# THE EFFECTS OF PACKAGING MATERIALS ON BREADFRUIT FLOUR'S PHYSICAL AND MICROBIAL PROPERTIES DURING STORAGE

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**ABSTRACT**

This study examined the physical and microbial properties of the breadfruit flour over a 16-week storage period at 25°C. Four packaging materials, including high- and low- density polyethylene (HDPE and LDPE), polyamide (PA), and polyamide/aluminum (PA-Al), were used. The flours moisture content, brightness, yellowness levels (L* and b* values, CIELab), water adsorption capacity (WAC), swelling power (SP), pH, total plate count (CFU/g) of aerobic bacteria and fungi were assessed every 3 weeks. Results indicated that flour stored in PA-Al bags showed the least moisture increase (7.32% to 8.31%), followed by PA, HDPE, and LDPE (up to 9.03%). PA-Al packaging also effectively maintained brightness (reduced by 1.1%), yellowness (increased by 5.5%), pH (increased by 1.5%), WAC and SP (increased 12% and 34%, respectively), making the flour preferable for food storage. Initial aerobic bacterial counts were under $10^2$ CFU/g, rising to 2.1 x $10^3$ CFU/g, while fungal counts increased at least from 0 to 17 x $10^2$ CFU/g in PA-Al bags compared to PA, HDPE, and LDPE. These findings demonstrated that PA-Al packaging is most effective in preserving its attributes over time.

# NGHIÊN CỨU ẢNH HƯỞNG CỦA LOẠI BAO BÌ BẢO QUẢN ĐẾN TÍNH CHẤT VẬT LÝ VÀ VI SINH CỦA BỘT SA KÊ

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Bao bì
Bảo quản

**TÓM TẮT**

Nghiên cứu này đã khảo sát tính chất vật lý và vi sinh của bột sa kê trong thời gian bảo quản 16 tuần ở 25°C. Bốn loại vật liệu bao bì gồm polyethylene mật độ cao và thấp (HDPE và LDPE), polyamide (PA) và polyamide/nhôm (PA-Al) được sử dụng. Độ ẩm, độ trắng, độ vàng (giá trị L* và b*, hệ màu CIELab), khả năng hấp phụ nước (WAC), độ trương nở (SP), độ pH, tổng số vi khuẩn hiếu khí và nấm men (CFU/g) được đánh giá 3 tuần một lần. Kết quả cho thấy bột được bảo quản trong túi PA-Al có độ ẩm tăng ít nhất (7,32% đến 8,31%), tiếp theo là PA, HDPE và LDPE (lên đến 9,03%). Bao bì PA-Al duy trì hiệu quả độ sáng (giảm 1,1%), độ vàng (tăng 5,5%), pH (tăng 1,5%), WAC và SP (tăng 12% và 34%). Số lượng vi khuẩn hiếu khí tăng thấp nhất từ dưới $10^2$ CFU/g lên 2,1 x $10^3$ CFU/g trong khi nấm tăng từ 0 đến 17 x $10^2$ CFU/g khi bảo quản trong túi PA-Al so với các túi PA, HDPE và LDPE. Kết quả này cho thấy bao bì PA-Al có hiệu quả nhất trong việc bảo quản loại bột này.

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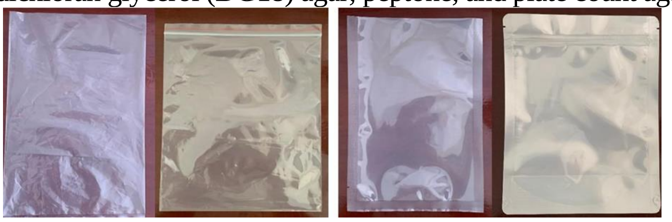
## 1. Introduction

Breadfruit (*Artocarpus altilis* (Parkinson) *Fosberg, Moraceae*) is a widely distributed plant found in tropical regions of Southeast and South Asia, as well as the Pacific islands [1]. These fruits offer significant nutritional benefits, containing carbohydrates, proteins, fats, vitamins, and carotenoids [2]. Additionally, their fiber content has been linked to cholesterol reduction, positioning breadfruit as a promising plant-based resource for global food security [3]. Notably, breadfruit does not contain gluten, making it a safe option for individuals with celiac disease and other gluten-related disorders. Following harvest, breadfruit ripens rapidly within 1-3 days, with extended ripening possible up to 5 days under cold storage conditions. Therefore, processing breadfruit into low-moisture products such as flour is a common method of preservation [4]. Breadfruit flour is gaining popularity worldwide due to its ability to substitute various flours and its ease of fortification in numerous baked recipes [5], [6]. Sun drying and air convection dehydration represent the prevailing methods used to reduce the water content of the fruit, thereby ensuring a significantly extended shelf-life of the products. Due to its high nutritional content such as fats, vitamins and polyphenols, the flour is prone to deterioration during storage, including microbial growth and enzymatic/non-enzymatic reactions. These processes result in off-flavors and color changes, such as darkening or browning, which ultimately restrict the shelf life to several weeks [7]. Packaging is important for the flour's stable quality by protecting against environmental contaminations such as moisture, microorganisms, oxygen,… [4]. Since packaging materials vary in their permeability to oxygen and moisture, selecting the right packaging is critical. Plastic materials such as PE, PP, PA are low cost, moldable, sealable, and easy to print; they were reported to significantly effects the functional properties of various powders such as cocoyam, cocoa, okra (orunla), and fermented cassava flours due to their resistance to water vapor transmission [8]. However, unlike laminated aluminum bags, these plastics are not lightproof, which led to enzymatic darkening and germination of peanut kernels during storage [9]. In Vietnam, PE, PA, and metallized laminate (PA-Al) are the most commonly used packaging materials for flours. Polyamide plastic is suitable for vacuum packaging, although it is more expensive than other plastics. Despite numerous studies on the storage of different flours, there is a lack of research on the use of various plastic materials for the long-term storage of breadfruit flour. Tran et al (2023) monitored the quality changes of breadfruit flour dried by microwaved method during 12 weeks in PE, PA and PA-Al bags [10]; this study aims to investigate the impact of various packaging materials, including HDPE, LDPE, PA, and PA-Al, on the physical and microbial properties of breadfruit flour dried by air convective method. Key quality parameters such as moisture content, color (L* and b*), microbial properties (total aerobic bacteria and fungi), pH, water adsorption capacity (WAC), and swelling index (SP) will be assessed over a 16-week storage period, with evaluations conducted at 3-week intervals.

## 2. Materials and Methods

Fresh, mature breadfruits (0.7 - 1 kg each fruit) (Can Tho, Vietnam) were harvested and kept at 5°C until used (maximum 3 days after harvest). Packaging materials made of LDPE, HDPE, PA, and PA-Al (7 cm × 10 cm, Figure 1) were purchased in Can Tho, Vietnam. Sodium metabisulfite ($Na_2S_2O_5$) (China), dichloran glycerol (DG18) agar, peptone, and plate count agar (India) were used.



LDPE HDPE PA PA-Al

**Figure 1.** *Four packaging materials*

### *2.1. Preparation of breadfruit flour and storage experiment*

The powder preparation method followed the procedure outlined by Tran Thi Minh Thu et at. (2022) [11]: The fruits were washed, peeled, removed cores and sliced into pieces (0.3 cm x 3 cm x 6 cm); the slices were soaked with a solution of $Na_2S_2O_5$ 0.45% (1:1, w:w) for 1 hour, rinsed with water several times to remove remained $Na_2S_2O_5$ and drained in the air. The blanching step was done with hot water (80˚C) within 2 minutes and drained before being processed by an air convection dryer at 70˚C to a water content under 9%. The dried flesh was ground and sieved (250 µm) for initial analysis and storage.

The dried flour was filled in 4 types of packages namely LDPE, HDPE, PA, PA-Al (size 7 cm × 10 cm, 100 g flour/pack), hot sealed tightly by a home-type vacuum sealer, and stored within 16 weeks at 25ºC [12]-[14]. Every three weeks, a new packet was opened to analyze moisture content, pH, swelling power and water adsorption capacity, and micro-organisms presence.

### *2.2. Quality analyses of the flour*

The water content (%) was monitored by a moisture analyzer (Ohause, USA), while colors (whiteness L* and yellowness b*) were determined using a colorimeter (Cielab sph870, Germany) based on the standard CIELAB Color System. To measure pH levels, a slurry consisting of 1 g of powder in 9 ml of water was prepared and analyzed using a pH meter (Hana Instruments, Italy). The water adsorption capacity (WAC, g/g) and swelling power (SP, g/g) were determined following the methods outlined by Adepeju et al. (2011) and Taruna et al. (2018) [10], [11]. For WAC measurement, 2 g of flour was dissolved and thoroughly mixed with 20 ml of water. After sedimentation for 30 minutes, the mixture was centrifuged at 4000 rpm for 20 minutes, decanted, and the sediment was allowed to drain for 10 minutes before being weighed. The WAC was calculated as the increase in weight relative to the initial 2 g of dried flour. To measure SP, a slurry of 3 g of flour and 30 ml of water was heated within a temperature range of 60, 70, and 80°C for 15 minutes with regular mixing. Following heating, the mixtures were centrifuged at 3000 rpm for 10 minutes, the supernatant was removed, and the sediment was dried for 30 minutes at 50°C, cooled, and weighed. SP was determined as the ratio of the weight of the dried sediment to the initial 3 g of flour. Microbial analyses involved evaluating the growth of total aerobic bacteria and fungi using the standard microbiological plating method. To begin, 1 g of powder was homogenized with 9 ml of sterilized peptone solution ($10^{-1}$) before being further diluted into serial dilutions of $10^{-2}$, $10^{-3}$, and $10^{-4}$ concentrations. Subsequently, 0.1 ml of each dilution was spread onto sterile petri plates containing nutrient agar media (Plate count agar for bacteria and dichloran glycerol 18% for mold). All agar preparations followed the producer's instructions and were sterilized accordingly. The plates were then incubated at 37°C for 48 hours for bacteria and at 30°C for 120 hours for molds. Visible colonies were manually counted and calculated according to Vietnam's standards system (TCVN) number 4884-1:2015.

### *2.3. Statistical analyses*

The experiments were replicated while the measurements were performed in triplicate. The effects of different treatment conditions on the quality of breadfruit flour were evaluated using ANOVA, with comparisons between groups conducted using LSD with significant differences at 95% confidence interval.

## 3. Results and Discussion

### *3.1. Effects of packaging materials on the breadfruit flour moisture content during storage*

The flour water content corresponding to packaging materials and storage time were summarized in Table 1.

Moisture plays a crucial role in determining the shelf life of food products, especially the hydroscopic dried flour. According to Vietnam's standards system (TCVN) number 4359:2008, wheat flour with a water content below 15.5% is considered to have an optimal shelf life and quality. However, this moisture content can vary significantly depending on processing conditions, packaging materials and their interactions [15]-[17]. In this study, the breadfruit flour was dried to an initial water content of 7.32%. After 16 weeks of storage, all the samples kept in HDPE, PA, and PA-Al bags showed an increase in moisture content of less than 2%, in which the powder in PA-Al was significantly stable with the lowest change to 8.31% compared to 8.7% and 8.58% of HDPE and PA samples; while that of LDPE flour was the highest (9.03%).

The consistent increase in moisture content observed across all treatments may be attributed to the varying relative water vapor transmission rate of these packaging materials, which was in agreement with the research of Daramola et al (2010) and Adebowale et al. (2017) on pupuru and yam flour during storage using different bags [7], [8]. The PA-Al or aluminum foil proved to be the most effective, with minimal moisture migration that could be primarily attributed to the low moisture permeability of this material, especially under humid conditions [18].

**Table 1.** *Moisture content (%) of flour kept in LDPE, HDPE, PA, PA-Al bags during storage*

| | Week 0 | Week 3 | Week 6 | Week 9 | Week 12 | Week 16 | |
|---|---|---|---|---|---|---|---|
| LDPE | 7.32±0.02bx | 6.64±0.07aw | 8.77±0.03cw | 8.83±0.11cdw | 8.89±0.11dz | 9.03±0.02ew | P <0.05 |
| HDPE | 7.32±0.02bx | 6.53±0.02ay | 8.37±0.03cz | 8.45±0.06dz | 8.48±0.05dy | 8.70±0.03ez | P <0.05 |
| PA | 7.32±0.02bx | 6.35±0.05az | 8.09±0.05cy | 8.27±0.04dy | 8.46±0.07ey | 8.58±0.05fy | P <0.05 |
| PA+ Al | 7.32±0.02bx | 6.17±0.06ax | 7.81±0.03cx | 8.06±0.13dx | 8.14±0.08dx | 8.31±0.05ex | P <0.05 |
| | P >0.05 | P <0.05 | P <0.05 | P <0.05 | P <0.05 | P <0.05 | |

*(Different superscripts a,b,c,d and x,y,z,w show significantly different (P < 0.05) within the same row and column, respectively)*

### *3.2. Effects of packaging materials on the breadfruit flour color during storage*

**Table 2.** *Colour of folurs kept in LDPE, HDPE, PA, PA-Al bags during 16 week-storage*

| $L^*$ value | Week 0 | Week 3 | Week 6 | Week 9 | Week 12 | Week 16 | |
|---|---|---|---|---|---|---|---|
| LDPE | 95.19±1.00ex | 93.70±0.11dx | 92.27±0.66cx | 91.34±0.45bx | 90.36±0.46ax | 90.24±1.91ax | P <0.05 |
| HDPE | 95.19±1.00dx | 93.86±0.39cx | 93.32±0.63bcy | 93.13±0.21abcy | 92.50±0.36aby | 92.36±0.63ay | P <0.05 |
| PA | 95.19±1.00dx | 94.54±0.23bcy | 93.91±0.60cdz | 93.91±0.23bcz | 93.44±0.20abz | 93.11±0.40az | P <0.05 |
| PA+ Al | 95.19±1.00bx | 94.93±0.61az | 94.44±0.56abw | 94.21±0.43abw | 94.21±0.39aw | 94.10±0.34aw | P <0.05 |
| | P >0.05 | P <0.05 | P <0.05 | P <0.05 | P <0.05 | P <0.05 | |
| **$b^*$values** | **Week 0** | **Week 3** | **Week 6** | **Week 9** | **Week 12** | **Week 16** | |
| LDPE | 9.86±0.07ax | 10.48±0.58abx | 10.98±0.48bcy | 11.46±0.57cdy | 12.04±0.07dy | 12.27±0.38ey | P <0.05 |
| HDPE | 9.86±0.07ax | 10.31±0.53ax | 10.44±0.31axy | 11.25±0.58by | 11.48±0.40by | 11.57±0.22cy | P <0.05 |
| PA | 9.86±0.07ax | 10.23±0.43abx | 10.27±0.34abx | 10.46±0.43bx | 10.52±0.25bx | 10.58±0.23bx | P =0.05 |
| PA+ Al | 9.86±0.07ax | 10.08±0.17ax | 10.15±0.54ax | 10.25±0.18ax | 10.37±0.82ax | 10.42±0.30ax | P >0.05 |
| | P >0.05 | P >0.05 | P >0.05 | P <0.05 | P <0.05 | P <0.05 | |

*(Different superscripts a,b,c,d and x,y,z,w show significantly different (P < 0.05) within the same row and column, respectively)*

Changes in the color or discoloration of food items indicate the extent of degradation over time during storage due to the enzymatic and non-enzymatic reaction of nutritious compound such as polyphenols. Particularly for fine powder, such as flour, the degree of whiteness and yellowness (measured by L* and b* values) significantly influence the appearance and consumer acceptance of products. In this study, powders' color was assessed using a portable colorimeter, recording L∗ and b∗ values over the storage period, and results were presented in Table 2. The brightness of flour stored in various packaging materials notably declined over 16 weeks. The LDPE sample exhibited the most substantial L* reduction, dropping from 95.19 to 90.24 compared to 92.36, 93.11, and 94.09 of HDPE, PA, and PA-Al samples, respectively. The decline in flour whiteness corresponded with an increase in yellowness. The sample stored in LDPE bags demonstrated the highest rise in b* value, reaching 24.4% after 16 weeks, while

HDPE, PA, and PA-Al samples experienced increases of 17.3%, 7.3%, and 5.6%, respectively. These findings suggest color degradation of breadfruit flour during prolonged storage due to enzymatic reactions [11]; aligning with previous research on the impact of packaging materials on cassava flour color [19].

### *3.3. Effects of packaging materials on the breadfruit flour pH during storage*

Various packaging materials demonstrated different effects on the pH value of flour throughout the storage period, and the results was demonstrated on Table 3. The greatest reduction occurred in the LDPE sample, with the pH decreasing from 5.73 to 5.58, followed by HDPE and PA samples, while the smallest change was observed in PA-Al samples, reaching to 5.64 after 16 weeks. The decline of the pH value at the end of the study period might be attributed to the enzymatic oxidation of the flour during storage, leading to the accumulation of organic acids which was seen in the storage of some types of flour such as pupuru and teff flour [8], [15], [16]. The pH value serves as a crucial parameter indicating the quality of fine powder, with low pH indicating a sour taste that may decrease consumer acceptance [20].

**Table 3.** *The pH of flour storage in 4 types of bags in the period of 16 weeks*

| | **Week 0** | **Week 3** | **Week 6** | **Week 9** | **Week 12** | **Week 16** | |
|---|---|---|---|---|---|---|---|
| LDPE | 5.73±0.02cx | 5.70±0.02cx | 5.67±0.06bcx | 5.66±0.02bcx | 5.61±0.08abx | 5.58±0.06ax | P <0.05 |
| HDPE | 5.73±0.02bx | 5.69±0.04abx | 5.67±0.05abx | 5.67±0.06abx | 5.63±0.02abx | 5.62±0.10ax | P >0.05 |
| PA | 5.73±0.02bx | 5.71±0.02bx | 5.69±0.03abx | 5.68±0.05abx | 5.64±0.04ax | 5.63±0.08ax | P <0.05 |
| PA+ Al | 5.73±0.02ax | 5.71±0.04ax | 5.69±0.08ax | 5.69±0.07ax | 5.67±0.05ax | 5.64±0.10ax | P >0.05 |
| | P >0.05 | P >0.05 | P >0.05 | P <0.05 | P <0.05 | P >0.05 | |

*(Different superscripts a,b,c,d and x,y,z,w show significantly different (P < 0.05) within the same row and column, respectively)*

### *3.4. Effects of packaging materials on the breadfruit flour WAC, SP during storage*

The water adsorption capacity and swelling power are important functional properties of cereal-grain-flours for ready-to-eat food development. These properties are crucial for ensuring the cohesiveness of food products [21]. The WAC notably decreased from 2.92 to 2.4 g/g in LDPE bags during storage. However, HDPE, PA, and PA-Al ones demonstrated better storage performance, with WAC declines to 2.43, 2.49, and 2.57, respectively, as depicted in Table 4. Overall, WAC decreased significantly ($p < 0.05$) over time for each packaging material, with the smallest change observed in PA-Al samples. The protein content and its characteristics, such as type and hydrophilic properties, are believed to significantly influence WAC, alongside the carbohydrate composition of the flour. Reductions in amylose and amylopectin interactions during storage may contribute to the observed decline in WAC, a phenomenon noted in maize and water yam flour before [17], [18].

**Table 4.** *The WAC (g/g) of flour storage in 4 types of bags in the period of 16 weeks*

| | **Week 0** | **Week 3** | **Week 6** | **Week 9** | **Week 12** | **Week 16** | |
|---|---|---|---|---|---|---|---|
| LDPE | 2.92±0.03dx | 2.65±0.09cx | 2.65±0.03cx | 2.49±0.05bx | 2.42±0.06abx | 2.40±0.07ax | P <0.05 |
| HDPE | 2.92±0.03dx | 2.71±0.09cx | 2.67±0.03bcx | 2.58±0.04bxy | 2.47±0.09ax | 2.43±0.07ax | P <0.05 |
| PA | 2.92±0.03cx | 2.73±0.09bx | 2.69±0.07bx | 2.63±0.07aby | 2.51±0.10ax | 2.49±0.10ax | P <0.05 |
| PA+ Al | 2.92±0.03cx | 2.75±0.13bx | 2.73±0.07bx | 2.73±0.07bz | 2.65±0.06aby | 2.57±0.17ax | P <0.05 |
| | P >0.05 | P >0.05 | P >0.05 | P <0.05 | P <0.05 | P >0.05 | |

*(Different superscripts a,b,c,d and x,y,z,w show significantly different (P < 0.05) within the same row and column, respectively)*

The swelling power of flour tends to increase as the heating temperature rises, as the starch granules hydrate gradually. This process leads to the disruption of hydrogen bonds, causing expansion in amorphous regions and allowing granules to absorb water and swell [22]. In the present study, the swelling power of breadfruit flour exhibited a similar increasing trend with the processing temperature ranging from 60°C to 80°C. However, during the storage period, the swelling capacity significantly decreased across different packaging materials. The most substantial change was observed in the LDPE samples, while those of HDPE, PA, and PA-Al followed in descending order, as illustrated in Table 5. The findings presented align with the results reported by Shobha et al. (2014) regarding protein maize flour [21].

**Table 5.** *The SP (g/g) values of flour storage in 4 types of bags in the period of 16 weeks at 60, 70 and 80*°C

| **60°C** | **Week 0** | **Week 3** | **Week 6** | **Week 9** | **Week 12** | **Week 16** | |
|---|---|---|---|---|---|---|---|
| LDPE | 3.71±0.02dx | 3.54±0.09cx | 2.78±0.04bx | 2.12±0.02ax | 2.11±0.02abx | 2.08±0.06ax | P <0.05 |
| HDPE | 3.71±0.02cx | 3.64±0.08cx | 2.81±0.09bx | 2.22±0.03ay | 2.20±0.02ay | 2.18±0.10ax | P <0.05 |
| PA | 3.71±0.02cx | 3.67±0.08cx | 2.83±0.09bx | 2.41±0.01az | 2.40±0.02az | 2.37±0.08ay | P <0.05 |
| PA+ Al | 3.71±0.02cx | 3.94±0.22dy | 2.85±0.07bx | 2.53±0.02aw | 2.50±0.02aw | 2.44±0.08ay | P <0.05 |
| | P >0.05 | P <0.05 | P >0.05 | P <0.05 | P <0.05 | P <0.05 | |
| **70°C** | **Week 0** | **Week 3** | **Week 6** | **Week 9** | **Week 12** | **Week 16** | |
| LDPE | 4.70±0.01cx | 4.52±0.12bx | 3.34±0.04ax | 3.31±0.08ax | 3.29±0.02ax | 3.26±0.04ax | P <0.05 |
| HDPE | 4.70±0.01cx | 4.57±0.08bx | 3.36±0.02ax | 3.34±0.06ay | 3.33±0.02ax | 3.32±0.02ax | P <0.05 |
| PA | 4.70±0.01ex | 4.61±0.06dx | 3.55±0.02cy | 3.49±0.03bz | 3.46±0.04aby | 3.43±0.02ay | P <0.05 |
| PA+ Al | 4.70±0.01cx | 4.64±0.06cx | 3.63±0.02bz | 3.59±0.04abw | 3.57±0.09abz | 3.54±0.09az | P <0.05 |
| | P >0.05 | P >0.05 | P <0.05 | P <0.05 | P <0.05 | P <0.05 | |
| **80°C** | **Week 0** | **Week 3** | **Week 6** | **Week 9** | **Week 12** | **Week 16** | |
| LDPE | 6.57±0.05cx | 6.20±0.11bx | 6.19±0.04bx | 6.15±0.06bx | 5.90±0.07ax | 5.86±0.16ax | P <0.05 |
| HDPE | 6.57±0.05cx | 6.43±0.08bcy | 6.39±0.10aby | 6.30±0.07aby | 6.3±0.11aby | 6.27±0.13axy | P <0.05 |
| PA | 6.57±0.05dx | 6.48±0.06cy | 6.41±0.03bcy | 6.38±0.07aby | 6.33±0.04ay | 6.30±0.06ay | P <0.05 |
| PA+ Al | 6.57±0.05cx | 6.53±0.04bcy | 6.43±0.01aby | 6.40±0.09ay | 6.37±0.08ay | 6.35±0.10ay | P <0.05 |
| | P >0.05 | P <0.05 | P <0.05 | P <0.05 | P <0.05 | P <0.05 | |

*(Different superscripts a,b,c,d and x,y,z,w show significantly different (P < 0.05) within the same row and column, respectively)*

### *3.5. Effects of packaging materials on the breadfruit microbial quality during storage*

Table 6 presents the results for colony count of aerobic bacteria and molds found in breadfruit powder packed in various types of bags over a 16-week period. As can be seen, there was a notable difference in the total plate count for aerobic bacteria and fungi across different packaging materials and storage durations. Breadfruit flour stored in LDPE bags exhibited the highest count of aerobic bacteria and mold, while the lowest count was observed in PA-Al bags. The microbial load of the flour increased over time due to higher moisture content, which was absorbed by the flour and made available for microbial activity. This correlation between moisture content and the deterioration of pupuru flour was also observed by Daramola et al. (2010) [8] and was attributed to the moisture permeability of the packaging materials. LDPE was found to have the highest permeability compared to HDPE [23], which influenced the microbial growth in the flour samples.

**Table 6.** *Total count of aerobic bacteria and mold present in different bags*

| | | **LDPE** | **HDPE** | **PA** | **PA-Al** |
|---|---|---|---|---|---|
| Total bacteria count x $10^2$ (CFU/g) | Week 0 | < 1 | | | |
| | Week 3 | 40 | 23 | 17 | <1 |
| | Week 6 | 43 | 29 | 23 | 1 |
| | Week 9 | 50 | 33 | 29 | 5 |
| | Week 12 | 57 | 38 | 32 | 11 |
| | Week 16 | 63 | 46 | 48 | 21 |
| Total fungi count x $10^2$ (CFU/g) | Week 0 | < 1 | | | |
| | Week 3 | 13 | 6 | 2 | <1 |
| | Week 6 | 16 | 9 | 5 | 1 |
| | Week 9 | 21 | 13 | 7 | 3 |
| | Week 12 | 27 | 19 | 11 | 7 |
| | Week 16 | 31 | 24 | 18 | 17 |

## 4. Conclusion

The current study underscores the considerable influence of common plastic packaging on the physical and microbial attributes of conventional dried breadfruit powder over a 4-month storage. The laminated or metalized plastic (PA-Al) demonstrated the most effective protective characteristics in maintaining the physical and microbial properties of the flour in contract to LDPE material. More research on storage temperature and vacuum packaging needs to be done to improve the powders storage time for more food applications.

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