JURNAL
TEKNOLOGI AGRO-INDUSTRI
Vol. 12 No. 2; November 2025

e-ISSN 2598-5884
p-ISSN 2407-4624

Color Stability of Gelamai With Added Oxygen Absorber During Shelf Life

Firmansyah Firmansyah[1*], Syafnil Syafnil[1], Laili Susanti[1]

[1] Department of Agricultural Industry Technology, Universitas Bengkulu, Indonesia
*Correspondence: ffirmansyah@unib.ac.id

Naskah diterima: 01 Juli 2025; Naskah disetujui: 10 November 2025

ABSTRACT

This study aims to analyze the effect of oxygen absorber on the color stability of gelamai. It evaluates changes in chroma and hue angle using the CIE Lab color system under two types of packaging (PE and vacuum) and two storage temperatures (room temperature and freezer) during 8 days. The colour changes observed in the samples were caused by oxidation. Throughout storage, the oxygen absorber reduces or retardes oxidative reactions. These findings revealed that vacuum packaging slowed colour changes more effectively than PE packaging, especially at room temperature, while freezer storage produced more complex and nonlinear patterns, likely due to physicochemical interactions. Kinetic analysis disclosed a difference in reaction rate constants (k) between packaging and temperature conditions, vacuum packaging disclosed lower kinetic value and more stable color than other conditions. PE room temp (R^2 = 0.9311), Vacuum room temp (R^2 = 0.5776), PE freezer (R^2 = 0.5847), Vacuum freezer (R^2 = 0.7258). Statistically disclosed no significant difference in all treatments. This study concludes that oxygen absorbers are effective in preserving the color quality of gelamai during storage.

Keywords: color, gelamai, kinetic, packaging

INTRODUCTION

From West Sumatera, galamai is a traditional food made from coconut milk, brown sugar, and glutinous rice flour. Traditionally made with wood-fired cooking methods, the preparation entails folding the ingredients and heating them at high heat until a dark brown dough develops (Murtius & Hari, 2016). Historically, a traditional semi-moist confection, it is cited as hailing from Payakumbuh Regency, West Sumatra, Indonesia (Ermiati & Gusmalini, 2022). Classified as an intermediate-moisture food product, inherently limiting its shelf life (Kasmita et al., 2018). It makes an excellent gift due to its palatable taste. Additionally, it's frequently sold as a memento to tourists going to other places (Ermiati & Gusmalini, 2022).

Gelamai is a semi-moist food that is supposed to look good for lasting over several month and the challenge of this product lies in its high moisture and fat content, which makes it prone to oxidation (Wen-xuan et al., 2020). Because of its high water and coconut milk content, the remaining gelamai oxidizes and becomes rancid. The remaining oxygen in the packing is the cause of this alteration in sensory qualities. Oxygen absorber is one method where it can be used to lower the amount of oxygen in the container. To the best of the authors' knowledge, no prior studies have investigated the effect of oxygen absorbers on the quality of gelamai during storage.

By actively regulating the in-package conditions, oxygen absorber aims to prolong the product's shelf life and preserve its quality. Common oxygen absorber materials include compounds that absorb or otherwise adsorb oxygen, ethylene, carbon dioxide, or moisture or those that release carbon dioxide or ethanol (López-Cervantes et al., 2003). Iron-based oxygen scavengers within a polymer matrix react at a relative humidity of 75% or higher, meaning the oxygen scavengers are activated by moisture. This behaviour is because non-nano scale sodium chloride absorbs water vapor at relative humidities above approximately 75% at 23°C (Cichello, 2015).

Recognized as aerolabile, foods are required to reduce environmental oxygen access or packaged in multi-layered O_2-resistant plastic packaging (Mueller et al., 2013). O_2 permeability observed during recovery is levels and leads to spoilage. To reduce the increase in oxygen permeation caused by retort shock, an O_2 scavenger layer is voated in a distinct layer within multi-layered construction. It uptakes O_2 diffusion and functions as an active barrier. The oxygen absorbers repeatedly applied for the layer are Fe powders spread throughout agents within a polymer matrix (Cichello, 2015). Light influences gene activity engaged in anthocyanin biosynthesis, which leads to the red, blue, and purple colors in many fruits, according to Ermiati & Gusmalini. (2022) the advantage of packaging is effective in preserving food. Based-O_2 abrsobtion packaging is acknowledged as the most advanced and addressed packaging.

Numerous foods are responsive to O_2 (Miltz & Perry, 2005). In theory, 300cc of CO_2 and oxygen may be absorbed by 1g of iron (Miltz & Perry, 2005). The most popular metal agents in packaged food items are iron-based scavengers, which provide increased effectiveness, affordability, and a quicker rate of oxidation (Gupta, 2023). Based on the aforementioned concerns, it can be concluded that powder has the advantage of absorbing oxygen, making it possible to mathematically model the active oxygen absorber packaging for gelamai at various temperatures and packaging types.

Polyethene (PE) packaging and vacuum techniques can reduce exposure to oxygen and moisture (Dong-ying et al., 2020), thereby slowing down product degradation. Color stability evaluation can be performed using the CIE Lab system, with parameters a* (redness-greenness), b* (yellowness-blueness), chroma (color intensity), and hue angle (color dominance). Reaction kinetics approaches can be applied to predict the rate of color stability by modelling the data using zero-order, first-order equations to assess the effect of temperature on the reaction rate constant. The results of this study are expected to provide recommendations for optimal packaging techniques and storage to preserve gelamai while maintaining its color quality. The kinetic models produced can also be used as a guide in the food business to forecast how the quality of products will change over time. The study aimed to predict the dynamics of color stability using the chroma kinetics equation and examine gelamai's color stability under various storage conditions and packaging methods.

RESEARCH METHODOLOGY

Tools and Material

Glutinous rice flour, instant coconut milk, water, palm sugar, salt, pandan leaves, vacuum packaging, Polyethylene (PE), and O-Buster - oxygen absorber. The tools used in this study include a wok, knife and cutting board, weighing scale, sealer, and colorimeter.

Experimental Design

The experimental design used is a Completely Randomized Design (CRD) with two factor: variations in storage temperature and packaging type. The experiment was conducted with three replications, as shown in Table 1. A total of four samples were used, each with three replications, resulting in 12 samples in total. Room temperature was measured in the range of approximately 23–30 °C.

Table 1. Experiment Design

Storage Temperature	**Packaging Type**	
	PE (K1)	**PE (K2)**
Freezer (3ºC) (T1)	K1T1	K2T1
Room Temperature (20-25ºC) (T2)	K1T2	K2T2

Data Analysis

Color

The sample’s color was measured periodically using a colorimeter. The readings were expressed in CIELab L, a*, and b* values. Chroma (C*) and Hue angle (h°) were calculated using the method adopted by Darvish et al. (2022). The calculation of Hue angle and Chroma values is shown in Equations (1) and (2).

$$\text{Hue angle } (^{o}) = tan^{-1}(\frac{b^*}{a^*}) \quad (1)$$

$$\text{Chroma} = \sqrt{(a^*)^2 + (b^*)^2} \quad (2)$$

Kinetics

Equation (3) shows that the changes in the sample's Hue Angle and Chroma values of the sample during storage under different temperatures and packaging conditions were analyzed using kinetic equations, as shown in Equation (3).

Preparation of Experimental Apparatus and Materials

a. *Production of Gelamai*

The Gelamai samples were prepared using a 1:1:0.5 kg ratio of glutinous rice flour, palm sugar, and white sugar. They were cut into pieces and weighed approximately 50 grams each.

b. *Packaging Procedure*

After cooking, the samples were weighed to 200 grams each. Each sample was then wrapped in packaging material, and one sachet of iron powder was placed inside each package. The samples were stored under different temperature conditions for each treatment. Observations were carried out on days 0, 2, 4, 6, and 8 of storage.

c. *Determination of Kinetic Model*

In general, the quality fluctuation of a product during storage can be described utilizing 0-order, 1-order, or higher-0 kinetics (Zhang et al., 2021). Equations 2 and 3 present the integrated forms of the 0- and 1- order models.

d. *Kinetics*

The gelamai attributes during storage were analyzed using 0-, 1-, and 2-order kinetic analysis, depending on the shape of the graph obtained from each quality parameter. The general kinetic equation is presented in Equation (3) (Zhang et al., 2021).

$$\frac{dM}{dt} = \text{-k. } M^n \quad (3)$$

Where:

k = Change Rate Constant

M = measurable quality data

n = order

Equation (4) is used to calculate order 0, equation (5) order 1, and equation (6) order 2.

$$M_t = -\text{k.t} + M_0 \tag{4}$$

$$M_t = M_0 . e^{-kt} \tag{5}$$

$$M_t = \frac{M_0}{M_0 - k.t + 1} \tag{6}$$

Table 2. Gelamai Color Measurement Data During Storage

Type of packaging	Condition Storage	Storage Time (Day)	*a**	*b**	*Chroma**	*Hue angle* (^{o})
PE Packaging	Room Temperature	0	4.63	3.53	5,82	37.3°
		2	4.77	3.78	6,08	38.3°
		4	4.77	3.89	6.16	39.1°
		6	4.77	4.22	6.55	40.1°
		8	5.10	5.00	7.14	44.4°
	Freezer Temperature	0	4.63	3.53	5.82	37.3°
		2	4.78	3.90	6.16	39.1°
		4	4.67	5.01	6.86	47.1°
		6	5.01	5.44	7.39	47.1°
		8	5.23	5.82	7.83	47.1°
Vacuum Packaging	Room Temperature	0	4.63	3.53	5.82	37.3°
		2	4.55	3.54	5.76	37.9°
		4	4.84	3.89	6.22	38.8°
		6	4.89	3.99	6.31	39.2°
		8	4.89	3.93	6.96	45.2°
	Freezer Temperature	0	4.63	3.53	5.82	37.3°
		2	4.88	3.90	6.23	38.6°
		4	4.90	4.01	6.33	39.3°
		6	5.10	4.99	7.15	44.4°
		8	5.11	5.02	7.17	44.5°

RESULTS AND DISCUSSION

The red-green axis in the CIELAB color system may originate from composition of the pigment (anthocyanins, carotenoids, betalains, and chlorophyll) is one of the primary contributors (Dubinina et al., 2020; J. Lee & Schwartz, 2005; Leo, 2004; Podsędek, 2023; Rockland, 2017), pH level (Walkowiak-Tomczak et al., 2016), temperature and light exposure (Walkowiak-Tomczak et al., 2016) as well as oxygen and water activity (Nollet, 2004; Rockland, 2017). Indirectly, packaging nanoencapsulation protecting products against light and oxygen can retain colour (Anna, 2023; Berthold et al., 2024; Nollet, 2004; Podsędek, 2023; Shivani et al., 2023). Likewise, the thermal process helps maintain the natural color of food (Nowacka et al., 2021; Pandiselvam et al., 2023). Discolouration in the samples was attributed to oxidative reactions (Petrozziello et al., 2018). Throughout storage, the oxygen absorber functioned as an oxygen scavenger, effectively reducing or retarding oxidation (Villmann & Weickhardt, 2021).

Materials containing glutinous rice flour show an initial increase followed by a decrease in color value as environmental temperature rises, with the lightness reaching its minimum at 55°C (Wei et al., 2020). According to Nakagawa et al. (2016) increased hydrophobicity is caused by protein modification, foods containing glutinous rice flour undergo dramatic color stability at high temperatures.

As the yellow-blue chromaticity axis, the b* value in CIELAB color is very important. Furthermore, b* is crucial for determining the product’s ripeness and quality. For example, a more yellowish color, which is often associated with fruit ripeness, can be indicated by a higher b* value (Molina et al., 2023). Consumer preferences can be strongly influenced by the yellow-blue axis (b*); customers are more likely to choose foods with an attractive b* (Lis & Bartuzi, 2020; Nollet, 2004).

Changes that take put amid the generation and capacity of nourishment may be shown by changes within the b*. For occasion, a drop within the b* implies that yellow colors are being misplaced, which might affect the product's stylish, engaging quality (Molina et al., 2023). To secure customers, the utilization of color additives—including those that modify the b*—is firmly controlled. Characteristic colorants are progressively being utilized in put of engineered ones since they are thought to be more secure and may have wellbeing b* (Lipman, 2008). When measuring nourishment color, the b* may be a factor influencing shopper choice, quality assessment, and administrative compliance. Long-term nourishment color analysis is being molded by innovative progressions and the move toward common colorants, which can ensure that nourishment things fulfill client desires and security controls.

The color characteristics of nourishment have a critical effect on its brightness. For example, the ingredients used in food goods might affect their L*. Depending on the kind of fruit powder used, the brightness in a study on pudding compositions varied from 42.57 to 81.91 (Popova et al., 2024). Likewise, protein balls color lightness value dropped from 40 to 30 when cricket flour was added (Khalil et al., 2024).

The brightness level of food products can be changed by adding specific substances. Salted egg white (SEW), for instance, lessens the brightness of steamed bread (Abker et al., 2024), and muffins made with cold-pressed anise flour (CAF) have lower lightness ratings (Gökşen & Ekiz, 2021). Food. brightness includes how food looks as well as how consumers perceive its nutritional value. Ingredients and processing techniques can greatly impact brightness levels, while labeling and sensory characteristics have an impact on how consumers perceive snack items. Proper illumination can improve food products's perceived freshness and aesthetic appeal. Developing food items that satisfy customer tastes and follow health trends requires understanding these elements.

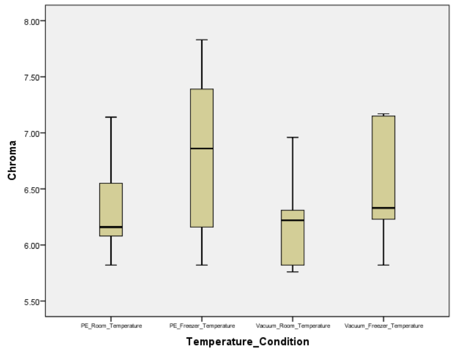


Figure 1. Chroma Normality Test

Based on Figure 1. the normality test, all chroma value samples—K1T2 (Sig. = 0.605), K1T1 (Sig. = 0.796), K2T2 (Sig. = 0.436), and K2T1 (Sig. = 0.299)—showed normal distributions as their significance values were greater than 0.05. The homogeneity of variance test yielded a significance value of 0.385, above 0.05, indicating equal or homoscedastic variances across the four storage temperature conditions, thus fulfilling the homogeneity assumption required for one-way ANOVA. The ANOVA results showed a significance value of 0.478, greater than 0.05, indicating no significant differences among the four storage temperature conditions, so a post-hoc DMRT test was unnecessary.

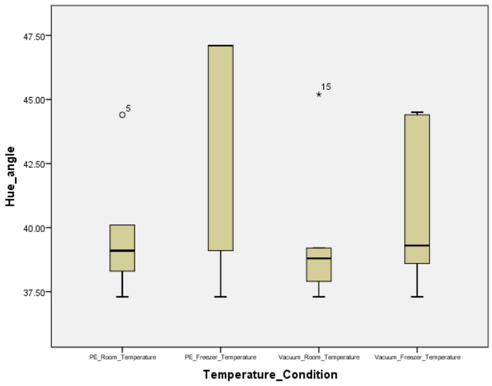


Figure 2. Hue angle Normally Test

Based on Figure 2. the normality test, the Hue angle data showed a mixed distribution; K1T2 (0.302) and K2T1 (0.144) were normally distributed (Sig. > 0.05), while K1T1 (0.023) and K2T2 (0.043) were not (Sig. < 0.05). The homogeneity of variance test yielded a significance value of 0.108, indicating homogeneous variances across the four storage temperature conditions, thus meeting the assumption for one-way ANOVA. The ANOVA result (Sig. = 0.343) showed no significant differences between the conditions, so a post-hoc DMRT test was unnecessary.

Kinetic

Table 3 displayed a kinetics analysis gelamai chroma change at various storage and packaging conditions. Vacuum packaging is more effective in preserving color stability than PE, both at room and freezer temperatures. At room temperature, PE packaging exposed chroma enhancement patterns linearly by time (Ht=H0+5.82×10−2t+1). Meanwhile, vacuum packaging retrieved a slower rate of change (Ht=H0+5.76×10−2t+1). At freezer temperature, PE packaging showed greater non-linear variations. while vacuum packaging showed a stable pattern with a lower rate of change (Ht=H0+6.33×10−2t+1). These findings asserted that vacuum packaging should preserve gelamai color because of chemical degradation and oxidation, thus extending its shelf-life.

Table 3. Chroma Kinetic Analysis

Day(s) Storage	PE (Room Temp)	Chroma Kinetic	Vacuum (Room Temp)	Chroma Kinetic
0	5.82	$H_t = \frac{H_0}{H_0 x\ 5.82x10^{-2}x\ t + 1}$	5.82	$H_t = \frac{H_0}{H_0 x 5.82x10^{-2} * t + 1}$
2	6.08	$H_t = \frac{H_0}{H_0 x 6.08x10^{-2}x\ t + 1}$	5.76	$H_t = \frac{H_0}{H_0 x 5.76x10^{-2}x\ t + 1}$
4	6.16	$H_t = \frac{H_0}{H_0 x 6.16x10^{-2}xt + 1}$	6.22	$H_t = \frac{H_0}{H_0 x 6.22x10^{-2}x\ t + 1}$
6	6.55	$H_t = \frac{H_0}{H_0 .x 6.55x10^{-2}xt + 1}$	6.31	$H_t = \frac{H_0}{H_0 x 6.31x10^{-2}x\ t + 1}$
8	7.14	$H_t = \frac{H_0}{H_0 x 7.14x10^{-2}x\ t + 1}$	6.96	$H_t = \frac{H_0}{H_0 x 6.96x10^{-2}x\ t + 1}$
Day(s) Storage	**PE (Freezer Temp)**	**Chroma Kinetic**	**Vacuum (Freezer Temp)**	**Chroma Kinetic**
0	5.82	$H_t = \frac{H_0}{H_0 x 5.82x10^{-2}x\ t + 1}$	5.82	$H_t = \frac{H_0}{H_0 x 5.82x10^{-2}x\ t + 1}$
2	6.16	$H_t = \frac{H_0}{H_0 x\ 6.16x10^{-2}x\ t + 1}$	6.23	$H_t = \frac{H_0}{H_0 x\ 6.23x10^{-2}x\ t + 1}$
4	6.86	$H_t = \frac{H_0}{H_0 x 6.86x10^{-2}x\ t + 1}$	6.33	$H_t = \frac{H_0}{H_0 .x 6.33x10^{-2}x\ t + 1}$
6	7.39	$H_t = \frac{H_0}{H_0 x 7.39x10^{-2}x\ t + 1}$	7.15	$H_t = \frac{H_0}{H_0 x 7.15x10^{-2}x\ t + 1}$
8	7.83	$H_t = \frac{H_0}{H_0 x 7.83x10^{-2}xt + 1}$	7.17	$H_t = \frac{H_0}{H_0 x 7.17x10^{-2}x\ t + 1}$

Table 4 exposed analysis of hue change kinetics of angle gelamai at various storage and packaging conditions. It exposed that vacuum packaging more effective in preserving hue angle compared to PE packaging both room and freezer temperatures. At room temperature, PE packaging exposed hue angle enhancement pattern in lineer by time

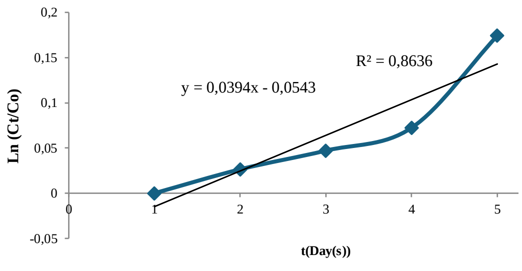
(Ht=H0+37.3×10−2t+1). Meanwhile, vacuum packaging showed a lower enhancement pattern (Ht=H0+37.9×10−2t+1). At freezer temperature, PE packaging is exposed higher non-linear various. Meanwhile, vacuum packaging showed a stable pattern with a lower rate of change (Ht=H0+45.2×10−2t+1). These findings asserted that vacuum packaging preserves gelamai hue angle. Thus, these could preserve gelamai quality visually.

Table 4. Hue Angle Kinetic Analysis

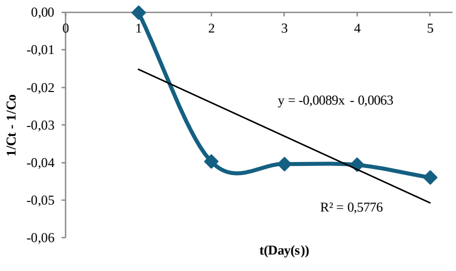
Day(s) Storage	PE (Room Tempt)	Hue angle Kinetic	Vacuum (Room Tempt)	Hue angle Kinetic
0	37.3	$H_t = \frac{H_0}{H_0 x 37.3 x 10^{-2} x\ t + 1}$	37.3°	$H_t = \frac{H_0}{H_0 x\ 0.10^{-2} x\ t + 1}$
2	38.3	$H_t = \frac{H_0}{H_0 x 38.3 x 10^{-2} x\ t + 1}$	37.9°	$H_t = \frac{H_0}{H_0 x 37.9 x 10^{-2} x\ t + 1}$
4	39.1	$H_t = \frac{H_0}{H_0 x 39.1 x 10^{-2} x t + 1}$	38.8°	$H_t = \frac{H_0}{H_0 x\ 38.8 x 10^{-2} x\ t + 1}$
6	40.1	$H_t = \frac{H_0}{H_0 x 40.1 x 10^{-2} x\ t + 1}$	39.2°	$H_t = \frac{H_0}{H_0 x 39.2 x 10^{-2} x\ t + 1}$
8	44.4	$H_t = \frac{H_0}{H_0 x\ 44.4\ x\ 10^{-2} * t + 1}$	45.2°	$H_t = \frac{H_0}{H_0 x\ 45.2 x 10^{-2}\ x\ t + 1}$

Day(s) Storage	PE (Freezer Tempt)	Hue angle Kinetic	Vacuum (Freezer Tempt)	Hue Angle Kinetic
0	37.3°	$H_t = \frac{H_0}{H_0 x\ 0.10^{-2} x\ \ t + 1}$	37.3°	$H_t = \frac{H_0}{H_0 x\ 0 x 10^{-2} x\ t + 1}$
2	39.1°	$H_t = \frac{H_0}{H_0 x\ 24.31 x 10^{-2} x\ t + 1}$	38.6°	$H_t = \frac{H_0}{H_0 x 38.6 x 10^{-2} x\ t + 1}$
4	47.1°	$H_t = \frac{H_0}{H_0 x 32.31 x 10^{-2} x\ t + 1}$	39.3°	$H_t = \frac{H_0}{H_0 x 39.3 x 10^{-2} x\ t + 1}$
6	47.1°	$H_t = \frac{H_0}{H_0 .x\ 24.31 x\ 10^{-2} x\ t + 1}$	44.4°	$H_t = \frac{H_0}{H_0 x 7.1 x 10^{-2} x\ t + 1}$
8	47.1°	$H_t = \frac{H_0}{H_0 .x\ 24.31 x\ 10^{-2}\ x\ t + 1}$	44.5°	$H_t = \frac{H_0}{H_0 x 7.2 x 10^{-2} x\ t + 1}$

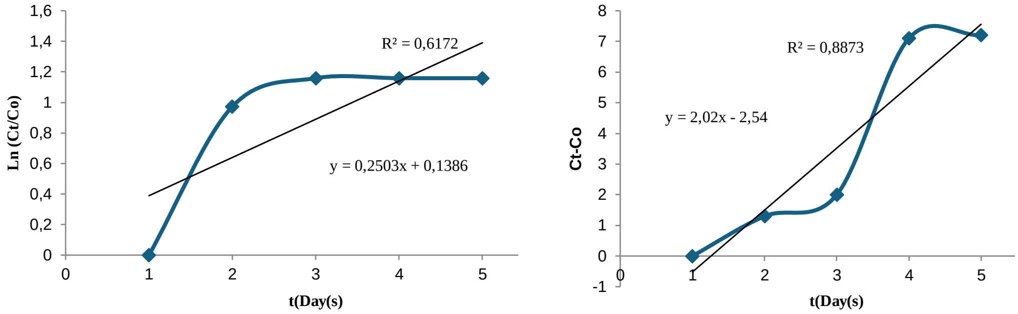
Regression



PE (Room Temperature)



Vacuum (Room Temperature)

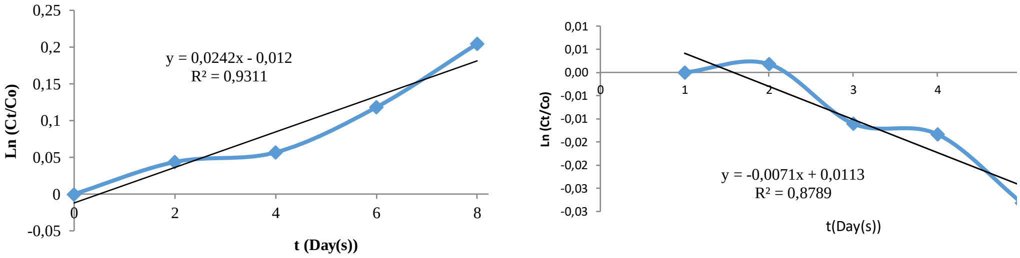


PE (Freezer Temperature)

Vacuum (Freezer Temperature)

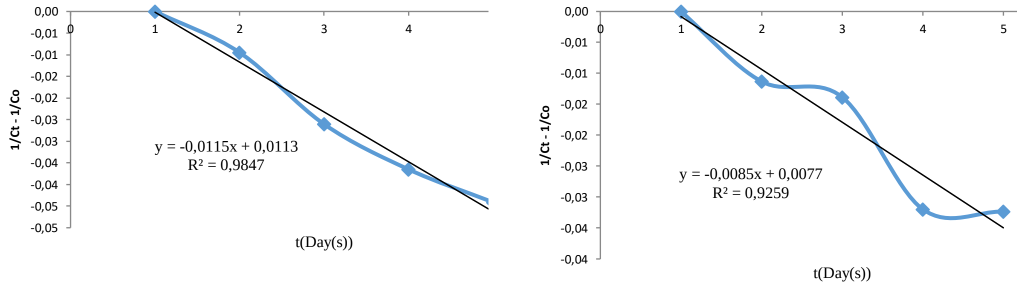
Figure 3. Hue Angle Values

This study investigated gelamai discoloration during shelf-life using different conditions and packaging. Based on Figure 3, In a nutshell, vacuum condition demonstrates more ability in colorfastness gelamai than PE packaging.



PE (Room Temperature)

Vacuum (Room Temperature)



PE (Freezer Temperature)

Vacuum (Freezer Temperature)

Figure 4. Chroma Values

Figure 4 demonstrates that chroma stability of gelamai is strongly influenced by storage conditions and packaging methods. PE packaging, at room temperature, showed a positive (linear) chroma change pattern with R² = 0.9311. Whereas vacuum packaging showed a negative trend (R² = 0.5776), indicating that deceleration or stabilization of discoloration. At freezer temperature, PE packaging showed a non-linear pattern ($R^2 = 0.5847$), whereas vacuum packaging showed a positive linear pattern ($R^2 = 0.7258$), although rate of color stability is slower than PE. This results emphasize that vacuum packaging is more effective in slowing down color stability, both at room temperature and freezer temperature. Thus, it could preserve the shelf life of gelamai in color stability. According to Lee et al. (2024) vacuum packaging minimises lipid oxidation, a primary factor contributing to colour stability.

CONCLUSION

This study demonstrated that the application of oxygen absorber preserved the color quality of gelamai during storage. Compared to PE packaging, oxygen absorber treatment extended the shelf life of gelamai by approximately 2–3 days at room temperature and up to 8 days under freezer storage before noticeable discoloration occurred. The chroma and hue angle kinetics indicated that the critical limit of acceptability for color stability was reached when the hue angle exceeded ≈45°, as this shift was associated with visible browning and reduced consumer acceptability. Therefore, the integration of oxygen absorber into vacuum packaging is a reliable strategy to slow oxidative discoloration and extend the shelf life of gelamai while maintaining its visual quality.

REFERENCES

Abker, A. M., Xia, Z., Hu, G., Fu, X., Zhang, Y., Jin, Y., Ma, M., & Fu, X. (2024). Using salted egg white in steamed bread: Impact on functional and structural characteristics. *Food Chemistry*, *454*, 139609. https://doi.org/10.1016/j.foodchem.2024.139609

Anna, P. (2023). Food Colorants. In *Chemical and Functional Properties of Food Components* (p. 18).

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*, *2*, 100265. https://doi.org/10.1016/j.foohum.2024.100265

Cichello, S. A. (2015). Oxygen absorbers in food preservation: a review. *Journal of Food Science and Technology*, *52*(4), 1889–1895. https://doi.org/10.1007/s13197-014-1265-2

Darvish, H., Ramezan, Y., Khani, M. R., & Kamkari, A. (2022). Effect of low-pressure cold plasma processing on decontamination and quality attributes of Saffron

(*Crocus sativus* L.). *Food Science and Nutrition*, *10*(6), 2082–2090. https://doi.org/10.1002/fsn3.2824

Dong-ying, X., Fu-hui, Z., Hai-feng, J., Ai-li, J., Sheng, W., Xue-qing, G., Chen, C., & Wen-zhong, H. (2020). Effect of vacuum combined with light-proof packaging on quality of fresh-cut potatoes. *China Food Publishing Co.*, *41*(13), 184–192.

Dubinina, A., Selyutina, G., Shcherbakova, T., Letuta, T., Belyayeva, I., Khatskevych, Y., Popova, T., Frolova, T., & Afanasieva, V. (2020). The effect of technological parameters on low-salted cucumbers color change under using low-temperature non-brine process of manufacture. *Journal of Hygienic Engineering and Design*, *31*, 3–7.

Ermiati, E., & Gusmalini, G. (2022). Modification of Gelamai Payakumbuh Through the Addition of Yellow Pumpkin (Cucurbita Moschata Duch) and Improved Packaging. *IOP Conference Series: Earth and Environmental Science*, *1097*(1). https://doi.org/10.1088/1755-1315/1097/1/012003

Gökşen, G., & Ekiz, H. İ. (2021). Use of aniseed cold-pressed by-product as a food ingredient in muffin formulation. *LWT*, *148*(July 2020). https://doi.org/10.1016/j.lwt.2021.111722

Gupta, P. (2023). Role of oxygen absorbers in food as packaging material, their characterization and applications. *Journal of Food Science and Technology*, *61*(2), 242–252. https://doi.org/10.1007/s13197-023-05681-8

Kasmita, Gusnita, W., Holinesti, R., Faisal, D., Asnur, L., & Pasaribu. (2018). Program Pengembangan Produk Unggulan Daerah Diversifikasi Produk Gelamai di Kanagarian Harau Kecamatan Harau Kabupaten Lima Puluh Kota Sumatera Barat. *Jurnal Ilmiah Pengabdian Kepada Masyarakat*, *2*(2).

Khalil, R., Kallas, Z., Pujolà, M., & Haddarah, A. (2024). Organoleptic characteristics of high-protein snacks with novel and sustainable ingredients: Cricket flour and carob powder. *Food Science and Nutrition*, 9443–9457. https://doi.org/10.1002/fsn3.4392

Lee, D., Kim, H. J., Lee, S., Choi, M., Kumar, S. A., & Jo, C. (2024). The combined effect of vacuum-skin packaging and oxygen absorbers on the color stability and physicochemical properties of wet-aged Chikso beef. *Food Packaging and Shelf Life*, *43*, 101275. https://doi.org/10.1016/j.fpsl.2024.101275

Lee, J., & Schwartz, S. J. (2005). Pigments in plant foods. In Y. H. Hui & F. Sherkat (Eds.), *Handbook of Food Science, Technology, and Engineering* (1st Edition, p. 3632). Boca Raton: CRC Press.

Leo, M. L. N. (2004). Handbook of Food Analysis. In *Food Chemistry*. Boca Raton: CRC Press.

Lipman, A. L. (2008). Regulatory Aspects of Colorants: Regulations, Regulations, Regulations in the United States of America! In *Color Quality of fresh and processed food* (pp. 416–436). Washington D.C: American Chemical Society.

Lis, K., & Bartuzi, Z. (2020). Natural food color additives and allergies. *Alergia Astma Immunologia*, *25*(2), 95–103.

López-Cervantes, L., Sánchez-Machado, D. I., Pastorelli, S., Rijk, R., & Paseiro-Losada, P. (2003). Evaluating the migration of ingredients from active packaging and development of dedicated methods: A study of two iron-based oxygen absorbers. *Food Additives and Contaminants*, *20*(3), 291–299. https://doi.org/10.1080/0265203021000060878

Miltz, J., & Perry, M. (2005). Evaluation of the performance of iron-based oxygen scavengers, with comments on their optimal applications. *Packaging Technology and Science*, *18*(1), 21–27. https://doi.org/10.1002/pts.671

Molina, A. K., Corr, C. G., Prieto, M. A., & Pereira, C. (2023). *Bioactive Natural Pigments' Extraction, Isolation, and Stability in Food Applications*. 1–25.

Mueller, K., Schoenweitz, C., & Langowski, H.-C. (2013). Thin Laminate Films for Barrier Packaging Application – Influence of Down Gauging and Substrate Surface Properties on the Permeation Properties. *Packaging and Technology and Science*, *29*, 399–412. https://doi.org/10.1002/pts

Murtius, W. S., & Hari, P. D. (2016). The properties of Zingiberaceae starch films for Galamai packaging. *International Journal on Advanced Science, Engineering and Information Technology*, *6*(2), 221–225. https://doi.org/10.18517/ijaseit.6.2.710

Nakagawa, M., Tabara, A., Ushijima, Y., Matsunaga, K., & Seguchi, M. (2016). Hydrophobicity of stored (15, 35°C), or dry-heated (120°C) rice flour and deteriorated breadmaking properties baked with these treated rice flour/fresh gluten flour. *Bioscience, Biotechnology and Biochemistry*, *80*(5), 983–990. https://doi.org/10.1080/09168451.2015.1136875

Nollet, L. M. L. (2004). Synthetic colorants. In *Handbook of Food Analysis Second Edition: Residues and Other Food Component Analysis* (p. 30). CRC Press.

Nowacka, M., Dadan, M., Janowicz, M., Wiktor, A., Witrowa-Rajchert, D., Mandal, R., Pratap-Singh, A., & Janiszewska-Turak, E. (2021). Effect of nonthermal treatments on selected natural food pigments and color changes in plant material. *Comprehensive Reviews in Food Science and Food Safety*, *20*(5), 5097–5144. https://doi.org/10.1111/1541-4337.12824

Pandiselvam, R., Mitharwal, S., Rani, P., Shanker, M. A., Kumar, A., Aslam, R., Barut, Y. T., Kothakota, A., Rustagi, S., Bhati, D., Siddiqui, S. A., Siddiqui, M. W., Ramniwas, S., Aliyeva, A., & Mousavi Khaneghah, A. (2023). The influence of non-thermal technologies on color pigments of food materials: An updated review. *Current Research in Food Science*, *6*, 100529. https://doi.org/10.1016/j.crfs.2023.100529

Petrozziello, M., Torchio, F., Piano, F., Giacosa, S., Ugliano, M., Bosso, A., & Rolle, L. (2018). Impact of increasing levels of oxygen consumption on the evolution of color, phenolic, and volatile compounds of Nebbiolo wines. *Frontiers in Chemistry*, *6*, 1–15. https://doi.org/10.3389/fchem.2018.00137

Podsędek, A. (2023). Food Colorants. In H. Staroszczyk & Zdzislaw E. Sikors (Eds.), *Chemical and Functional Properties of Food Components* (4th Edition, p. 18). Boca Raton: CRC Press.

Popova, A., Doykina, P., Mihaylova, D., & Dimitrova-Dimova, M. (2024). Assessment of Pudding Formulations Using Lyophilized Apricot, Plum, and Plum–Apricot Powders: Texture, Bioactivity, and Sensory Quality. *Dairy, 5*(4), 688–701. https://doi.org/10.3390/dairy5040051

Rockland. (2017). Water Activity: Theory and Applications to Food. In *Food Chemistry* (p. 424). Abingdon: Routledge.

Shivani, S., Vidhu, A., & Vasudha, S. (2023). Encapsulated natural pigments: Techniques and applications. *Journal of Food Process Engineering*, *46*(12). https://doi.org/https://doi.org/10.1111/jfpe.14311

Villmann, B., & Weickhardt, C. (2021). The Influence of Atmospheric Oxygen on the Color Change of Selected Historic Pigments and Dyes Caused by Narrow Band Optical Radiation. *Studies in Conservation*, *66*(3), 167–173. https://doi.org/10.1080/00393630.2020.1762401

Walkowiak-Tomczak, D., Czapski, J., & Młynarczyk, K. (2016). Assessment of colour changes during storage of elderberry juice concentrate solutions using the optimization method. *Acta Scientiarum Polonorum, Technologia Alimentaria*, *15*(3), 299–309. https://doi.org/10.17306/J.AFS.2016.3.29

Wei, S., Xuan, C., Kun, Z., Bei-bei, Z., & Qing-yun, L. (2020). Effect of Tempering Temperature and Time on the Quality of Semi-dry Black Glutinous Rice Flour. *Science and Technology of Food Industry*, *41*(5), 17–22.

Wen-xuan, L., Xin, L., Xiao-yin, Y., Yi-min, Z., Li-xian, Z., Yan-wei, M., Rong-rong, L., Ming-shan, H., & Hai-jian, C. (2020). Recent progress in research on the effect of lipid oxidation on meat color. *China Food Publishing Co.*, *41*(21), 238–247.

Zhang, W., Luo, Z., Wang, A., Gu, X., & Lv, Z. (2021). Kinetic models applied to quality change and shelf life prediction of kiwifruits. *Lwt*, *138*, 110610. https://doi.org/10.1016/j.lwt.2020.110610