*Plant Archives* Vol. 25, Supplement 1, 2025 pp. 2846-2851 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.v25.supplement-1.393

# SHELF-LIFE CHARACTERISTICS OF EXTRUDATES FROM PIGMENTED MAIZE

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(Date of Receiving : 03-11-2024; Date of Acceptance : 31-12-2024)

**ABSTRACT**

Extrusion processing of pigmented maize offers a promising method for developing nutrient-rich food products with desirable textures. This study aimed to evaluate the shelf-life characteristics of pigmented maize extrudates, focusing on key quality parameters such as moisture content, free fatty acid levels, overall acceptability, and total plate count. Pigmented maize was ground into grits, and extrudates were prepared using a twin-screw extruder under varying extrusion conditions, including moisture content (14-18%), temperature (130-150°C), and screw speed (400-550 rpm). After extrusion, the extrudates were stored for six months in low-density polyethylene (LDPE) and laminated pouches at ambient temperature. Over time, moisture content and free fatty acid levels significantly increased, with laminated pouches showing slightly less moisture gain compared to LDPE pouches. The overall acceptability of the extrudates declined over storage, but they remained acceptable with final scores of 6.00 and 6.23 for LDPE and laminated pouches, respectively. Total plate count remained within permissible limits, ensuring microbiological safety throughout the storage period. These results suggest that extrusion processing and packaging material significantly impact the shelf life of pigmented maize extrudates, with laminated pouches providing a better storage option. This study highlights the potential of pigmented maize as a viable ingredient for the development of extruded snacks with extended shelf life.
***Keywords* :** Extrusion processing, Microbiological safety, Packaging material, Pigmented maize, Shelf life.

## Introduction

Extrusion is a high-temperature, short-duration process that involves thermal, pressure, and mechanical shearing effects, leading to changes such as starch gelatinization, protein denaturation, enzyme inactivation, and reduction of anti-nutritional factors (Singh *et al*., 2007). Extrusion technology facilitates the design and development of innovative food products, ensuring high quality, distinctive shapes, and characteristics, along with energy efficiency and zero effluent generation (Faraj *et al*., 2004). This technology has enabled the production of a diverse range of cereal-based foods, protein supplements, and sausage products. Various products such as pasta, breakfast cereals, bread crumbs, biscuits, crackers, croutons, baby foods, snack foods, confectionery items, chewing gum, texturized vegetable protein, modified starch, pet foods, dried soups, and dry beverage mixes are developed through extrusion (Chang and Ng, 2009). Extruded products are typically prepared from starch-rich cereals and/or protein sources, as these ingredients contribute to desirable qualities such as texture, structure, expansion, crispiness, and mouthfeel in finished products (Singh *et al*., 2007; Jamora *et al*., 2001). Various ingredients such as wheat flour, rice flour, maize grits, barley flour, and their combinations, as well as industrial byproducts like carrot and grape pomace, have been extensively utilized in extrusion processes.

Maize being the third most important crop provides about half of the proteins in the human diet of developing countries. Maize is also gaining popularity not only for food security but also for quality feed. Thus, Maize can prove to be a potential source of protein for humans and animals. Maize is a highly nutritious crop, rich in vitamins, minerals, and functional elements, making it a valuable resource for meeting the needs of a growing population. Its primary component is starch, which constitutes around 70% of the maize kernel. Typically, maize starch consists of approximately 25% amylose and 75% amylopectin. It is widely utilized as a bonding agent, setting agent, in corrugated boxes, biodegradable plastics, food additives, packaging materials, and as a substitute for cream or gelatin, among other uses.

The texture of expanded cereal-based snacks is primarily influenced by extrusion conditions and their moisture levels. During storage, moisture absorption leads to texture degradation, which significantly impacts the shelf life of these products. Higher moisture content softens the starch-protein matrix, resulting in increased toughness or reduced crispiness of the snacks (Gonzalez *et al*., 2004). Selection of packaging material is important for shelf-life of the product. Storage study plays a very crucial role for acceptability of the product. The choice of packaging material is crucial for extending the product's shelf life. Additionally, storage studies are vital in determining the product's acceptability.

The objective of the current research was to evaluate the shelf-life characteristics of extrudates made from pigmented maize by assessing quality parameters, including moisture content, free fatty acid levels, overall acceptability, and total plate count.

## Materials and Methods

### Sample Preparation

Pigmented maize was sourced from local farmers in Manipur. The maize grains (Fig.1) were cleaned briefly and ground using a multi-purpose mill to produce grits that passed through a BSS sieve No. 18. The prepared grits were stored in a deep freezer until used for the extrusion experiments.

A

B

**Fig. 1 :** Pigmented maize (A) and its extrudate (B).

### Experimental Design

The experimental combinations were designed using Response Surface Methodology (RSM). A central composite rotatable design was employed for three independent variables: moisture content (14–18%), temperature (130–150°C), and screw speed (400–550 rpm), based on preliminary trials. Central Composite Design (CCD) is widely used in food processing as it minimizes the number of experimental runs, optimizes process variables, and provides statistically reliable results. A total of 20 experimental runs were conducted, each evaluated for key quality parameters of the pigmented cereals. The experimental runs (Table 1) were generated using the Design Expert software by inputting the range of each process variable.

**Table 1 :** Experimental design for pigmented maize extrusion.

| Independent parameters | Level Range | Coded values | | |
|---|---|---|---|---|
| | | +1 | 0 | -1 |
| Moisture (%) | 14-18 | 18 | 16 | 14 |
| Screw Speed (rpm) | 400-550 | 550 | 475 | 400 |
| Barrel Temp. (∘C) | 130-150 | 150 | 140 | 130 |

## Extrusion Cooking

The extrusion of pigmented cereals grit was done using twin- screw co-rotating extruder (Basic Technology Pvt. Ltd., Kolkata). The extruder had with 3 zones having constant set temperature of 40, 70, and 100 °C, respectively, while the temperature of the last zone was changed as 130, 140, or 150 °C. The material was fed at a constant speed through a rotating screw hopper and extrusion was done at 3 different temperatures (130, 150, and 175 °C). The feeding section of barrel was maintained cool by running water and an induction heating belt was used to heat the terminal section. The feed rate was kept constant at 20 kg/h and screw speed was kept between 400 to 550 rpm, based on the experimental design. Feed moisture content was calculated prior to extrusion and was adjusted between 14-18 % based on the experimental design by injecting water (at approximately 50 °C) into extruder using a water pump. The die diameter, length/diameter (L/D) ratio, and screw diameter of the extruder were 6, 16, and 25 mm, respectively.

## Shelf-life study

Extrudates were packed in low-density polyethylene (LDPE) and laminated packages and stored at ambient temperature for six months to study their shelf life. Quality parameters such as moisture content, free fatty acid levels, overall acceptability, and total plate count were observed monthly.

Portions of the extrudates (50 g each) were individually packed and sealed in LDPE and transparent laminated pouches, which allowed visible changes to be monitored.

**Table 2 :** Methods adopted for study of shelf life of extrudates

| **Parameters** | **Method** |
|---|---|
| Moisture content | AOAC methods, 2005 |
| Free fatty acid | Mahesar *et al.*, 2014 |
| Total Plate Count | Adegoke, 2004 |

## Statistical analysis

Mean and standard error were applied wherever necessary. The statistical significance of the terms in tables was inspected by one-way analysis of variance (ANOVA) using SPSS 16.0 version, 2007.

# Results and Discussion

The storage study results revealed that storage duration and packaging materials significantly influenced the moisture content, free fatty acid levels, and overall acceptability of the optimized extrudates.

The rise in free fatty acid levels was attributed to the hydrolysis of triacylglycerols, which breaks down ester linkages to produce free fatty acids, diglycerides, monoglycerides, and glycerol (Choe and Min, 2007). This process can lead to undesirable changes, including the development of off-flavors. Free fatty acid levels are a direct measure of hydrolyzed fatty acids and indicate lipid degradation.

**Table 3 :** Effect of storage period on quality characteristics of optimized pigmented maize extrudate

| **Storage month** | **Moisture %** | | **Free fatty acids (%)** | | **Overall acceptability** | | **Total plate Count (cfu/g) × $10^3$** | |
|---|---|---|---|---|---|---|---|---|
| | **LDPE** | **Laminated** | **LDPE** | **Laminated** | **LDPE** | **Laminated** | **LDPE** | **Laminated** |
| 0 | 4.72±0.55$^{a}$ | 4.72±0.55$^{a}$ | 0.14+0.02$^{a}$ | 0.14+0.02$^{a}$ | 7.63+0.15$^{c}$ | 7.63+0.15$^{d}$ | ND | ND |
| 1 | 5.23±0.02$^{ab}$ | 5.09±0.02$^{b}$ | 0.24+0.03$^{b}$ | 0.21+0.02$^{b}$ | 6.83+0.29$^{abc}$ | 7.33+0.29d$^{c}$ | ND | ND |
| 2 | 5.37±0.06$^{b}$ | 5.24±0.02$^{c}$ | 0.37+0.02$^{c}$ | 0.31+0.02$^{c}$ | 6.93+0.40$^{bc}$ | 7.23+0.25$^{cd}$ | ND | 0.1 |
| 3 | 5.57±0.06b$^{c}$ | 5.49±0.10$^{d}$ | 0.45+0.04$^{d}$ | 0.44+0.02$^{d}$ | 6.67+0.29$^{ab}$ | 6.87+0.15$^{bc}$ | 0.3 | 0.2 |
| 4 | 5.71±0.09$^{bc}$ | 5.65±0.05$^{e}$ | 0.57+0.02$^{e}$ | 0.53+0.03$^{e}$ | 6.70+0.26$^{ab}$ | 7.07+0.12$^{abc}$ | 0.5 | 0.6 |
| 5 | 6.16±0.06$^{cd}$ | 5.85±0.06$^{f}$ | 0.69+0.03$^{f}$ | 0.73+0.02$^{f}$ | 6.43+0.12$^{ab}$ | 6.60+0.17$^{ab}$ | 0.9 | 1.3 |
| 6 | 6.35±0.06$^{c}$ | 6.16±0.02$^{g}$ | 0.90+0.02$^{g}$ | 0.86+0.01$^{g}$ | 6.00+0.50$^{a}$ | 6.23+0.25$^{a}$ | 1.3 | 2.0 |

Mean ± standard deviation values of three determinations in rows followed by different superscripts differ significantly.

## Moisture content

The initial moisture content of the pigmented maize extrudates was 4.72%. Over six months of storage at ambient temperature, both the moisture content and free fatty acid levels exhibited a gradual and significant increase, as shown in Table 3. However, the increase in these parameters was less pronounced in extrudates stored in laminated pouches compared to those stored in LDPE pouches. By the end of the storage period, the moisture content had risen to 6.35% in LDPE pouches and 6.16% in laminated pouches. The variation in moisture content over the storage duration is illustrated in Fig. 2. The moisture content of the extruded product increased with a longer storage period, regardless of the pouch type. However, the sample stored in laminated pouches showed the highest moisture gain compared to LDPE pouches. This was expected, as laminated pouches have a higher water vapor permeability than LDPE. A similar observation was reported by Sahu *et al.* (2020) in their study on the storage of defatted soy-incorporated maize-millet-based extruded products.

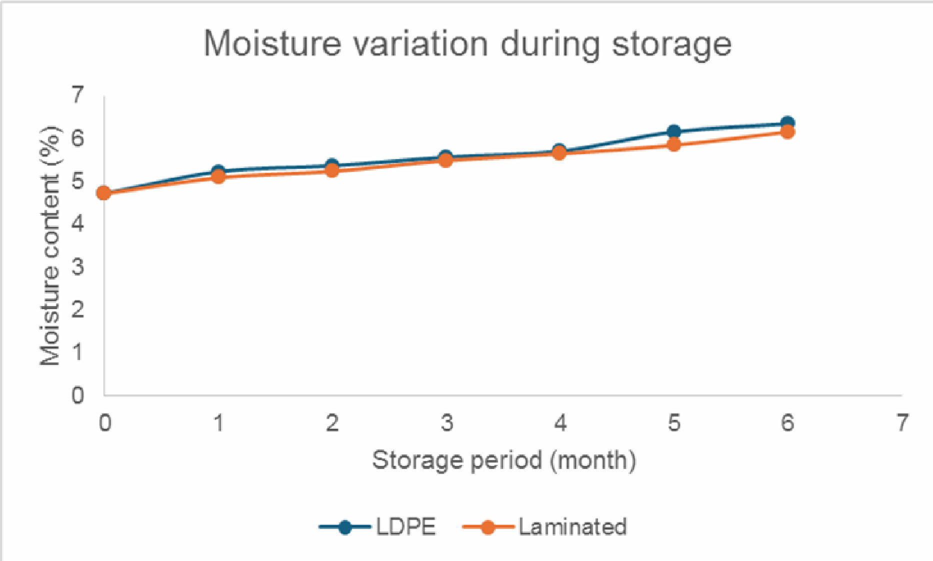


**Fig. 2 :** Moisture content of pigmented maize extrudate during storage period.

## Free fatty acids

The initial free fatty acid content in pigmented maize extruded products was 0.14%. By the end of the storage period, this increased to 0.9% in LDPE pouches and 0.86% in laminated pouches (Fig. 3). Free fatty acids are generated through the hydrolysis of fats present in the sample, which can occur either hydrolytically due to moisture or oxidatively due to the presence of oxygen at elevated temperatures. This rise in free fatty acids aligns with the findings reported by Nkubana *et al.*, 2019.

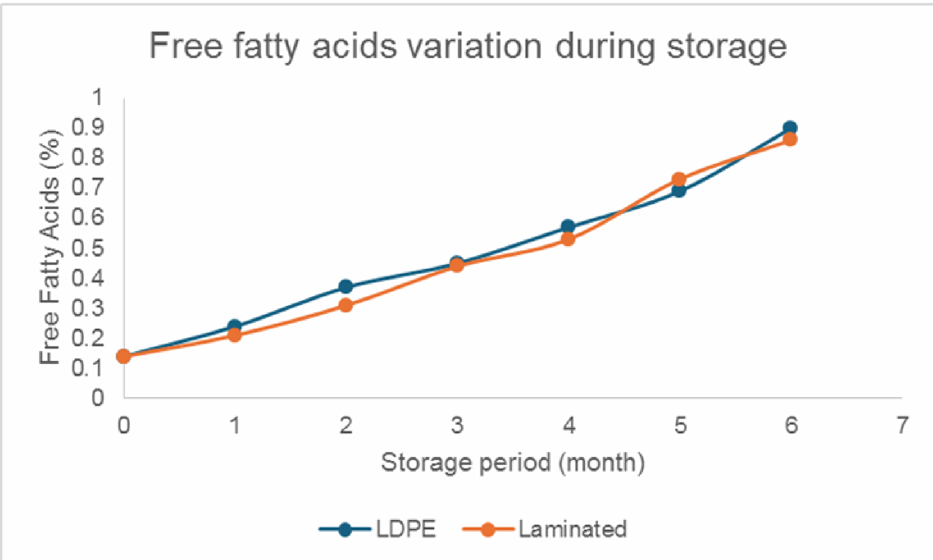


**Fig. 3 :** Free fatty acids of pigmented maize extrudate during storage period.

## Overall Acceptability

The overall acceptability trends of pigmented maize extrudates during storage are illustrated in Fig. 4. It is evident from the figure that the acceptability of the extruded products declined over the storage period. However, the decrease was minimal, and the products remained acceptable by the end of the storage period. The final acceptability scores for the extruded snacks were 6.00 and 6.23 for LDPE and laminated pouches, respectively, indicating that the panel members still found them highly acceptable. The decline in overall acceptability may be attributed to increased moisture content and free fatty acid levels during storage.

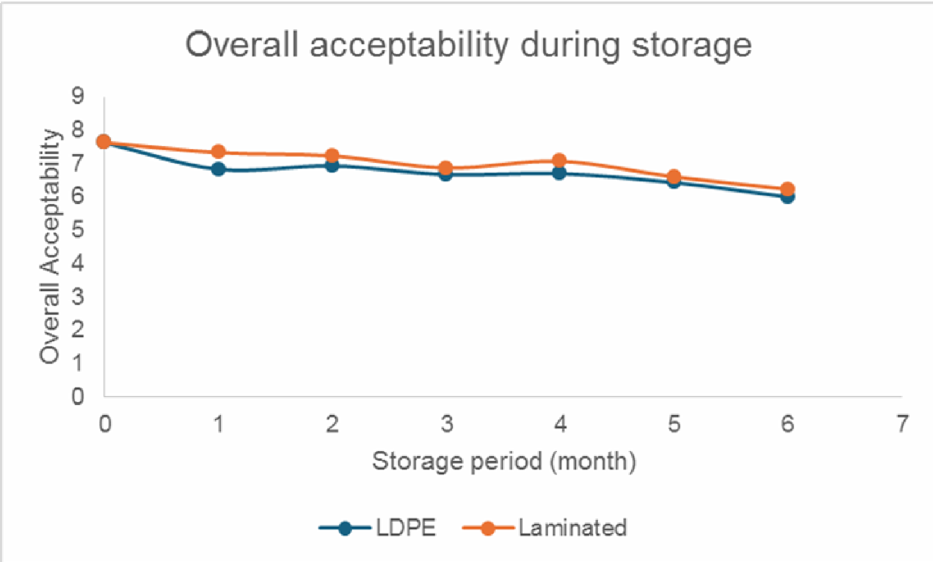


**Fig. 4 :** Overall acceptability of pigmented maize extrudate during storage period.

### Total plate Count

Due to the low water activity of the extrudates and high-temperature thermal processing, no total plate count was detected in either packaging material during the first two months of storage. However, by the second month, a total plate count of 0.1×10³ cfu/g was observed in extrudates stored in laminated pouches. By the third month, this increased to 0.3×10³ cfu/g in extrudates stored in LDPE pouches. After six months, the total plate count reached 2×10³ cfu/g in laminated pouches and 1.3×10³ cfu/g in LDPE pouches. Despite the increase, the microbial counts remained within permissible limits, ensuring the extrudates were microbiologically safe (ICMFS, 2018). The trends in total plate count are detailed in Table 3 and illustrated in Fig. 6.

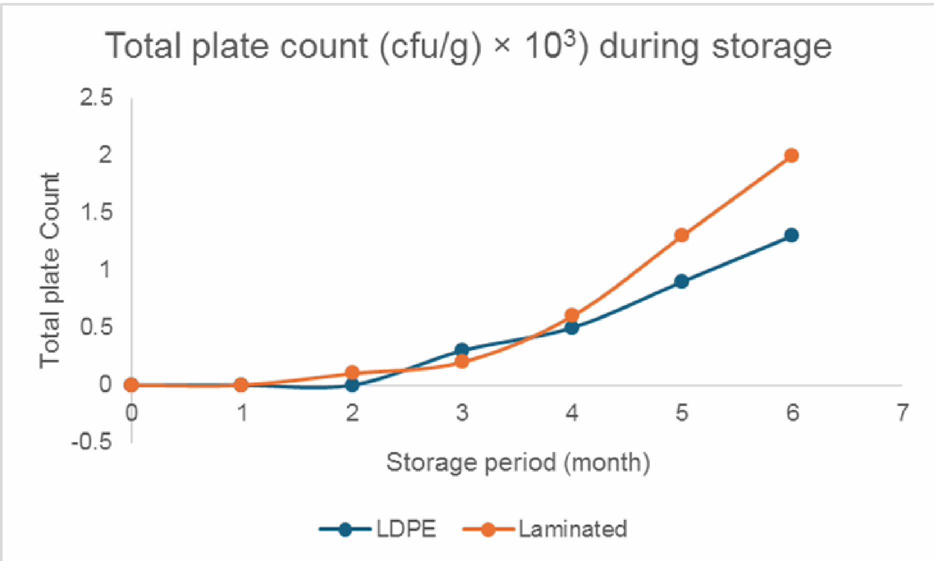


**Fig. 5 :** Total plate count of pigmented maize extrudate during storage period.

## Conclusion

The study on the shelf-life characteristics of extrudates prepared from pigmented maize revealed that storage duration and packaging materials significantly influence key quality parameters, including moisture content, free fatty acid levels, overall acceptability, and microbial safety. Laminated pouches demonstrated better performance in preserving the product's quality attributes compared to LDPE pouches, as evidenced by lower moisture uptake and free fatty acid levels over the six-month storage period.

While both packaging types maintained the products within acceptable sensory and microbiological limits, the laminated pouches provided superior protection against environmental factors, extending the shelf life and maintaining higher overall acceptability. The increase in microbial counts, although within permissible limits, underscores the importance of choosing appropriate packaging materials and storage conditions to ensure product safety and quality.

The findings highlight the potential of pigmented maize as a valuable raw material for the development of extruded snack products with extended shelf life. Future research should focus on optimizing packaging solutions and exploring additional functional and sensory enhancements to further improve the shelf life and marketability of such products.

## Authors contribution

**Khwairakpam Bembem:** Data Acquisition, Investigation, Software, Writing – original draft, preparation, Visualization. **Thongam Sunita**: Supervision, Formal analysis, Conceptualization, Writing–review & editing. **Thingujam Bidyalakshmi**: Data Acquisition, Formal analysis.

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