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EVALUATING THE IMPACT OF PACKAGING TYPES ON BREAD QUALITY AND SHELF LIFE

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ABSTRACT
This study evaluated the effects of packaging materials (HDPE, PP, and no packaging) and storage on the physicochemical and sensory properties of fried and baked bread over six days. Moisture content increased initially, peaking on the third and fourth days, before declining, with HDPE-packaged bread exhibiting the least fluctuation and superior moisture retention (approximately 15% lower moisture loss than unpackaged bread). Free fatty acid (FFA) content, indicative of lipid oxidation, increased over time, with unpackaged fried bread showing the highest values. Sensory evaluation revealed significant differences in color, aroma, texture, and overall acceptability. Fried bread packed in PP exhibited the best texture, while baked bread packed in PP scored highest in overall acceptability. This study highlights the importance of optimized packaging materials in preserving the quality and sensory attributes of bread during storage.

1. Introduction

Bread is a dietary staple globally, renowned for its versatility, convenience, and cultural significance. As a perishable product, maintaining its quality and prolonging its shelf life present significant challenges for producers, particularly in warm and humid climates where microbial spoilage is accelerated. The economic implications of bread waste further amplify the urgency of implementing effective preservation strategies since it contains promising energy block made from polysaccharides (Hafyan et al., 2024).

Fungal spoilage, primarily caused by Aspergillus and Penicillium species, is one of the leading factors reducing bread's shelf life. Mold growth is directly influenced by water activity, a critical parameter determining microbial proliferation (Peleg, 2022). Concurrently, oxidative rancidity—particularly in fried bread containing higher fat content—poses another quality concern. Unchecked, these factors result in sensory degradation and loss of consumer acceptability.

Packaging plays an indispensable role in mitigating these challenges by serving as a physical and chemical barrier against environmental influences. Among the numerous packaging materials available, Polypropylene (PP) and High-Density Polyethylene (HDPE) are widely utilized in food packaging. PP is favored for its clarity, mechanical strength, and low cost, while HDPE offers exceptional barrier properties against oxygen and moisture, making it particularly effective in high-humidity environments (Furqon et al., 2016). HDPE (High-Density Polyethylene) and polypropylene are two of the most widely used polymers globally due to their versatility and extensive applications (Awad et al., 2019).

Although extensively used, the specific performance of PP and HDPE in preserving bread under varying storage conditions has been insufficiently studied. Previous research has highlighted their general effectiveness in reducing water loss and oxidative degradation in food products (Khabbaz et al., 2024). However, comparative analyses focused on bread, particularly differentiating fried and baked varieties, remain limited.

This study aims to fill this gap by evaluating the impact of PP and HDPE packaging on key quality attributes of bread, including water content, free fatty acid (FFA) levels, and sensory acceptability, over six days of room-temperature storage. By integrating physicochemical and sensory assessments, this research seeks to provide actionable insights for the bakery industry, emphasizing the role of packaging in minimizing food waste and enhancing product appeal.

2. Research Materials and Methods

2.1. Materials

Bread samples (fried and toasted) were obtained from Malika Bakery, Mantingan, East Java. The bakery employs traditional and consistent production methods to ensure uniformity in the samples. Packaging materials (PP and HDPE plastics) were obtained from Surabaya, Indonesia. Chemicals (analytical-grade reagents) including 96% ethanol (Merck), 0.05 M NaOH (Merck), and other laboratory supplies, were utilized. Key instruments included an oven (Memmert) for moisture analysis, a burette (Pyrex) for titration, and sensory evaluation tools.

2.2. Water Content Analysis

The water content of bread samples was determined using an oven-drying method at 105°C (AOAC, 2005), until a constant weight was achieved. The water content percentage was calculated as wet basis.

2.3 Free Fatty Acid (FFA) Analysis

FFA levels were assessed by dissolving 14 g of bread sample in 25 mL of ethanol and titrating with 0.05 M NaOH until a stable pink color persisted for 30 seconds. The results of free fatty acids are calculated using the molecular weight (BM) of palmitic acid which is 256 included in the following formula:

$$\%FFA: \frac{\text{ml NaOh x N NaOH x BM x 100\%}}{\text{sample weight x 1000}}$$

2.4. Sensory Evaluation

Sensory acceptability was evaluated by 25 semi-trained panelists who rated attributes such as color, aroma, taste, texture, and overall preference using a 5-point hedonic scale (1 = very dislike, 5 = very like). The evaluations were conducted daily during the six-day storage period.

2.4. Statistical Analysis

All data were statistically analyzed using Two-Way ANOVA at a significance level of $p < 0.05$. Tukey's post hoc test was applied for pairwise comparisons to identify significant differences between treatments.

3. Results and Discussion

3.1. Moisture content

The moisture content of bread is a critical determinant of its freshness, texture, and shelf life. In this study, investigation conducted on different packaging materials—High-Density Polyethylene (HDPE), Polypropylene (PP), and no packaging—that affect the moisture content of fried and baked bread over a six-day storage period. Based on the water content of the type of bread and the type of packaging can be seen in **Fig. 1**. during storage, the occurrence of water content increases on the 3rd and 4th days, later decreases again in the next day. This study also indicated that HDPE-packaged bread exhibited the lowest fluctuations in water content throughout the storage period, reflecting its superior barrier against water vapor. Moisture loss in HDPE-packaged bread was approximately 15% lower than unpackaged bread by day six (**Table 1**). These findings align with those reported by Jaime et al., (2022), who highlighted the effectiveness of HDPE in minimizing moisture loss in food products.

The moisture content for all samples remained within acceptable limits set by the Indonesian National Standard (SNI 01-3840-1995), which specifies a maximum moisture content of 40% for bread products. However, fluctuations observed on the third and fourth days of storage in unpackaged and PP-packaged bread indicate a need for improved barrier properties to sustain freshness. Based on the data presented in **Table 1**, no statistically significant differences were observed in final average water content across packaging types and bread types during the storage period ($p > 0.05$).

HDPE packaging known for its low permeability to moisture and gases, while PP offers moderate barrier properties. HDPE effectively creates a barrier that can trap moisture within the bread. This characteristic likely contributed to the initial increase in moisture content observed in both fried and baked bread samples. However, over time, factors such as moisture redistribution within the bread matrix and potential condensation could lead to a subsequent decrease in moisture content (Julyanti et al., 2024).

In the unpackaged bread sample, exposure to ambient conditions without protective packaging facilitates continuous moisture loss, leading to staling and textural degradation. The more pronounced decline in moisture content in baked bread compared to fried bread could be due to differences in initial moisture levels and fat content, with fried bread's higher fat content potentially slowing moisture loss (Martins et al., 2020).

3.2. Free fatty acids (FFA)

The free fatty acid (FFA) content of bread samples (A to F) was analyzed over a six-day storage period to evaluate lipid hydrolysis and oxidative stability under different packaging and storage conditions. FFA values fluctuated but generally increased across the samples, suggesting progressive lipid degradation, consistent with oxidative rancidity trends in bakery products during storage. FFA levels, indicative of lipid hydrolysis and oxidation, increased in all samples over time. Fried bread, with its higher fat content, showed a more pronounced rise in FFA values (**Table 2**). Notably, "baked" bread maintained FFA levels below the 0.30 threshold for acceptability throughout the six days, whereas fried bread exceeded this threshold day by day.

Samples A, B, and C exhibited higher average FFA contents of 0.397%, 0.290%, and 0.377%, respectively, compared to samples D, E, and F, which showed averages of 0.305%, 0.386%, and 0.208%. This suggests that the lipid composition or initial quality of the fats used in samples A, B, and C may be more susceptible to hydrolytic and oxidative reactions during storage. Such increases in FFA are common in stored bakery products, as triglycerides undergo hydrolysis, leading to the production of free fatty acids (Edwards & Mohiuddin, 2023).

Notably, sample F consistently maintained the lowest FFA levels throughout the storage period, with an average of 0.208% (**Table 2**). This stability could be attributed to several factors, including the use of more stable fats, the presence of antioxidants, or effective packaging that limits exposure to oxygen and moisture. Effective packaging is known to play a significant role in preserving the quality of bakery products by minimizing oxidative rancidity (Bhise & Kaur, 2014).

Table 1. Moisture content of bread during storage

Sample	Day							
	0	1	2	3	4	5	6	Average
A	21.447	28.249	33.201	50.000	29.125	26.202	26.804	30.718a
B	23.461	24.000	24.844	50.000	24.475	27.139	23.554	28.210a
C	27.232	23.000	45.921	33.951	25.538	23.370	27.996	29.572a
D	22.772	20.790	25.000	50.000	58.000	23.370	25.910	32.263a
E	23.786	23.253	23.000	50.000	23.386	26.483	19.517	27.061a
F	25.002	20.799	15.000	50.000	36.658	15.293	14.705	25.351a

*Different notation letter showing significant difference. [A = fried (HDPE); B = baked (HDPE); C = fried (PP); D = baked (PP); E = fried (Unpackaged); F = baked (Unpackaged)]

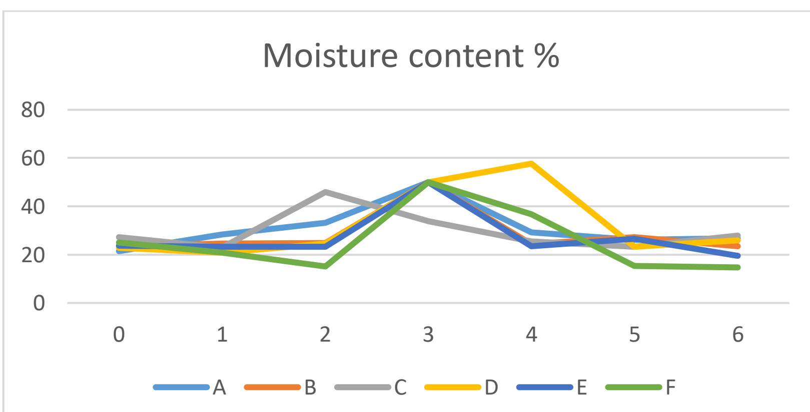

Fig. 1 Moisture content during storage of three bread samples [A = fried (HDPE); B = baked (HDPE); C = fried (PP); D = baked (PP); E = fried (Unpackaged); F = baked (Unpackaged)]

Table 2. Free fatty acids (FFA) content of bread during storage

Sample	Days						
	1	2	3	4	5	6	Average
A	0.350	0.313	0.458	0.524	0.381	0.355	0.397a
B	0.268	0.407	0.263	0.275	0.297	0.231	0.290a
C	0.475	0.402	0.328	0.370	0.370	0.314	0.377a
D	0.247	0.267	0.348	0.310	0.338	0.321	0.305b
E	0.421	0.504	0.362	0.395	0.291	0.342	0.386b
F	0.244	0.206	0.220	0.212	0.214	0.153	0.208c

*Different notation letter showing significant difference. [A = fried (HDPE); B = baked (HDPE); C = fried (PP); D = baked (PP); E = fried (Unpackaged); F = baked (Unpackaged)]

Table 3. Average score of bread sensory attributes during storage

Sample	Color	Taste	Aroma	Texture	Overall
A	2.57a	2.26a	3.39a	2.67bc	2.31ab
B	2.86b	2.23a	3.04b	2.55bc	2.48bc
C	2.44a	2.25a	3.21b	2.79c	2.38bc
D	2.86b	2.22a	3.06b	2.69bc	2.61c
E	2.44a	2.19a	2.06c	2.43b	2.29ab
F	2.91b	2.10a	2.87b	1.93a	2.10a

*Different notation letter showing significant difference. [A = fried (HDPE); B = baked (HDPE); C = fried (PP); D = baked (PP); E = fried (Unpackaged); F = baked (Unpackaged)]

The observed fluctuations in FFA content across different samples and storage days underscore the complex interplay between fat composition, storage conditions, and packaging materials. Understanding these dynamics is essential for improving the shelf life and sensory qualities of bread, as elevated FFA levels can lead to off-flavors and decreased consumer acceptance. Regular monitoring of FFA content during storage can serve as a valuable quality control measure to ensure product integrity.

3.3. Sensory properties

The sensory evaluation scores of bread samples stored under different packaging conditions and processing methods are presented in **Table 3.** Significant differences ($p < 0.05$) were observed across attributes such as color, aroma, texture, and overall acceptability, while taste showed no significant difference among the samples. Sample F (baked, unpackaged) exhibited the highest color score (2.91), significantly differing from samples A, C, and E, which received lower scores. The high score for baked samples (B, D, F) may be attributed to the Maillard reaction, which enhances browning and visual appeal during baking compared to frying (Purlis, 2010). Packaging materials also influenced the perception of color (Berthold et al., 2024), as unpackaged samples (E, F) (**Table 3**) may have experienced oxidation and environmental exposure, leading to changes in appearance.

Taste scores did not significantly differ among the samples, suggesting that the processing method and packaging type minimally affected the bread's flavor profile during storage. This stability in taste could be due to the limited volatilization of flavor compounds under the given conditions (Chitpan et al., 2015). Similar findings were reported in bread stored with modified packaging, where taste remained unaffected by external conditions (Pasqualone, 2019).

Aroma scores varied significantly, with Sample A (fried, HDPE) achieving the highest aroma rating (3.39) and Sample E (fried, unpackaged) scoring the lowest (2.06) (**Table 3**). Fried samples generally retained aroma better, likely due to lipid-derived flavor compounds formed during frying, which may be better preserved in sealed packaging. The high temperature of the oil causes a chemical reaction called the Maillard reaction, which is responsible for the characteristic golden-brown color and savory flavor of fried foods (Chen, 2023). Conversely, unpackaged samples showed significant aroma loss due to volatilization and exposure to external odors.

The texture of Sample C (fried, PP) scored the highest (2.79), differing significantly from Sample F (baked, unpackaged), which had the lowest score (1.93) (**Table 3**). This indicates that packaging materials, particularly PP, provided better texture retention by maintaining moisture content during storage. Unpackaged samples, on the other hand, showed reduced textural quality due to desiccation and exposure to humidity.

Sample D (baked, PP) had the highest overall acceptability score (2.61), significantly surpassing Sample F (2.10). The combination of baking and PP packaging likely preserved sensory qualities more effectively, making it favorable to panelists. Studies highlight that polypropylene packaging offers superior barriers against moisture, high heat distortion, transparency, dimensional stability (Maddah, 2016), contributing to enhanced sensory acceptability.

4. Conclusion

The study demonstrated that packaging materials significantly influence the physicochemical and sensory properties of bread during storage. HDPE provided the best moisture retention, reducing moisture loss by 15% compared to unpackaged bread, while PP showed moderate effectiveness. FFA content increased with storage time, indicating lipid degradation, with fried bread being more prone to oxidation due to its higher fat content. Sensory evaluation highlighted the superior acceptability of baked bread packaged in PP, which preserved attributes such as texture and aroma. These findings underline the necessity of selecting appropriate packaging materials to enhance bread's shelf life and maintain consumer satisfaction.

5. References

AOAC. 2005. Official method of analysis. 18th edition, Association of Officiating Analytical Chemists. Washington DC: Scientific Research Publishing

Awad, A., Elgamsy, R., Wahab, A., Hazem-Abdellatif, M. 2019. Mechanical and Physical Properties of PP and HDPE. *Engineering Science,* 4(2), 34-42. https://doi.org/10.11648/j.es.20190402.12

Berthold, A., Guion, S., Siegrist, M. 2024. The Influence of material and color of food packaging on consumers' perception and consumption willingness. *Food and Humanity Journal,* 2. https://doi.org/10.1016/j.foohum.2024.100265

Bhise, S., Kaur, A. 2014. Baking quality, sensory properties and shelf life of bread with polyols. *J Food Sci Technol.,* 51(9): 2054-2061. doi: https://doi.org/10.1007/s13197-014-1256-3

Chen, Z. 2023. The? chemisty behind fried foods: how frying affects flavor, texture, and health *J Food Microbiol Saf Hyg*. 8(205).

Chitpan, M., Wu, J.C., Pan, M.H., Ho, C.T. 2015. Reactivity and stability of selected flavor compounds. *Journal of Food and Drug Analysis*, 23. https://doi.org/10.1016/j.jfda.2015.02.001

Edwards, M., Mohiuddin, S.S. 2023. *Biochemistry, lipolysis*. US: StatPearls Publishing.

Hafyan R.H., Mohanarajan, J., Uppal, M., Kumar, V., Narisetty, V., Maity, S.K., Sadhukhan, J., Gadkari, S. 2024. Bread waste valorization: a review of sustainability aspects and challenges. *Front. Sustain. Food Syst*, 8: https://doi.org/10.3389/fsufs.2024.1334801

Jaime, S.B.M., Alves, R.M.V., Bocoli, P.F.J. 2022. Moisture and oxygen barrier properties of glass, PET and HDPE bottles for pharmaceutical products. *Journal of Drug Delivery Science and Technology*, 71. https://doi.org/10.1016/j.jddst.2022.103330

Julyanti, W.O.L., Duka, F.Z., Rahman, A.N.F., Outri, T.P. 2024. The effect of packaging type on the shelf life of fresh bread premix flour based on modified flour. *Bio Web Conferences*, 96, 1-8. https://doi.org/10.1051/bioconf/20249601022

Khabbaz, H.S., Demets, R., Gahleitner, M., Duscher, B., Stam, R., Dimitrova, A., Fiorio, R., Gijsman, P., Ragaert, K., Goonieie, A. 2024. Rheological insights into the degradation behavior of PP/HDPE blends. *Polymer Degradation and Stability*, 225. https://doi.org/10.1016/j.polymdegradstab.2024.110819

Maddah, H.A., 2016. Polypropylene as a Promising Plastic: A Review. *American Journal of Polymer Science*, 6(1): 1-11. https://doi.org/10.5923/j.ajps.20160601.01

Martins, I.E., Shittu, T.A., Onabanjo, O.O., Adesina, A.D., Soares, A.G., Okolie, P.I., Kupoluyi, A.O., Ojo, O.A., Obadina, A.O.. Effect of packaging materials and storage conditions on the microbial quality of pearl millet sourdough bread. *J Food Sci Technol*, 58(1):52-61. https://doi.org/10.1007/s13197-020-04513-3

Pasqualone, A. 2019. Bread packaging: features and functions *in Flour and Breads and their Fortification in Health and Disease Prevention (Second Edition),* 211-222. US: Academic Press. https://doi.org/1016/B978-0-12-814639-2.00017-4

Peleg, M. 2022. Models of the water activity effect on microbial growth rate and initiation. *Appl Microbiol Biotechnol* 106, 1375–1382 (2022). https://doi.org/10.1007/s00253-022-11792-7

Purlis, E. 2010. Browning development in bakery products – A review. *Journal of Food Engineering*, 99(3), 239-249. https://doi.org/10.1016/j.jfoodeng.2010.03.008