Evaluation of quality changes in nutritionally enriched extruded snacks during storage

Upasana Yadav^{1,3} · Ram Ran Bijoy Singh¹ · Shalini Arora²

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Abstract The aim of this study was to evaluate changes in the physical, chemical and sensory properties of a low fat-high protein, fiber enriched extruded snack. It was packed in metalized polypropylene/polyethylene (PP/PE) laminate pouches, under modified atmosphere packaging (MAP) with nitrogen flushing and without nitrogen flushing (control) and stored for a period of 22 weeks at 37 ± 1 °C and 80% RH. MAP had significant impact on the moisture content, a_w , TBA value, Hunter L* value and crispiness of the extruded snacks during storage. The moisture content of the snack significantly increased from 3.68 to 5.16% in control and from 3.66 to 4.31% in MAP. The oxidative rancidity in terms of TBA value of control sample increased from 0.02 to 0.07 while the product packaged under MAP, the value increased to 0.056. The sensory scores for flavour, color and appearance, texture and overall acceptability (OA) of the product significantly decreased during storage, but the product stored under MAP had better flavor (6.51) and OA scores (6.85) compared to control (5.58 and 6.04, respectively), after 22 weeks of storage. Thus, MAP tended to retard the storage induced changes and it could suitably be utilized for the delivery of low fat-high protein, fiber enriched

extruded snacks to the consumer, while keeping the sensorial acceptance of the product for 5 months.

Keywords Extruded snacks · Low fat-high protein · Nitrogen flushing · Physico-chemical parameters · Sensory scores

Introduction

With the advent of new technology and innovative advancement, an era has arrived where there is an increasing number of nuclear families and more working women in the society. Now people are getting lesser time for preparation of food. Further, lifestyle of the people has changed drastically that have resulted in varying eating habits and diverse choices of foods offered to each family member. Nowadays' people are more health conscious and moving towards nutritious food products with good taste. Extruded snacks are widely consumed all over the world and the characteristics of the preferred product are expanded snacks having porous crunchy texture, low density, porous make-up with thin walled air pockets (Thakur et al. 2017). For the preparation of extruded snacks, the starch-based material is usually preferred (Kaur et al. 2015) for its porous and crispy texture but nutritional quality of the snacks can be enhanced by incorporating raw material that are rich in protein (Yadav et al. 2016) and dietary fibre (Fleischman et al. 2016) or other ingredients that rich in lycopene (Shoar et al. 2010). Further, the particle size of the raw material affects the physico-chemical and rheological properties of extrudates (Shevkani et al. 2014). Therefore, the snacks could be considered under functional food and not the “junk” foods that provides specific health benefits in addition to good taste.

✉ Upasana Yadav
upasana.ndri@gmail.com

¹ Dairy Technology Division, National Dairy Research Institute (ICAR), Karnal 132001, Haryana, India

² College of Dairy Science and Technology, Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar 125004, Haryana, India

³ Present Address: Department of Food and Nutrition, Institute of Home Economics (University of Delhi), F-4, Hauz Khas, New Delhi 110016, India

Food manufacturers are always worried about the shelf stability and quality degradation of their food items during storage. Acceptability of old food items (product kept on shelf for longer time) or products having lesser shelf life is very less compared to fresh or immediately packed product. These products are prone to physico-chemical or microbial degradation if stored for prolonged time. Similarly, expanded food products particularly extruded foods, are susceptible to lipid oxidation (Viscidia et al. 2004). Food items, particularly rich in fats are prone to oxidative rancidity that deteriorates the product quality (Gulla and Waghray 2012) and result in a change of flavour of the product (Rogalski et al. 2016) thereby decrease its shelf life. Therefore, it is essential to understand changes in quality parameters that influence the product quality at various storage conditions. It is also critical to know the responses or willingness of consumers towards the purchase of these products that can further tell about the market trend about the product. The sensorial acceptability in terms of color, flavor, texture, taste, and overall acceptability is directly influenced by lipid oxidation in the food due to the formation of peroxides, aldehydes and ketones. It is known that sensory properties of food change during its storage because of various chemical, microbiological and/or biochemical reactions that occur over that time.

Extrusion cooking is high temperature-short time (HTST) process. Enzymes like lipase gets denatured at high extrusion temperatures therefore it does not induce immediate degradation of lipids. On the contrary, susceptibility to lipid oxidation increases during storage. The major causes of lipid oxidation in extruded snacks foods during storage are low moisture content, increased surface area due to expansion, and higher levels of iron caused by wearing of the screw and barrel during extrusion (Viscidia et al. 2004). Further different flavoring component like spices and condiments (hydrophobic) are mixed in fats or oils and sprayed or distributed on the surface of extrudates to entrap the added flavors also undergoes deterioration during storage (Yuliani et al. 2006). Although very few studies pertaining to the shelf-life of indigenous snack foods and nutritionally enriched extruded snacks food (protein and fibre supplemented snack foods) have been reported (Patel et al. 2015; Dar et al. 2016), therefore this paper tended to focus on the storage induced changes in physico-chemical and sensory parameters of nutritionally enriched snacks under MAP.

Materials and methods

Raw materials

The various ingredients used in the formulation of nutritionally enriched extruded snack were procured from

different sources. These include: (1) Sweet potato from Regional Centre of Central Tuber Crop Research Institute—Bhubaneswar, Odisha, India; (2) Barley (DWRB-73) from Directorate of Wheat Research, Karnal, Haryana, India; (3) Paddy (PR-44) from Indian Agricultural Research Institute—Regional Centre, Karnal, Haryana, India. All these ingredients were cleaned, washed, dried, milled and ground to powder, followed by storage in air-tight containers, until further use. (4) Rennet casein was procured from M/s Modern Dairies Ltd., Karnal, Haryana, India, (5) Various spices (MDH Ltd., New Delhi) (6) Iodized Salt (Tata Chemicals Ltd., Gujrat), (7) Powdered sugar were purchased from the local market. All the spices and sugar were mixed in required amounts and sieved (2 mm) to remove impurities and maintain uniformity.

Packaging materials

Laminated pouches (PP/Metalized PP/LDPE) were obtained from the Experimental Dairy of National Dairy Research Institute, Karnal. The oxygen transfer rate (OTR) of the film was 3.748 cc/m²/24 h at 23 °C, 0% RH and 1 atm pressure and water vapor transmission rate (WVTR) was 0.737 gm/m²/24 h at 38 ± 1 °C and 90 ± 2% RH.

Experimental design for optimization of product

RSM with CCRD was used to optimize the levels of ingredients. The independent factors were levels of Sweet potato flour (A), Barley flour (B), Rice flour (C) and Rennet casein (D) in the mix. The response functions (y) were expansion ratio, bulk density, hardness, protein content, sensory attributes (color and appearance, flavor, texture and overall acceptability), L*, a* and b* values, water absorption index and water solubility index.

Preparation of extruded snacks

The extrudates were prepared using sweet potato flour, barley flour, rice flour and rennet casein as per methodology described in our earlier study (Yadav et al. 2016). The product was collected in perforated aluminum tray and dried for 30 min. at 60 °C to equilibrate moisture at 4%. The dried extrudates were spiced with various spices mixed in and studied for various parameters during storage.

Storage studies

Flavored/spiced extruded snack (50 g) was packaged in laminated pouches (PP/Metalized PP/LDPE) under two conditions i.e. atmospheric air and modified atmosphere (nitrogen flushing) (0.24% oxygen, 1.0% carbon dioxide and 98.76% nitrogen) and stored at 37±1 °C with 80% RH

(using saturated KCL solution). The samples were withdrawn at predetermined intervals and subjected to sensory, physical and chemical tests to determine the quality changes in the product during storage.

Physico-chemical analysis of the nutritionally enriched extruded snacks

Proximate analysis

Moisture, protein, crude fat and ash content were determined by standard procedures as described in AOAC (2000).

Hunter color analysis (L^ , a^* , b^* values)*

The color of the product was measured using a HunterLab Colorflex colorimeter (Hunter Associated Laboratory, Inc., USA) using the Universal software version 4.10. Measurement was made by taking finely ground sample in the glass sample holder up to 2 cm height followed by tapping for ten times on bench-top. Before the test, the instrument was calibrated with standard black and white tiles as specified by the manufacturer.

Water activity

Water activity (a_w) of extruded snack was measured using water activity meter. Prior to the measurement, the samples were tempered at 25 °C. Two grams of powdered sample was weighed in plastic dish supplied with the instrument and subjected to instrumental measurement for a_w .

Thiobarbituric acid (TBA) value

Extent of fat oxidation in the product was measured in terms of TBA value. The extraction method of Strange et al. (1977) was followed with slight modification. Two grams sample was mixed with 50 mL of 20% TCA (Trichloroacetic acid) and 50 mL distilled water, and the content was left undisturbed for 10 min. The content was then filtered through Whatman No. 1 filter paper. 5 mL filtrate was taken and mixed with 5 mL 0.01 M 2-Thiobarbituric acid in a test tube. The content was incubated in boiling water bath for 30 min followed by cooling to room temperature. Absorbance was measured at 532 nm. Blank was determined using distilled water in place of sample. TBA value was expressed as absorbance at 532 nm.

Texture profile analysis

Modified method of Onwulata et al. (2001) was used for determination of hardness and crispiness of extruded snack

using TA-XT2i (Stable Micro Systems, UK) Texture Analyzer fitted with a 25 kg load-cell. HDP/BSW (Warner–Bratzler Blade) was used as the probe. The pre-test speed was kept 2 mm/s, test speed 1 mm/s and post-test speed 2 mm/s. The peak force during compression of the product was taken as a measure of hardness. Ten measurements were conducted on an extrudate sample and the resulting force–time curves were examined to obtain mean hardness. Crispiness was calculated by the total numbers of positive peaks.

Sensory evaluation

Sensory evaluation was conducted on extruded snack samples throughout the storage period by 10 trained panel members of Dairy Technology division, NDRI, Karnal. The panelists were explained about the nature of experiment without disclosing the identity of the samples. The samples were evaluated after every 2 weeks interval for 22 weeks. Panelists were provided with a glass of water and instructed to rinse mouth between samples. They were given written instructions and asked to evaluate the products for acceptability based on its flavor, texture, taste, color and appearance and overall acceptability using nine-point hedonic scale (1 = dislike extremely to 9 = like extremely).

Statistical analysis

The analysis of results was performed using tools from Design Expert™ 7.0, Microsoft Excel 2010 and SAS Enterprise 5.1.

Result and discussion

Formulation of nutritionally enriched extruded snacks

Optimization of the product was done using RSM with CCRD. Input for levels was drawn from the fed range of 20–35 Sweet Potato Flour, 15–30 Barley Flour, 10–30 Rennet Casein and 30–40 Rice Flour; all being in parts. Corresponding thirteen responses recorded were, bulk density, expansion index, hardness, protein, Hunter color values (L^* , a^* and b^*) and sensory attributes namely flavor, color and appearance, texture (as perceived) and overall acceptability (OA) and water absorption index (WAI) and water solubility index (WSI). The optimized product was flavored with laboratory made spice mix and rice bran oil. The final product contained 3.66% moisture, 24.30% protein, 6.73% fat, 4.24% ash, and 61.07% carbohydrate. The total dietary fiber of the product was 3.89%.

The spiced extruded snack was packed and stored at 37 ± 1 °C and 80% RH (relative humidity) for storage studies.

Changes in the moisture content and water activity (a_w) of nutritionally enriched extruded snacks during storage

Moisture content is one of the most critical parameter as it affects the crisp texture that is a unique property of extruded snacks. Changes in moisture content during storage at 37 ± 1 °C are shown in Fig. 1a. The initial moisture content of the samples was 3.66%. Statistical analysis showed an incessant significant ($p < 0.05$) increase in mean values throughout the storage period for samples packed normal condition, with the highest mean (5.17%) being on 22nd week. A rather similar but inconsistent trend was observed for samples packed with

nitrogen flushing. During initial weeks, the moisture content was insignificantly different ($p > 0.05$) though it was increasing in storage. But from 16th week (3.85%) onwards, till 22nd week (4.31%), a continuous significant ($p < 0.05$) increase in moisture content of the samples packed in nitrogen was observed. Upon comparing the moisture content within the treatments, significant difference ($p < 0.05$) was observed across every week, with the lower mean being towards the nitrogen-flushed samples suggesting the % moisture uptake was comparatively lower in case of samples packed in modified atmosphere. Continuous uptake of moisture by the product throughout the storage period can be correlated with the hygroscopic nature and porous structure of the product (Nazir et al. 2017) and storage environment (temperature, relative humidity) as well as nature of packaging material (Nagi et al. 2012). An increase in moisture content in the ready to eat (RTE) extruded snacks during storage were reported by Alam et al. (2015). Dar et al. (2016) reported that the mean moisture content (%) of bran enriched extruded snacks increased from 4.42 to 5.38% during 6 months of storage period. Reddy et al. 2014 studied the changes in RTE extruded snack during storage and their results were in concurrence with the air spaces of the extruded products in a cross-sectional view. Control snack had more air cells in the cross-sectional view, followed by extruded products made from potato and taro. This indicated that more the air spaces in the extruded products, more the increase in moisture content of the RTE extruded products on storage.

Water activity (a_w) accounts for the intensity with which water associates with various non-aqueous constituents and solids. It is an important means of predicting and controlling the shelf life of food products. Water activity of the extruded snack packed under air and nitrogen flushing, gradually increased throughout the storage period; though not being significant ($p > 0.05$) (Fig. 1b). Initial a_w was 0.24 which increased to 0.46 and 0.44 on 22nd week, in air and nitrogen flushed samples, respectively. Upon comparing the mean values of a_w within treatments, not only significant difference ($p < 0.05$) was observed but also values were lower in the nitrogen-flushed samples for the entire storage period. Increase in water activity of high protein extruded snack over 6 months storage time was observed by Kreger et al. (2012). Nazir et al. (2017) and Hussain et al. (2015) also reported the increase in a_w of extruded snacks from 0.42 to 0.50 and 0.40 to 0.56, respectively, on 3 months storage. The increase in water activity of extrudates might be attributed to the humid environmental conditions (Hussain et al. 2015). Staleness starts occurring during storage, a process in which water is removed from starch, resulting in amylose and amylopectin recrystallization (Gray and Bemiller 2003).

Fig. 1 a Moisture content; b water activity; c TBA value of the MAP and control extruded snack stored at 37 ± 1 °C

Changes in TBA value of nutritionally enriched extruded snacks during storage

The extent of lipid oxidation in the extruded snack during storage was measured in terms of thiobarbituric acid (TBA) value. The results with respect to change in TBA value (in terms of absorbance) for extruded snack stored at $37 \pm 1^\circ\text{C}$ are illustrated in Fig. 1c. The TBA value of extruded snack packed under air, increased from initial value of 0.02–0.07 while in the other snack (packed under nitrogen), it increased from 0.02 to 0.05 at end of the storage period. There was a significant difference ($p < 0.05$) in TBA value between the two types of packaging conditions throughout storage (Fig. 1c). The significant interaction between storage period and type of packaging suggest that TBA value was generally higher in the air-packed product than the nitrogen-packed one, and that the rate of increase was also higher in former product. Similar trend was observed by Yashoda et al. (2008) where lower TBA values of egg chips were obtained when packed using nitrogen as compared to air pack. The increase in TBA value could be due to increase in TBA-reactive compounds resulted from lipid oxidation and production of volatile metabolites especially in products packed without nitrogen. The extrusion rate also affects expansion and products with a higher degree of expansion are more likely to have larger cells and thinner cell walls, thereby increasing oxygen exposure and making them more susceptible to oxidation. Gulla and Waghray (2012) observed an increase in the TBA value of a deep fat fried corn extrudates stored at room temperature. A study reported increase in TBA value from 0.02 to 0.08 mg/kg in extruded maize snack stored at 25°C for 20 weeks. Storage under vacuum or under modified atmosphere (carbon dioxide and nitrogen) extend the oxidative stability of commercial corn flour compared to the control, but carbon dioxide and nitrogen exhibited the most promising effects during the 160 days study at 55°C (Márquez-Castillo and Vidal-Quintanar 2011). The effectiveness of nitrogen flushed packaging is, of course, dependent on the barrier properties of the packaging material and the efficiency of producing a hermetic seal after packing.

Changes in hardness and crispness of the nutritionally enriched extruded snacks during storage

The change observed in the hardness of the product packed under different conditions over the storage period is represented in Fig. 2a. The mean value of hardness (air packed samples) reflected a gradual descent over the entire storage duration. An almost replica of the reduced mean values in hardness, as in air packaged snack, was observed in

Fig. 2 a Hardness; b crispness of the MAP and control extruded snack stored at $37 \pm 1^\circ\text{C}$

nitrogen-flushed product, too. The highest mean value of hardness (N) here was 20.61 ± 0.26 at 0th week and lowest mean value was 15.90 ± 0.01 on 18th week. No significant difference ($p > 0.05$) was revealed across the treatments until 10th week, after which the mean values were significantly different ($p < 0.05$) every week, exception being on 20th week. Similar results were found in a study done by Alam et al. (2015) on carrot pomace-chickpea incorporated rice based extruded snacks stored for 6 months. Kreger et al. (2012) observed decrease in energy required to break the samples (having 28% protein) as measured by texture analysis over 6 months of storage time. Decline in hardness of the product maybe correlated with the increase in moisture content as evident from Fig. 1a.

Crispness is one of the most important and desirable textural attributes in quality evaluation of extruded products (Robin et al. 2011). It is perceived through a combination of tactile, kinesthetic, visual and auditory sensations and represents the key texture attributes of dry snack products (Heidenreich et al. 2004) and it greatly affects the consumer acceptance of the product. The changes in crispness during storage of the extruded snack are presented in Fig. 2b. The crispness of the snack decreased significantly ($p < 0.05$) throughout the storage period in case of nitrogen-flushed packaging, from initial value 80.35 ± 0.10 in 0th week to 57.48 ± 0.22 in 22nd week. In case of air packed snack, there was steep decrease in crispness, though values were non-significant ($p > 0.05$)

throughout the period. Upon comparing the change in crispness between the treatments, it is observed that there was a statistically significant difference ($p < 0.05$) throughout the storage period starting from the 2nd week of storage. Also, in case of air packed storage the drop in the value of crispness was more compared to nitrogen-flushed product, i.e. from initial mean value 78.68 ± 2.06 in 0th week to 50.44 ± 0.92 in 22nd week. The decreased crispness could be due to increased moisture content as it plays a significant role on the texture of ready to eat products. It indicates that at high moisture content, the same snack would not appear to be brittle or crisp. This happens as the number of major peaks approaches zero at moisture content of about 10%, which indicates that the product had lost all its characteristic crispness (Mazumdar et al. 2006). Water leads to plasticization and softening of the starch–protein matrix and thus alters the strength of the product (Martinez-Navarraete et al. 2004). Crispness of cereals has been related to their water content or the water activity by Martinez-Navarraete et al. (2004) and Heidenreich et al. (2004). Heidenreich et al. (2004) studied the texture parameters of extruded rice crisps which were adjusted to water activities in the range of 0.05 and 0.65. It was concluded that the crispness is affected when the sample exceeds a critical water activity value which has been reported to be above 0.5. In our study, though the value of crispness decreased from the initial, but it was still acceptable as the water activity did not reach the critical level.

Changes in the Hunter color (L^* , a^* and b^* value) of nutritionally enriched extruded snacks during storage

Color is an important quality attribute directly related to the acceptability of the food. Color of the product may change during storage due to undesirable reactions such as Maillard browning and degradation of color pigments, depending upon storage conditions viz., temperature, packaging material etc. The changes in color characteristics during 22 weeks of storage period were monitored instrumentally in terms of Hunter L^* , a^* and b^* values. The results are depicted in Fig. 3a–c. The initial L^* value of the extruded snack was 60.65 and 60.52. The values were similar in range as reported by Thakur et al. (2017) for corn extrudates. It can be seen that the Hunter L^* value decreased from 60.65 ± 0.15 on 0th week to 57.86 ± 0.14 on 22nd week for snack packed and stored without nitrogen flushing. The decrease was significant ($p < 0.05$) after 2 weeks in the air-packed and then remained non-significant till 10th week. In case of nitrogen flushed sample the L^* value decreased from 60.52 ± 0.29 on 0th week to 59.06 ± 0.06 on 22nd week of storage, though the

Fig. 3 a Hunter L^* color values; b Hunter a^* color values; c Hunter b^* color values of the MAP and control extruded snack stored at $37 \pm 1^\circ\text{C}$

decrease was not statistically significant ($p > 0.05$) throughout. Though L^* value decreased in both the treatments, but statistically significant difference was noticeable only after 10th week which then remained consistent throughout. High iron content (7.76 mg/100 g) of extruded snack may have potentially increased the oxidation rate of the snack packed in atmospheric condition. Maillard browning resulting in darkness of products must have also accounted for the decrease in L^* values during the storage period (Jan et al. 2017). Gaspar et al. (2012) found significant reduction in β -carotene content during storage, resulting reduction in the Hunter L^* value of the product.

The Hunter a^* value decreased in both the treatments, but the decrease was not statistically significant ($p > 0.05$) across the treatments except for 8th, 10th and 16th week of storage. In case of air packed product, the decrease was

significant from the 2nd week of storage and the value decreased from initial 10.48 ± 0.29 on 0th week to 7.11 ± 0.11 on 22nd week. In case of nitrogen-flushed product, Hunter a^* value reduced from initial value of 10.15 ± 0.15 to final value 7.63 ± 0.31 . Although there was consistent numerical drop in a^* value over initial 8 weeks, significance ($p < 0.05$) was observed only after 10th week of storage. The values then remained non-significant till 16th week and then again dipped significantly ($p < 0.05$).

The Hunter b^* value showed a declining trend during storage. It decreased from the initial value of 42.05 ± 0.05 to 37.89 ± 0.10 and 37.94 ± 0.06 for the snack packed under air and under nitrogen, respectively. In case of nitrogen packed product, there was statistically significant ($p < 0.05$) decrease in b^* value after 10th week of storage. In case of air-packed product the decrease in b^* value was significant after 6 weeks (Fig. 3c). Within treatments, significant difference ($p < 0.05$) was observed from 4th to 18th week after which the difference was non-significant ($p > 0.05$). The overall decrease in Hunter b^* value could be due to degradation of curcumin (turmeric) used in the formulation. Wani and Kumar (2016) observed the similar pattern of decrease in b^* values of composite extruded snack during storage.

Similar results were reported by Sowbhagya et al. (2005) in soy-corn extruded snack coated with water-soluble turmeric colorant when packed in polypropylene and stored at 27 °C for 10 weeks due to degradation of curcumin in turmeric. However, some reports, discrete to the current results can also be found in literature by different workers, e.g. Yashoda et al. (2008) observed that air or nitrogen packing had non-significant effect on Hunter color values in egg chips prepared using millet, barley and sorghum, whereas noticeable changes were seen in the Hunter a^* and b^* values from the Hunter colorimeter measurement as observed by Kreger et al. (2012). The latter found that both values decreased during the storage time, resulting in an overall more faded color. He suggested that a lower positive Hunter a^* value means a less red and more green hue, and a lower positive Hunter b^* value means a less yellow hue. The Hunter L^* value did not significantly change, indicating the samples did not darken.

Changes in sensory attributes of nutritionally enriched extruded snacks during storage

Sensory evaluation plays a vital role not only in product development but also in determining the shelf life and acceptability of a product. If a product is nutritionally superior but has less acceptability in terms of taste and flavour, then the product does not hold any commercial significance (Alam et al. 2015). The results pertaining to

flavor and color and appearance scores of extruded snacks (without and with nitrogen flushing) during storage at 37 °C are presented in Table 1. It may be seen that sensory scores for flavor and color and appearance of product, in both types of packaging, declined progressively with the storage. Within the storage period, the flavor scores of air packed extruded snack did not have a significant difference ($p > 0.05$), over the first 10 weeks but significant difference was observed in each week, after the 14th week. The flavor scores declined from 7.96 ± 0.04 (0th week) to 5.58 ± 0.08 (22nd week) and was remarked unacceptable by the sensory panelists. The decline in flavor scores was comparatively less in nitrogen-flushed samples (7.90 ± 0.04 to 6.51 ± 0.03) than air-packed and also the product was acceptable by the panelists. Statistically prominent ($p < 0.05$) drop in flavor scores, within treatment as well as storage period, was observed from 10th week onwards. This trend of decrease in flavor scores can be corroborated with increase in TBA value, which indicates lipid oxidation that in turn leads to off flavor development, thus decreasing sensory scores of the product. The decline in the sensory scores was more in case of snacks packed without nitrogen flushing (Patel et al. 2015). It is known that during the storage of extruded products characterized by low water activity, a developed inter-phase contact surface and containing polyunsaturated fatty acids as well as other active biological substances, various unfavourable oxidation processes will occur, leading to a changes in taste of a food product (Barden and Decker 2013).

The color and appearance scores decreased from initial value of 8.00 to 6.43 ± 0.022 in the snack without nitrogen flushing and to 7.05 ± 0.01 in the one with nitrogen flushing. In case of air packed snack there was no significant ($p > 0.05$) change in color and appearance score till 12th week, after which the scores declined significantly ($p < 0.05$) every consecutive week. In case of nitrogen-flushed product, though there was an uneven trend in the significant difference, but sensory scores declined consistently throughout the storage period. However, the scores were higher than the air-packed samples at the end of the storage period. Decrease in sensory color and appearance score during storage are in corroboration with the result of Hunter L^* value, and the product appeared dull and darker. Raja et al. (2014) reported decline in sensory scores was also reported in Fish snacks.

Statistically, the storage period had significant effect on texture score of the extruded snack but no significant difference ($p > 0.05$) was found between the two types of packaging condition 20th and 22nd week being exception (Table 1). The texture score dropped from initial 8.10 ± 0.06 to 6.53 ± 0.17 in the extruded snack without nitrogen flushing and from 7.69 ± 0.06 to 7.25 ± 0.03 in

Table 1 Changes in the sensory scores of the MAP and control nutritionally enriched extruded snack stored at 37 ± 1 °C

Weeks	Flavor		Color and appearance		Texture		Overall acceptability	
	Control	MAP	Control	MAP	Control	MAP	Control	MAP
0	7.96 ^{aA} ± 0.04	7.90 ^{aA} ± 0.04	8.00 ^{aA} ± 0.00	8.00 ^{aA} ± 0.04	8.10 ^{aA} ± 0.06	8.09 ^{aA} ± 0.06	8.04 ^{aA} ± 0.01	7.99 ^{aA} ± 0.02
2	7.84 ^{aB} ± 0.01	7.93 ^{aA} ± 0.02	7.87 ^{aB} ± 0.02	7.94 ^{abA} ± 0.02	7.93 ^{aA} ± 0.02	8.12 ^{bA} ± 0.03	7.98 ^{aA} ± 0.01	7.90 ^{abA} ± 0.09
4	7.82 ^{aA} ± 0.02	7.91 ^{aA} ± 0.04	7.85 ^{aA} ± 0.03	7.85 ^{bA} ± 0.03	7.87 ^{aA} ± 0.04	7.99 ^{bA} ± 0.01	7.87 ^{aA} ± 0.03	7.93 ^{abA} ± 0.01
6	7.79 ^{aA} ± 0.06	7.97 ^{aA} ± 0.05	7.85 ^{aA} ± 0.03	7.92 ^{abA} ± 0.08	7.88 ^{aA} ± 0.02	7.87 ^{bA} ± 0.01	7.79 ^{aB} ± 0.01	7.99 ^{aA} ± 0.07
8	7.68 ^{aA} ± 0.02	7.74 ^{aA} ± 0.02	7.81 ^{aA} ± 0.01	7.85 ^{bA} ± 0.03	7.72 ^{bB} ± 0.01	7.90 ^{bcA} ± 0.01	7.56 ^{bB} ± 0.02	7.85 ^{abcA} ± 0.03
10	7.53 ^{aB} ± 0.02	7.72 ^{bA} ± 0.01	7.72 ^{abB} ± 0.02	7.82 ^{bA} ± 0.01	7.74 ^{bB} ± 0.02	7.85 ^{bA} ± 0.03	7.53 ^{bcB} ± 0.01	7.79 ^{bcA} ± 0.03
12	7.25 ^{bB} ± 0.03	7.57 ^{cA} ± 0.01	7.77 ^{aA} ± 0.01	7.82 ^{aA} ± 0.02	7.57 ^{cB} ± 0.01	7.87 ^{cA} ± 0.01	7.44 ^{bcB} ± 0.03	7.71 ^{cA} ± 0.01
14	7.20 ^{bB} ± 0.00	7.44 ^{dA} ± 0.03	7.67 ^{bA} ± 0.02	7.64 ^{cA} ± 0.07	7.45 ^{cA} ± 0.03	7.72 ^{dA} ± 0.07	7.37 ^{cA} ± 0.01	7.37 ^{dA} ± 0.07
16	6.83 ^{cB} ± 0.06	7.07 ^{dA} ± 0.04	7.45 ^{cA} ± 0.05	7.59 ^{cdA} ± 0.02	7.28 ^{dA} ± 0.03	7.50 ^{dA} ± 0.08	7.04 ^{dB} ± 0.03	7.31 ^{dA} ± 0.02
18	6.51 ^{dB} ± 0.03	6.78 ^{eA} ± 0.02	7.36 ^{dA} ± 0.03	7.50 ^{dA} ± 0.05	7.29 ^{dA} ± 0.12	7.49 ^{dA} ± 0.04	6.40 ^{eB} ± 0.05	7.09 ^{eA} ± 0.09
20	6.22 ^{eB} ± 0.07	6.71 ^{eA} ± 0.07	6.80 ^{eB} ± 0.05	7.32 ^{eA} ± 0.04	7.01 ^{eB} ± 0.01	7.32 ^{eA} ± 0.03	6.42 ^{eB} ± 0.16	6.96 ^{efA} ± 0.02
22	5.58 ^{fB} ± 0.08	6.52 ^{fA} ± 0.03	6.43 ^{fB} ± 0.02	7.06 ^{fA} ± 0.01	6.53 ^{fB} ± 0.17	7.25 ^{fA} ± 0.03	6.04 ^{fB} ± 0.02	6.85 ^{fA} ± 0.02

Mean ± S.E. of three replications; A, B: Means with different superscripts within a row differ significantly ($p \leq 0.05$); a, b...f: Means with different superscripts within a column differ significantly ($p \leq 0.05$)

the product with nitrogen flushing at the end of 22nd week of storage. No significant difference was observed in first 6 weeks of storage and the significant difference ($p < 0.05$) was observed thereafter in every 4 weeks in case of air packed product. In case of nitrogen-flushed storage, there was significant increase ($p < 0.05$) in texture score in the 2nd week of storage. This might be due to the characteristic of the product that tend to equilibrate with the surrounding in terms of gain or loss of moisture packaged under modified atmosphere. Thereafter no significant difference ($p > 0.05$) was observed in the texture scores till 10th week. 12th week sample was significantly different ($p < 0.05$) from all samples but for that of 8th week. No significant difference was observed during 14th, 16th and 18th week of storage. However, in 20th and 22nd week significant difference was observed between and within the samples. The decline in the texture scores can be well drawn from the rising trend of moisture content and water activity in the corresponding samples as evident from Fig. 1a, b. Reddy et al. 2014, observed similar trend of decrease in sensory score for texture and they concluded that the product lost its crunchiness due to the increase in moisture. Moisture uptake affected the texture of the snack food by plasticizing and thereby softening the starch-protein matrix, which altered the mechanical strength of the product (Jakubczyk et al. 2008). The decrease in sensory scores of textures over storage period may correlate to instrumental hardness. Despite the decline in the value of texture scores, the sample was acceptable by the judges.

The overall acceptability scores decreased during the storage period in both the treatments. In case of air packed product, the overall acceptability scores decreased from 8.04 ± 0.01 on 0th week to 6.04 ± 0.02 on 22nd week, moreover it was declared unacceptable by the sensory panel members. The decrease in values was observed from the initial week itself but statistically significant difference ($p < 0.05$) appeared after 8th week of storage. In case of nitrogen packed product, statistically significant difference ($p < 0.05$) was observed after 12th week of storage. The scores reduced from the initial value 7.99 ± 0.01 on 0th week to 6.85 ± 0.02 on 22nd week, with product still carrying ‘acceptable’ remark. Extruded snack deterioration with respect to overall acceptability was significantly different between two types of packaging; it was more perceivable in air-packed samples as compared to those under nitrogen. Variation in the treatment did not attract any significant difference ($p > 0.05$) over the initial 4 weeks of storage. Thereafter consistent significant difference ($p < 0.05$) was observed throughout the storage period, but for 14th week. Overall acceptability scores may decrease due to change in flavor, color and crispness of the snack. Oxidative changes as reflected by the gradual increase in TBA values could be responsible for the descending trend

in the overall rating for sensory quality of foods (Sen and Karim 2003).

If an overall acceptability rating 7.0 (corresponding to “like moderately”) is considered to be the minimum acceptance score of the product, the composite extruded snack supplemented with milk protein packed without nitrogen flushing appeared to keep well for about 20 weeks at 37 °C. As the temperature used in the study was higher than the ambient temperature (25 °C), the present product would have higher shelf life at 25 °C. Therefore, the product packed using MAP would have much longer shelf life than 22 weeks when stored at lower temperature, which is fairly comparable with the commercial products of similar type.

Conclusion

In the light of the presented results, the study suggests that the developed nutritionally enhanced extruded snack can be stored under MAP for 22 weeks, keeping the sensorial acceptability of the product while the air-packed (control) sample was considered unacceptable after 16 weeks of storage. The changes in the physico-chemical and sensory properties were lower in case of nitro-flushed sample even at 37 °C thus, a combination of MAP with better barrier properties can retain the sensory properties and increase the shelf stability of the high protein-high fibre extruded product.

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