RESEARCH PAPER International Journal of Agricultural Engineering | Volume 11 | Sp. Issue | April, 2018 | 46-52
ISSN–0974–2662 ■ Visit us : *www.researchjournal.co.in* ■ **DOI: 10.15740/HAS/IJAE/11.Sp. Issue/46-52**

Studies on storability of maize-millet based soy fortified extruded snacks

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Received : 10.04.2018; **Accepted :** 13.04.2018

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■ **Abstract :** Storability and shelf-life of any products are most important for producers as well as consumers. Shelf-life of products depends on moisture content of the products which should be stored in different packaging materials and storage conditions. In the present study storage stability of extruded snack were carried out at accelerated conditions of 40°C and 90 % RH. The extruded snacks using ingredients: maize, finger millet, defatted soy and elephant foot yam in the proportion of 40:30:20:10, respectively was developed under optimized conditions of 110°C barrel temperature, 301 rpm screw speed and 14% moisture content. The effect of storage period on the quality of extruded snacks packed in pouches of low density polyethylene (LDPE), aluminium foil, high density polyethylene (HDPE) and metalized polyethylene terephthalate (MPET) at accelerated condition were determined. The quality parameters such as moisture content, hardness and crispness for storage stability of extruded snacks were evaluated. Packaging material affects the quality of extruded snack products during storage. Packaging material and storage period both had significantly ($P< 0.05$) affected the moisture content, hardness and crispness of extruded snack product. On the basis of packaging material used, the extruded snacks packed in LDPE pouches showed greater changes to quality parameters and minimum packed in MPET. The shelf-life of extruded snack packed in LDPE, aluminium foil, HDPE and MPET under accelerated condition of storage was found to be 6, 8, 11 and 35 days, respectively. Hence MPET was better packaging material for storing the extruded snack.

■ **Key words :** Crispness, Extruded snack, Hardness, Moisture content, Packaging, Shelf-life

■ **How to cite this paper :** Sahu, Chandrahas, Patel, S. and Khokhar, D. (2018). Studies on storability of maize-millet based soy fortified extruded snacks. *Internat. J. Agric. Engg.*, **11**(Sp. Issue) : 46-52, **DOI: 10.15740/HAS/IJAE/11.Sp. Issue/46-52.**

Extruded snack foods are mostly developed from cereal grains used as main raw materials. Expansion is the most important quality characteristics of extruded products that were obtained from starch rich cereal grains like rice, wheat, maize, etc. Cereals are not only low in protein content but also lacking in certain essential amino acids. The improvement of protein quality in extruded foods in India has been geared toward the incorporation or supplementation of cereal-based extruded foods with grain legumes like soybeans, grams, mungbean, etc. Mixing of legume flour into cereals has been shown to cause positive impact on proteins and dietary fibre levels of extruded snacks (Berrios, 2006). Maize is the affluent sources of carbohydrate, fibre and minerals like potassium, phosphorus, magnesium, calcium, etc. Maize (corn) is the main cereal grain as measured by production but ranks third as a staple food, after wheat and rice. It is the cereal of major significance in the developing world and has the maximum hereditary production potential of all the cereal crops. Maize flour (MF) contains about 72-76.9% carbohydrates, 6.9-10.5% protein, 2.9-3.9% fat, 6.5-7.3% total fibre and 0.8-1.7% ash (US Department of Agriculture, 2013).

Finger millet (FM) is the richest source of minerals like calcium, phosphorus, iron, fibre and vitamin contents. By introducing finger millet in our daily diet, calcium and iron deficiency can be overcome. Starch content of finger millet is also high, which is a desirable property for extrusion cooking. Magnesium in millet can help to reduce the effects of migraines and heart attacks. Millet is gluten-free, non-allergenic and it gives substantial addition to a vegetarian diet. Due to lack of awareness finger millet is rarely consumed in diet. It is also rich in protein along with the presence of essential amino acids, vitamin A, vitamin B and phosphorus (Gopalan *et al.*, 2004). Finger millet is a good source of diet for growing children, expecting womens', old age people and patients. The dietary fibre and mineral content is higher than wheat, rice and fairly well balanced protein.

Defatted soy flour (DS) is the by-product obtained after extraction of oil from soybean in the oil processing industry. The use of this flour for the production of extruded products will reduce the production cost because the cost of defatted soy flour is less compared to other high protein sources and increase the protein content of the extruded products. Soy protein represents a safe, viable and practical non-pharmacological approach to lowering cholesterol. The physiological function of soybean is that many minor components that were considered as anti-nutrient factor are now thought to have preventing effect on cancer. Addition of soy flour can acts as a good source of protein in formulated food besides offering other functional, nutritional and health benefits (Friedman and Brandon, 2001).

Elephant foot yam (*Amorphophallus paeoniifolius*) contains carbohydrate, protein, vitamins, antioxidants, minerals, dietary fibre and calories rich vegetable. They are affluent in the content of minerals like potassium, phosphorus, manganese and vitamins (Seth *et al.*, 2015). It improves digestive system functioning by reducing the irregular bowel movements and bloating. It prevents from the occurrence of heart diseases and digestive disorders like constipation, piles, etc. Its richness in the omega-3 fatty acid helps in reducing bad cholesterol level and increasing good cholesterol level. It has anti-coagulating property thus helps in preventing from the unnecessary blood clotting. It helps in enhancing the red blood cells production and formation.

Storage studies and shelf-life are most important parameter for producers as well as consumers to analyze the quality characteristics and product behavior of extruded products during storage. Evaluation of shelf-life of the product helps in estimating the "Best before date" which is the main requirement for packaged product to the producers as well as consumers. The present study was carried out to determine the effect of packaging materials and storage period on quality parameters viz moisture content, hardness and crispness when stored under accelerated storage conditions.

■ METHODOLOGY

Raw materials :

Maize, finger millet and elephant foot yam (YP) were purchased from local market of Raipur city. Defatted soy flour (DS) was purchased from Bhatnagar Industry, Bhopal. Elephant foot yam was firstly washed with fresh water then cut into small pieces for easy to boiling. It was boiled in pressure cooker for 15-20 minutes to peel the outer skin easily. After peeling, the yam tubers were cut into slices (2 cm thickness) and mashed to paste. The yam paste was spread uniformly over the trays for drying at 95^{o}C for 12 hours. Dried yam were ground into powder by grinder and stored in cool and dry place for further experiments.

Preparation of extruded snack :

The extruded product was developed using a co-rotating twin-screw extruder (Lab model, BTPL, Kolkata, India). The diameter of the die opening used in this study was 3 mm. The feed rate was kept constant at 24 rpm by knob provided in the extruder and control by display into control panel. The optimized ingredient level of composite flour (maize: 40%, finger millet: 30%, DS: 20% and YP: 10%) was used for the preparation of extruded snack product in this study. The optimized values of feed moisture content, barrel temperatures and screw speed were 14%, 110^{o}C and 301 rpm, respectively for development of extruded snack. Extruded snacks were allowed to cool at room temperature and collected into zip lock packet for further investigation of storage study.

Storage study :

The freshly prepared extruded snack products were packed in four different types of pouches of packaging materials *viz.*, low density polyethylene (LDPE), Aluminium foil, metalized polyethylene terephthalate (MPET) and high density polyethylene (HDPE). Extrudates of about 10 g were packed in these packaging materials and sealed with polyethylene sealing machine. These samples were placed in a desiccators containing saturated salt solution of potassium nitrate so as to provide relative humidity of 90% at 40 ± 1 ^{o}C temperature to study the storage behaviour of developed extruded snack product under accelerated storage condition as suggested by Labuza (1975). One packet each of different packaging materials was taken out from the desiccators at an interval of 05 days upto 90 days and the stored product (snack) was analyzed for properties of moisture content hardness and crispness. Every time a new packet was opened for analysis.

Water vapour permeability :

Water vapour permeability (*K)* of the packaging material was calculated using the following formula (Labuza, 1984).

$$K = \frac{\frac{d_w}{d_\theta}}{A_p P^*} \qquad (1)$$

where,

w – mass of moisture gain by silica gel kept in packaging material (kg),

¯ – time (days), *K* – permeability of the packaging material (kg day^{-1} m^{-2} Pa^{-1}),

Ap – area of the package (m^{2}), *P** – saturated water vapor pressure at 40°C (Pa)

Moisture gain by silica gel (w) was plotted against time (*è*) to get a straight line relationship. The rate of water vapour transmission *i.e.*, slope (*dw/dè*) was determined by regression (Jena and Das, 2011).

Moisture content :

The moisture content of extruded snack products were determined by drying the samples in a hot air oven at a temperature of 105± 5 ^{o}C for 24 h (to constant mass) by methods of AOAC (2000).

Hardness and crispness :

The textural characteristics of extruded snacks were measured using a stable micro system TA-HD plus texture analyzer (Texture Technology corp., UK) fitted with a crisp fracture rig fixture and P/0.25 probe. The studies were conducted at a pre test speed of 1.0 mm/s, test speed of 1.0 mm/s, post test speed of 10 mm/s, distance of 5 mm, and load cell of 50 kg. Hardness value was considered as force expressed in Newton (N) at highest positive peak during fracture. Crispness was measured in terms of number of fractures (positive peaks) recorded in texture analyzer graph obtained during product fracture by Exponent Lite software, version 6.1.11.0. Average values of ten extruded samples were recorded for crispness.

Shelf life :

The Shelf life of the product was calculated using method described by Kumar and Mishra (2004) by using the following equation:

$$\theta = \frac{W_{dm}}{P^* A_p K} \times \int_{X_i}^{X_c} \frac{dx}{RH - a_{wc}} \qquad (2)$$

where,

¯ – duration at which critical moisture will be arrived (days); W_{dm} – dry matter in the product (kg); *P** – saturated vapour pressure of water at *T* °C (Pa) calculated using relation given by Geankoplis (2003) as per the Eq. 3

$$P^* = \exp\left(23.0603 - \frac{3723.6}{222.857 + T}\right) \qquad (3)$$

K – permeability of the packaging material (kg day^{-1} m^{-2} Pa^{-1}); A_p – area of the package (m^{2});

RH – relative humidity in which package is placed (fraction); a_w – water activity (fraction) of the product at *T* °C = f (*X*); a_{wc} – critical water activity and is less than or equal to *RH*;

X – moisture content of the RTE snack product (kg water per kg dm);

i and c are the suffix for initial and critical conditions, respectively.

Statistical analysis :

The data were statistically analyzed using factorial Randomized Block Design by using statistical software package of OP state. The factors were packaging materials and storage periods. The critical difference (CD) was calculated at 5% level of significance (p≤0.05).

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Changes in moisture content during storage :

Absorption of moisture plays a significant role on the textural properties of RTE extruded snack products as it directly affects the crispness, which is a key factor for overall acceptability of the snacks. Effect of storage period on moisture content of extruded snack products stored in four different packaging materials under accelerated conditions is graphically presented in Fig. 1. Figure shows that increase in moisture content of extruded snack product packed in all four types of packaging materials was observed with the increase of storage period. The moisture gained by sample packed in the LDPE pouches was more as compared to other packaging materials with storage period. This increase in moisture of sample packed in LDPE pouches was due to the fact that permeability of water vapour in LDPE pouches was higher in comparison to other three packaging materials. Similar result was observed by Wani and Kumar (2016) in stored extruded snack made from fenugreek, oat and pea flour in different packaging materials.

Two ways analysis of variance for moisture content of samples packed in different packaging materials with storage periods is shown in Table 1. It was revealed from the Table that the type of packaging material and storage period both had significantly ($P < 0.05$) affect the moisture content of extruded snack product.

The hardness and crispness are the most important textural properties for quality and acceptability of the RTE extruded snack products by the consumers. The hardness of extruded snack products at regular interval of time during storage packed in LDPE, aluminum foil, HDPE and MPET pouches varied from 4.781 to 11.773, 5.964 to 11.773, 6.384 to 11.773 and 8.075 to 11.773 N, respectively. Decrease in hardness of extruded snack products packed in different packaging materials with storage periods was observed at accelerated conditions of storage (Fig. 2). The decrease in hardness might be related to gain in moisture of extruded snack (Dar *et al*., 2014). A sharp decrease in hardness of extruded snack

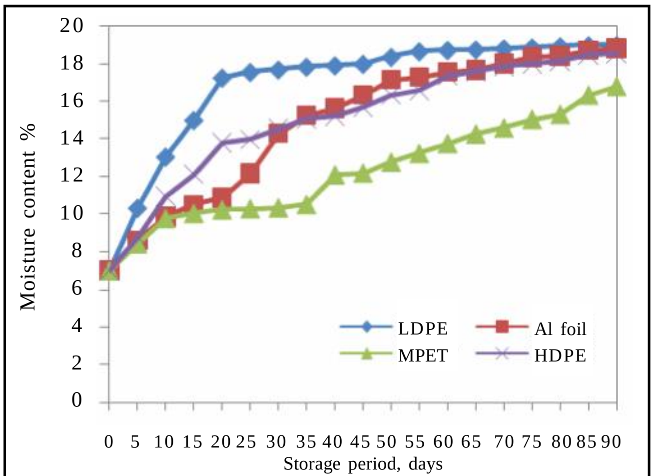

Fig. 1 : Effect of packaging materials and storage period on moisture content of extruded snacks stored at accelerated conditions

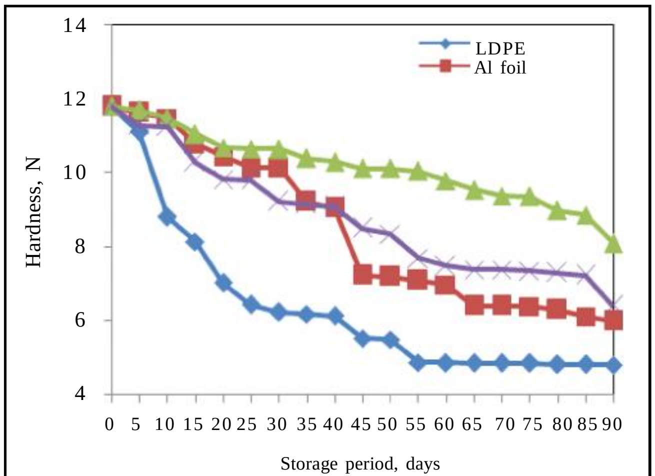

Fig. 2 : Effect of packaging materials and storage period on hardness of extruded snacks stored at accelerated conditions

Table 1 : ANOVA for variation in moisture content of product during storage

Sr. No.	Source	DF	MS	F cal	S.E.±	C.D. (P=0.05)
1.	Packaging material (PM)	3	204.75	106423.48**	0.03	0.02
2.	Storage (S)	18	121.93	63374.44**	0.01	0.04
3.	PM*S	54	3.42	1777.18**	0.03	0.07
4.	Error	152	0.0019			

** indicates significance of value at P=0.05 level packed in LDPE was observed as compared to other packaging materials in the study. Two ways ANOVA for hardness (Table 2) showed that the type of packaging material and storage period affect significantly (P< 0.05) the hardness of extruded snack product. The hardness of extruded snack packed in LDPE pouches decreased more as compare to snack packed in other packaging materials. This may be due to higher water vapour permeability of LDPE, which absorb more water and reduces hardness during storage. Hardness is inversely correlated with the moisture content of extruded snacks with the increase of storage period. Similar type of results also observed by Alam *et al.* (2015) for carrot pomace-chickpea incorporated rice based snacks and Wani and Kumar (2016) for stored extruded snack made from fenugreek, oat and pea flour in different packaging materials.

Changes in crispness during storage :

Crispness is the most important textural property of extruded RTE snack foods during storage because it affects the consumers' acceptability. Graphical representation of changes in crispness of extruded snack foods packed in different packaging materials during storage period is shown in Fig. 3. A sharp decrease in crispness of product packed in LDPE was observed as compared to packed in other packaging materials under accelerated condition of storage (40°C and 90% RH). This may be due to high water vapour transmission rate of LDPE followed by HDPE, aluminium foil pouch and MPET. The crispness of product packed in MPET was decreased slowly and acceptable for longer duration of storage under accelerated condition.

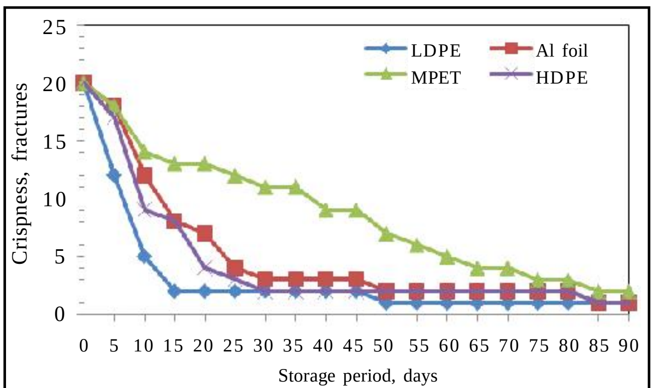

Fig. 3 : Effect of packaging materials and storage period on crispness of extruded snacks stored at accelerated condition

Two ways ANOVA for crispness (Table 3) showed that the type of packaging materials and storage period affect significantly (P< 0.05) the crispness of extruded snack product. The crispness of extruded snack packed in LDPE pouches decreased more as compare to snack packed in other packaging materials. This may be due to higher water vapour permeability of LDPE, which absorb more water and reduces crispness during storage. Crispness is inversely correlated with the moisture content of extruded snacks with the increase of storage period.

The extruded snacks are low in moisture content and its change in moisture content directly affects crispiness, and the less crispy snacks are not acceptable. This happens as the number of major peaks approaches to zero at a moisture content of about 10%, which indicates that the product lost all its crispiness. Moisture leads to plasticization and softening of the starch–protein matrix and thus alters the strength of the product (Martinez-Navarraete *et al*., 2004).

Shelf-life of extruded products :

The surface area of pouches and the value of saturated vapor pressure of water are given in Table 4. The experimental values of water vapour permeability for packaging materials namely, LDPE, aluminium foil, MPET and HDPE were determined as 1.13×10^{-6}, 8.22×10^{-7}, 5.34×10^{-7} and 1.05×10^{-6} kg day^{-1} m^{-2} Pa^{-1}, respectively.

Optimized extruded snack product was packed in four packaging materials and put into accelerated storage condition (40°C and 90% RH) for shelf-life evaluation

Table 2 : Two way ANOVA for variation in hardness of the product during storage

Sr. No.	Source	DF	MS	F cal	S.E.	C.D. (P=0.05)
1.	Packaging material (PM)	3	137.07	9873155.04**	0.00	0.00
2.	Storage (S)	18	33.02	2378346.58**	0.00	0.00
3.	PM*S	54	1.59	115223.20**	0.00	0.01
4.	Error	152	0.000014			

** indicates significance of value at P=0.05 level

Table 3 : Two way ANOVA for variation in crispness of the product during storage

Sr. No.	Source	DF	MS	F cal	S.E.±	C.D. (P=0.05)
1.	Packaging material (PM)	3	312.13	297.76**	0.14	0.38
2.	Storage (S)	18	305.23	291.18**	0.30	0.82
3.	PM*S	54	9.85	9.39**	0.59	1.64
4.	Error	152	1.05			

**indicates significance of value at P=0.05 level

Table 4 : Water vapour permeability of packaging materials used for maize millet legume extruded snack product storability

Sr. No.	Packaging material	dw/dθp (kg water/day)	A (m^2)	P* (Pa)	K (kg day^{-1} m^{-2} Pa^{-1})
1.	LDPE	0.000107	0.0130	7291.19	1.13×10^{-6}
2.	Aluminum foil pouch	0.0000762	0.0127	7291.19	8.22×10^{-7}
3.	Metalized Polyethylene Terephthalate (MPET)	0.0000448	0.0115	7291.19	5.34×10^{-7}
4.	HDPE	0.0000699	0.0091	7291.19	1.05×10^{-6}

A - Area of the packaging material; P*- Saturated vapor pressure of water; K - permeability of the packaging material

Table 5 : Actual and predicted shelf -life of extruded maize-millet-legume RTE snack product at accelerated storage conditions

Sr. No.	Packaging materials	Shelf –life (days)	
		Actual	Predicted
1.	LDPE	6	8
2.	HDPE	8	14
3.	Al foil	11	12
4.	MPET	35	22

of product. The packaging materials used for this study were LDPE, HDPE, Al foil and MPET. The initial moisture content of the extruded snack samples was 6.97% (db) and the critical moisture content was decided on the basis crispness of the samples reduced below 11 fractures, which was around 10% (db) moisture content of extruded snacks. In this study crispness of 11 fractures was observed at the critical water activity (a_{wc}) as per moisture sorption studies. The critical water activity obtained by LDPE, HDPE, aluminium foil and MPET packed extruded snack stored at accelerated condition upto period of 6, 8, 11 and 35 days, respectively. Shelf life of the snack packed in MPET is 35 days and predicted shelf-life is 22 days in accelerated condition. The predicted value of shelf life of extruded snack was obtained by using Eq. 2. Actual and predicted values for all the four packaging materials at the accelerated condition are given in Table 5.

Conclusion :

The packaging materials and storage period both had significantly affected the quality of extruded snack. The moisture content of packed product increased with increasing the storage period. Hardness and crispness of the extruded snacks decreased with the increase of storage period under accelerated condition. The shelf life of extruded snack packed in MPET was higher (35 days) than other three packaging materials under accelerated storage conditions. These results suggested that MPET was better packaging material for packing the extruded snack for longer shelf life.

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