iron contents of extruded snacks (Table 3).

Storage Days	Protein Content		Mean	Iron		Mean
	P1	P2		P1	P2	
0	13.20	13.20	13.20	5.16	5.16	5.16
15	13.18	13.19	13.18	5.14	5.16	5.15
30	13.15	13.19	13.17	5.13	5.13	5.13
45	13.14	13.17	13.16	5.10	5.11	5.11
60	13.14	13.17	13.16	5.01	5.03	5.02
75	13.14	13.15	13.14	5.00	5.00	5.00
90	13.10	13.15	13.13	5.00	5.00	5.00
Mean	13.15	13.17		5.08	5.09	
CD (p ≤0.05)	Packaging Material 0.005 Storage Days 0.009 Interaction (P × S) 0.012			Packaging Material 0.002 Storage Days 0.004 Interaction (P × S) 0.005		

Table 3: Effect of packaging materials and storage days on protein and iron of extruded snacks.

The iron content of extruded snacks stored in different packaging materials decreased from 5.159 mg/100 g to 5.0 mg/100 g, 5.085 mg/100 g and 5.010 mg/100 g in LDPE and Al laminates respectively. Results are in line with Rubin *et al*. [17] and Misfa *et al*. [18] who too observed reduction in iron content during storage of cereal based products and wheat chapati.

FFA and PV

The packaging material and storage period tangibly affected free fatty acid and peroxide value of stored extruded snacks (Table 4). Packaging manifested a conspicuous effect on the FFA. The FFA was higher in the snack packed in LDPE pouches, than the laminate pouches as evident from Table 4. Kaur [19] too reported that formation of FFA was higher in cookies stored in LDPE as compared to those stored in aluminium laminates. This could be due to the fact that aluminium laminates protect biscuits against light, which acts as catalyst for oxidation.

Storage Days	FFA, %		Mean	PV		Mean
	P1	P2		P1	P2	
0	0.36	0.36	0.36	0.32	0.32	0.32
15	0.42	0.38	0.40	0.48	0.38	0.43
30	0.55	0.44	0.50	0.52	0.48	0.50
45	0.68	0.57	0.63	0.96	0.87	0.92
60	0.79	0.69	0.74	1.25	1.42	1.34
75	1.06	0.96	1.01	2.10	1.74	1.92
90	1.54	1.22	1.38	2.42	2.10	2.26
Mean	0.36	0.36	0.36	1.15	1.04	
CD (*p ≤0.05*)	Packaging Material 0.013 Storage Days 0.024 Interaction (P × S) 0.034			Packaging Material 0.077 Storage Days 0.143 Interaction (P × S) 0.203		

Table 4: Effect of packaging materials and storage days on FFA and PV of extruded snacks.

Storage period also had perceptible effect on the FFA contents of snacks. There was a significant increase in the FFA with storage days. The increase may be attributed to the increase in the moisture content of the sample leading to the fat hydrolysis. Singh *et al*. [20] too found increase in free fatty acid content of soy-fortified biscuits with storage period and ascribed the increase to the fat hydrolysis. It has been suggested that in fried snacks if FFA > 1%, product is not fit for consumption [21]. However, no off/rancid smell in the snacks was observed in the study despite FFA being 1.54% after 90 days of storage.

Peroxide values (PV) measure the content of hydroperoxides and are used as indicators of lipid oxidation [22]. The peroxide value of the extruded snack samples increased significantly (P ≤0.05) from 0.5 to 2.35 meq/kg during storage of 90 days (Table 4). Peroxide value increased with increase in storage period. But the product quality remained well during 90 days storage, which was further verified through sensory evaluation. The peroxide level of < 5 meq/kg of oil [23,24] has been suggested to be acceptable for consumption of product. However, the finding was not in line with the Tiwari *et al*. [25], who found that that if the peroxide value of snacks (prepared with rice broken and legume) increased more than 2 meq/kg of oil, then product developed a slight rancid smell affecting its sensory quality. However, in the present study, no rancid smell was observed in the product up to 90 days even though the value of PV was more than 2 meq/kg of oil. It was also inferred from the study that the better quality of the product can be retained in Al laminated packets than LDPE as revealed by the FFA and the PV values.

Texture of snacks

Crispness and hardness are important sensory attributes for expanded products on which the consumer acceptability of the products depend. It is therefore important to control these properties during processing and storage.

The packaging material and storage period both had significant effect on crispness and hardness of snacks (Table 5). The value of crispness (number of peaks) and hardness (peak force) varied from 441 to 330 and 1.96 N to 1.54 N. The higher loss in crispness and hardness was observed in case of LDPE packed snacks (33.63% in crispness whereas 27.27% in hardness). This is mainly due to gain in moisture content. Same reason was also cited by Primo-Martín and Van-Vliet [26]. The crispness and hardness of the snacks were found to be high throughout the storage period in Al laminated packets whereas in case of LDPE, a noticeable drop was observed after 60 days, which was primarily due to more gain in moisture content.

Storage Days	Crispness (No. of Peaks)		Mean	Hardness (Peak Force), N		Mean
	P1	P2		P1	P2	
0	441.00	441.00	441.00	1.96	1.96	1.96
15	432.00	439.00	435.50	1.91	1.93	1.92
30	416.00	434.00	425.00	1.83	1.89	1.86
45	402.00	427.00	414.50	1.76	1.86	1.81
60	370.00	410.00	390.00	1.62	1.81	1.72
75	347.00	405.00	376.00	1.59	1.78	1.69
90	330.00	401.00	365.50	1.54	1.73	1.62
Mean	391.14	422.43		1.74	1.85	
CD ($p \leq 0.05$)	Packaging Material 5.349 Storage Days 10.007 Interaction (P × S) 14.151			Packaging Material 1.348 Storage Days 2.059 Interaction (P × S) 3.566		

Table 5: Effect of packaging materials and storage days on crispness and hardness of extruded snacks.

Microbial quality

The data presented in Table 6 reveals the influence of packaging material and storage period influenced on the microbial quality of extruded snacks. The total plate count on nutrient agar were found as 5.3×10^3 cfu/g and 5×10^3 cfu/g, the yeast and mold counts were 3.52×10^2 cfu/g, and 3.46×10^2 cfu/g in the extrudates packed in LDPE and Al-laminated packages respectively after 90 days of storage. As per Indian standard, the standard total bacterial count/g (cfu/g) should not be more than 5×10^4 in ready-to-eat protein rich extruded snacks [27]. The studies indicated that the extruded snacks packed in the 3 selected packaging materials had microbial load within the permissible limits at room temperature throughout the storage period, which showed the stability of the product as snacks. Packaging material had no significant effect on the microbial quality (TPC and yeast and mold count) of snacks, however, growth was observed more in snacks packed in LDPE than the laminate packed snacks. Storage period showed significant effect on the microbial population of snacks. The storage mean total plate count increased from 23×10^2 cfu/g to 51.5×10^2 cfu/g and yeast and mold from 1.037×10^2 cfu/g to 3.373×10^2

cfu/g after 90 days of storage. The increase in microbial load as the storage period lengthened might be due to a corresponding increase in moisture content during storage.

Storage Days	Total Plate Count		Mean	Yeast and Mold Count		Mean
	P1	P2		P1	P2	
0	ND	ND	--------	102	104	103.7
15	25×10^2	21×10^2	23×10^2	146	185	165
30	27×10^2	29×10^2	28×10^2	186	210	213.7
45	37×10^2	35×10^2	36×10^2	260	290	276.7
60	39×10^2	38×10^2	38.5×10^2	285	255	277.7
75	48×10^2	45×10^2	46.5×10^2	305	283	299.3
90	53×10^2	50×10^2	51.5×10^2	352	346	337.3
Mean	33×10^2	31×10^2		233.7	239	
CD ($p \leq 0.05$)	Packaging Material NS Storage Days 574.807 Interaction (P×S) NS			Packaging Material NS Storage Days 33.56 Interaction (P×S) NS		

Table 6: Effect of packaging materials and storage days on microbial quality of snacks.

Sensory attributes

It is clear from Table 7 that the sensory attributes decreased during storage. The decrease was noticeable after 75 days in all the packages. The snacks packed in LDPE showed relatively rapid deterioration between 60 days to 90 days of storage and had a significant softer texture (Table 7), as also evidenced by objective measurement of texture. This was mainly due to gain in moisture content of about 2% by the product.

The product nature become soggy gradually [28] if the moisture is gained by the products from air. According to Tiwari *et al.* [24], the moisture gain > 1.5% is not suitable for crispness in case of storage studies of dried snacks. Moisture gain in LDPE packed sample exceeded this limit of moisture content on 75th day. However, the sensory parameters like appearance, taste, texture as well as overall acceptability of snacks were found acceptable throughout the storage period of 90 days in all packaging materials.

Storage Days	P1				P2			
	Appearance	Texture	Taste	Overall Acceptability	Appearance	Texture	Taste	Overall Acceptability
0	8.23 ± 0.03	8.15 ± 0.12	8.31 ± 0.05	8.54 ± 0.43	8.23 ± 0.03	8.15 ± 0.12	8.31 ± 0.05	8.54 ± 0.43
15	7.25 ± 0.05	7.03 ± 0.02	7.21 ± 0.06	8.17 ± 0.03	7.24 ± 0.04	7.12 ± 0.03	7.28 ± 0.06	8.29 ± 0.24
30	7.21 ± 0.04	7.09 ± 0.03	7.29 ± 0.05	7.85 ± 0.06	7.25 ± 0.05	7.03 ± 0.02	7.21 ± 0.06	7.45 ± 0.03
45	7.16 ± 0.04	7.00 ± 0.04	7.21 ± 0.04	7.10 ± 0.04	7.18 ± 0.04	7.0 ± 0.04	7.16 ± 0.06	7.11 ± 0.03
60	7.11 ± 0.04	6.91 ± 0.05	6.8 ± 0.06	6.98 ± 0.03	7.12 ± 0.04	7.0 ± 0.06	7.15 ± 0.06	7.05 ± 0.04
75	6.5 ± 0.04	6.5 ± 0.01	6.5 ± 0.03	6.63 ± 0.03	7.02 ± 0.02	6.91 ± 0.05	6.80 ± 0.06	6.98 ± 0.03
90	6.0 ± 0.01	6.7 ± 0.05	6.48 ± 0.04	6.42 ± 0.04	6.38 ± 0.01	6.7 ± 0.05	6.48 ± 0.04	6.42 ± 0.04
CD ($p \leq 0.05$)	NS	0.72	0.86	0.39	NS	0.21	NS	0.29

Table 7: Sensory score of RTE extruded snacks during storage packed in different packages.

CONCLUSION

Storage study of pearl millet based snacks for 90 days showed its storage stability at ambient condition. It was found that the Al laminates (P2) were more effective compared to the LDPE packages (P1) in retaining quality of snacks. Microbiological quality of the product indicated significant (P ≤0.05) increase in counts during storage of 90 days, although the total counts were within acceptable limit during the entire period of storage. Protein and iron contents decreased during storage but phytic acid increased during storage. Sensory evaluation indicated decrease in overall acceptability but acceptable throughout the storage period.

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