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Effect of Storage Duration and Temperature on the Total Fat Content of Durian Seed (*Durio zibethinus* Murr.) Using the Acid Hydrolysis-Soxhletation Method

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ABSTRACT
Durian (Durio zibethinus Murr.) seed is an underutilized by-product with potential as a raw material for flour or vegetable oil, but its fat fraction may deteriorate during storage. This study analyzed the effects of storage temperature (25, 30, and 35 °C), storage duration (0, 3, 6, 9, and 12 days), and their interaction on the total fat content of durian seed of an unidentified local variety using the acid hydrolysis-Soxhletation method. A 3 × 5 factorial completely randomized design with three replicates was applied. Data were analyzed using two-way ANOVA and Duncan's test at 95% confidence. Storage temperature, storage duration, and their interaction significantly affected total fat content ($p < 0.05$). Total fat content decreased from 5.26% at day 0 to 4.26%, 2.35%, and 1.28% after 12 days at 25, 30, and 35 °C, equivalent to cumulative declines of 19.01%, 55.32%, and 75.67%, respectively. Linear regression showed decline rates of 0.08, 0.23, and 0.33 percentage points per day ($R^2 = 0.93$-0.99). The decline is attributed to residual lipase activity and lipid oxidation accelerated by temperature. The best condition was no storage; if storage is unavoidable, seed should be kept at 25 °C for no longer than 3 days.

INTRODUCTION

Durian (*Durio zibethinus* Murr.) is one of the most popular tropical fruit commodities in Southeast Asia, including Indonesia, and demand for it continues to grow alongside the expansion of agricultural processing industries. This rising consumption is directly mirrored by the volume of solid waste generated, primarily husk and seed, which together can account for 60-70% of the whole fruit's weight (Gamay et al., 2024; Tan et al., 2023). Durian seed is typically discarded as organic waste, even though numerous compositional studies show that it contains complex carbohydrates, protein, and a nutritionally meaningful amount of fat (Nuryanti et al., 2024; Sujang et al., 2024). This composition gives durian seed considerable potential to be further processed into composite flour, a functional food filler, or an alternative source of vegetable oil.

Previous studies have explored various processed forms of durian seed, including its use as a filler in processed meat products (Sembor et al., 2023), as a raw material for composite flour whose functional properties vary with variety and processing method (Baraheng & Karrila, 2019; Deh-ae et

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al., 2026), and as a source of bioactive compounds with antioxidant and anti-inflammatory activity (Charoenphun & Klangbud, 2022). The reported fat content of durian seed itself also varies considerably across studies and varieties, ranging from roughly 1-2% to more than 5% on a dry-weight basis, depending on variety of origin, fruit maturity stage, and postharvest handling (Alfayet et al., 2026; Suharjo & Nadja, 2021; Yongyut et al., 2025). This variability indicates that the compositional stability of durian seed, particularly its fat fraction, remains an aspect that requires closer examination before the seed can be reliably utilized at an industrial scale.

A key challenge in utilizing durian seed as a raw material is its susceptibility to postharvest deterioration. Unlike cereal grains, which are relatively stable under dry storage, fresh durian seed has a high initial moisture content and a tissue structure that is vulnerable to enzymatic activity, particularly from endogenous lipase, which hydrolyzes triglycerides into free fatty acids and glycerol (Corbineau, 2024). This lipid hydrolysis process is generally accelerated by a combination of high temperature and humidity, as widely reported for other oil-bearing seeds, such as soybean seed, which loses physiological and nutritional quality during uncontrolled room-temperature storage (Coradi et al., 2020); sesame seed, whose oil composition and stability decline under suboptimal storage conditions (Abdiani et al., 2024); and various commercial seed oils, whose oxidative stability is significantly affected by storage conditions (Ahmed et al., 2024; Siol et al., 2025). Indonesia's tropical climate, with ambient room temperatures of 27-30 °C and high relative humidity year-round, further heightens the risk of fat degradation in fresh durian seed when processing is delayed after separation from the fruit pulp.

Unfortunately, studies specifically examining the dynamics of total fat decline in durian seed during room-temperature storage remain very limited. Most available publications instead focus on characterizing the chemical composition of durian seed after it has been processed into flour under various pretreatments, such as soaking in sodium metabisulfite solution to improve physicochemical and functional flour properties (Kumoro & Hidayat, 2018), a combination of peeling and boiling (Sovia et al., 2026), or optimized drying temperature and duration for chemical and organoleptic flour quality (Ananda et al., 2025), without further tracing how quality decline unfolds while the seed is still in its raw or only minimally processed form. Yet information on the safe storage window before durian seed is further processed is essential for establishing appropriate postharvest handling procedures, whether at the household scale, small and medium enterprises, or fruit-waste-based food processing industries.

This time-limitation issue aligns with the broader circular-economy rationale in tropical fruit processing, namely how by-products once regarded as waste can be converted into value-added products without losing the nutritional quality that makes them attractive in the first place (Tan et al., 2023). Experience with other grains and legumes shows that the success of agricultural-waste valorization depends heavily on the timeliness of postharvest handling, since delayed processing is often the critical point determining whether a material remains suitable for high-quality food processing or has already undergone irreversible nutritional decline (Gamay et al., 2024). A quantitative understanding of the rate of fat decline in durian seed during storage is therefore an important scientific basis, not only for academic purposes but also for supporting more efficient postharvest handling practices among processors.

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Based on this background, the present study aimed to analyze the effects of storage temperature (25, 30, and 35 °C), storage duration (0, 3, 6, 9, and 12 days), and their interaction on the total fat content of durian seed (*Durio zibethinus* Murr.) using an acid hydrolysis-Soxhletation method, an adaptation of the standard Soxhlet extraction method widely used in oil-extraction studies of other tropical fruit seeds, such as papaya seed (Andriana & Broto, 2023) and rambutan seed (Minh, 2021). The findings are expected to provide a scientific basis for recommending an optimal storage condition for durian seed before it is processed into flour or vegetable oil, while also contributing to the compositional database of durian seed, which to date remains highly variable and scattered across different varieties and testing methods (Aziz & Jalil, 2019; Nurhalisa et al., 2023).

METHODS

This laboratory experiment used a completely randomized design (CRD) with a 3 × 5 factorial arrangement. Factor A was storage temperature at three levels (25, 30, and 35 °C) and Factor B was storage duration at five levels (0, 3, 6, 9, and 12 days), giving 15 treatment combinations. Each combination was prepared in three replicates, resulting in 45 experimental units (Table 1). The dependent variable was the total fat content of durian seed (% dry weight), while oven drying temperature, solvent type, extraction duration, initial sample weight, and seed size were kept uniform and recorded as control variables. The study was carried out over approximately five weeks, covering material preparation, staged sample storage, laboratory fat extraction, and statistical data analysis.

Table 1. Experimental Design of Storage Temperature (S) and Storage Duration (L) Treatment Combinations

Storage temperature	L0 (0 d)	L3 (3 d)	L6 (6 d)	L9 (9 d)	L12 (12 d)
S1 (25 °C)	S1L0 (n = 3)	S1L3 (n = 3)	S1L6 (n = 3)	S1L9 (n = 3)	S1L12 (n = 3)
S2 (30 °C)	S2L0 (n = 3)	S2L3 (n = 3)	S2L6 (n = 3)	S2L9 (n = 3)	S2L12 (n = 3)
S3 (35 °C)	S3L0 (n = 3)	S3L3 (n = 3)	S3L6 (n = 3)	S3L9 (n = 3)	S3L12 (n = 3)

Note: S1, S2, S3 = storage at 25, 30, and 35 °C; L0 = control analyzed without storage; n = number of replicates.

The main material was durian seed (*Durio zibethinus* Murr.) of an unidentified local variety obtained from a traditional market in Padang, West Sumatra. Seeds were selected for being fresh, intact, free from signs of spoilage, and from the same variety, and technical-grade n-hexane was used as the non-polar extraction solvent. The main equipment consisted of a Soxhlet extraction apparatus (fat flask, extractor tube, and condenser), a drying oven operating at 100-105 °C, a desiccator, an analytical balance with 0.0001 g precision, a digital caliper, incubators for controlled-temperature storage, and an electric heating mantle as the extraction heat source. To ensure homogeneity, seeds were sorted by weight (8-12 g; analytical balance), diameter (2.0-2.5 cm), and length (2.5-3.5 cm) (digital caliper). The selected seeds had a mean weight of 10.2 ± 1.3 g, diameter of 2.3 ± 0.2 cm, and length of 3.1 ± 0.3 cm. The initial moisture content, determined before drying, was approximately 50-60% (wet basis).

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Seeds were peeled of their thin outer skin, thoroughly washed, drained, and sliced uniformly to a thickness of 1-2 mm to accelerate drying. The slices were oven-dried at 60-70 °C until the moisture content fell below 10%. The dried slices were then placed in open containers and stored in incubators set at 25, 30, or 35 °C for 0, 3, 6, 9, or 12 days according to the assigned treatment, while the incubator temperature was monitored and recorded daily. After storage, the slices were ground and sieved through a 60-mesh screen to obtain a powder of uniform particle size, since particle size is known to significantly affect the efficiency and yield of fat extraction from seed-based materials (Andriana & Broto, 2023; Minh, 2021). The L0 control samples were ground and analyzed without storage.

Total fat content was determined based on the principle of the standard Soxhlet extraction method commonly used for fat analysis in seed-based food materials (AOAC International, 2019), an approach widely adapted in oil-extraction studies of tropical fruit seeds, such as papaya seed (Andriana & Broto, 2023), and in comparisons of extraction systems for walnut kernel oil (Ahmed et al., 2019). Briefly, 2-5 g of dried powder was weighed analytically (Ws) and wrapped in a fat-free cotton-lined paper thimble, then placed in the Soxhlet extractor tube connected to a fat flask of known empty weight (W0). Extraction was carried out using n-hexane for six hours of continuous solvent circulation until the solvent dripping back into the flask ran clear, indicating that fat extraction was complete. The residual solvent was then distilled off, and the remaining fat extract was dried in an oven at 100-105 °C, cooled in a desiccator, and weighed (W1) repeatedly until a constant weight was reached, defined as a difference between successive weighings of less than 0.001 g. Total fat content was calculated using the following equation:

$$Total\ Fat\ Content\ (\%) = \left[\frac{W_1 - W_0}{W_S}\right] \times 100\% \qquad (1)$$

where W1 is the weight of the flask plus fat after drying (g), W0 is the weight of the empty flask (g), and Ws is the initial sample weight (g).

Fat-content data were first subjected to prerequisite tests, namely the Shapiro-Wilk normality test on the model residuals and Levene's homogeneity-of-variance test, before further analysis using two-way analysis of variance (ANOVA) at a 95% confidence level ($\alpha = 0.05$) to test the effects of storage temperature, storage duration, and their interaction on total fat content. Where ANOVA indicated a significant effect, analysis proceeded to Duncan's Multiple Range Test (DMRT) to determine differences among treatment means. The relationship between storage duration and total fat content at each temperature was examined using simple linear regression and a first-order (exponential) kinetic model, $\ln C = \ln C_0 - kt$, with the half-life calculated as $t_{1/2} = \ln 2/k$, to obtain predictive models of the rate of fat decline. All statistical data processing was performed using computer-based statistical software.

RESULTS

Soxhlet extraction of the 45 experimental units (three temperatures × five storage durations × three replicates) showed that the total fat content of durian seed declined as storage duration and

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storage temperature increased, and that the rate of decline depended on temperature (Table 2). At day 0 (control) the total fat content was 5.26% on a dry-weight basis. After 12 days of storage it had decreased to 4.26 ± 0.06% at 25 °C, 2.35 ± 0.09% at 30 °C, and 1.28 ± 0.08% at 35 °C, equivalent to cumulative declines of 19.01%, 55.32%, and 75.67%, respectively.

Table 2. Mean Total Fat Content of Durian Seed at Various Storage Temperatures and Durations (% Dry Weight)

Temp.	Duration (days)	R1 (%)	R2 (%)	R3 (%)	Mean ± SD (%)	Stage-wise decline (%)	Cumulative decline (%)
25 °C	0	5.22	5.30	5.26	5.26 ± 0.04^{aA}	-	0.00
	3	5.00	5.12	5.08	5.07 ± 0.06^{bA}	3.61	3.61
	6	4.78	4.90	4.84	4.84 ± 0.06^{cA}	4.54	7.98
	9	4.55	4.65	4.60	4.60 ± 0.05^{dA}	4.96	12.55
	12	4.20	4.32	4.26	4.26 ± 0.06^{eA}	7.39	19.01
30 °C	0	5.24	5.28	5.26	5.26 ± 0.02^{aA}	-	0.00
	3	4.75	4.90	4.99	4.88 ± 0.12^{bB}	7.22	7.22
	6	3.88	4.10	3.84	3.94 ± 0.14^{cB}	19.26	25.10
	9	3.60	3.85	3.80	3.75 ± 0.13^{dB}	4.82	28.71
	12	2.25	2.40	2.40	2.35 ± 0.09^{eB}	37.33	55.32
35 °C	0	5.25	5.28	5.25	5.26 ± 0.02^{aA}	-	0.00
	3	4.30	4.45	4.40	4.38 ± 0.08^{bC}	16.73	16.73
	6	3.20	3.35	3.30	3.28 ± 0.08^{cC}	25.11	37.64
	9	2.40	2.55	2.50	2.48 ± 0.08^{dC}	24.39	52.85
	12	1.20	1.35	1.30	1.28 ± 0.08^{eC}	48.39	75.67

Values are mean ± SD (n = 3). Different lowercase letters within a temperature (across durations) and different uppercase letters within a storage duration (across temperatures) indicate significant differences (Duncan, $\alpha = 0.05$); a and A denote the highest means. Stage-wise decline is relative to the preceding storage duration and cumulative decline is relative to day 0, both calculated from the mean values.

Prerequisite testing showed that the model residuals were normally distributed according to the Shapiro-Wilk test ($W = 0.974$; $p = 0.396$, greater than 0.05), while Levene's test indicated that the variances among the 15 treatment combinations were homogeneous ($W = 1.891$; $p = 0.070$, greater than 0.05). Both ANOVA assumptions were therefore satisfied. Two-way ANOVA showed that storage temperature ($F(2,30) = 1231.08$; $p < 0.05$), storage duration ($F(4,30) = 1440.47$; $p < 0.05$), and their interaction ($F(8,30) = 166.22$; $p < 0.05$) each had a significant effect on the total fat content of durian seed (Table 3). The ANOVA model explained 99.7% of the variability in total fat content (R^2 of the ANOVA model = 0.997), with partial η^2 values of 0.988, 0.995, and 0.978 for temperature, duration, and their interaction, respectively. The significant interaction indicates that the effect of storage duration depended on storage temperature, with a steeper decline at higher temperatures (Figure 1).

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Table 3. Summary of Two-Way Analysis of Variance (ANOVA) for Total Fat Content of Durian Seed

Source of variation	SS	df	MS	F value	Sig.
Storage temperature (A)	16.146	2	8.073	1231.08	0.000
Storage duration (B)	37.785	4	9.446	1440.47	0.000
Interaction (A × B)	8.720	8	1.090	166.22	0.000
Error	0.197	30	0.0066	-	-
Total	62.848	44	-	-	-

Significant at a = 0.05. R^2 of the ANOVA model = 0.997.

Duncan's Multiple Range Test (DMRT) at the 95% confidence level showed that the marginal mean total fat content differed significantly among all temperature levels (4.81% at 25 °C, 4.04% at 30 °C, and 3.34% at 35 °C) and among all storage durations (5.26%, 4.78%, 4.02%, 3.61%, and 2.63% on days 0, 3, 6, 9, and 12), with each level placed in its own subset (Table 4). For comparisons among the 15 treatment combinations (Table 2), the least significant range was 0.135-0.150 when comparing durations within a temperature and 0.135-0.142 when comparing temperatures within a duration. Within each temperature, every successive storage duration differed significantly from the preceding one (lowercase letters in Table 2). Among temperatures, the control (day 0) showed no difference, whereas from day 3 onward all three temperatures differed significantly from one another (uppercase letters in Table 2).

Table 4. Duncan's Homogeneous Subsets for Marginal Mean Total Fat Content

Storage temperature	N	Mean (%)	Duncan subset
25 °C	15	4.81	a
30 °C	15	4.04	b
35 °C	15	3.34	c
0 days	9	5.26	a
3 days	9	4.78	b
6 days	9	4.02	c
9 days	9	3.61	d
12 days	9	2.63	e

Means in different subsets (letters) differ significantly (Duncan, a = 0.05).

Simple linear regression of total fat content on storage duration at each temperature (Table 5; Figure 1) showed that fat content decreased by an average of 0.08, 0.23, and 0.33 percentage points per day at 25, 30, and 35 °C, respectively (R^2 = 0.972, 0.932, and 0.995). The stage-wise decline differed among temperatures. At 25 °C it increased gradually from 3.61% (day 0-3) to 7.39% (day 9-12). At 30 °C it was uneven: 7.22% during day 0-3, 19.26% during day 3-6, only 4.82% during day 6-9, and 37.33% during day 9-12. At 35 °C the decline was already large in the first stage (16.73%) and reached 48.39% during day 9-12. The cumulative decline from the initial content after 3, 6, 9, and 12 days was 3.61%, 7.98%, 12.55%, and 19.01% at 25 °C; 7.22%, 25.10%, 28.71%, and 55.32% at 30 °C; and 16.73%, 37.64%, 52.85%, and 75.67% at 35 °C (Figure 2).

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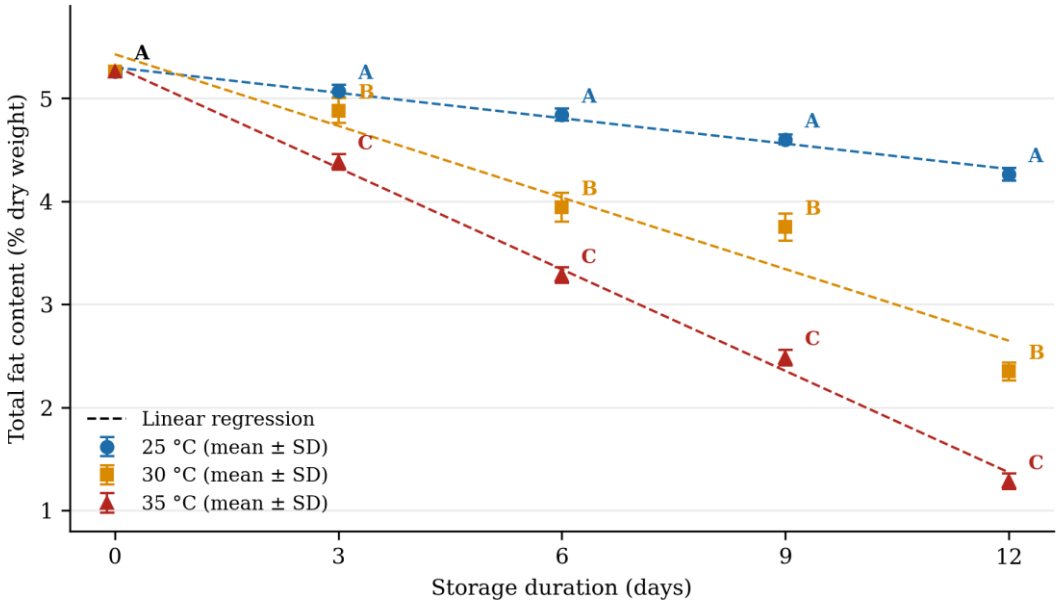


Figure 1. Effect of Storage Duration on Mean Total Fat Content of Durian Seed at 25, 30, and 35 °C

Points are mean ± SD (n = 3); dashed lines are linear regression lines. Uppercase letters indicate Duncan subsets among temperatures at the same storage duration (α = 0.05).

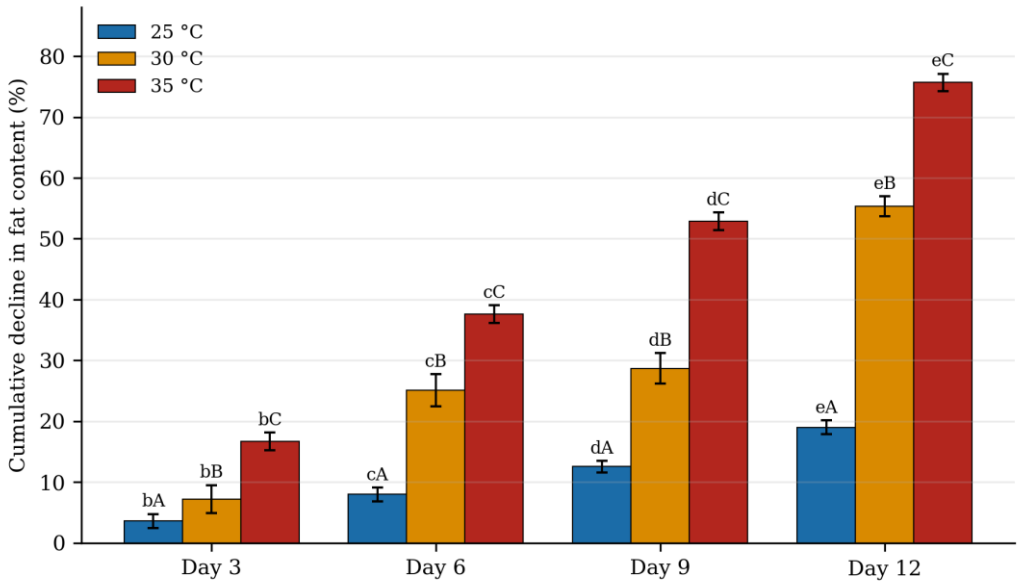


Figure 2. Cumulative Percentage Decline in Total Fat Content of Durian Seed at Various Storage Temperatures and Durations

Bars are mean ± SD (n = 3). Lowercase letters (within a temperature) and uppercase letters (within a storage duration) indicate Duncan subsets (a = 0.05).

For comparison, the same data were also fitted to a first-order (exponential) kinetic model, commonly used to describe food-quality degradation during storage. The first-order model yielded a lower coefficient of determination than the linear model at every temperature (R^2 = 0.964, 0.877,

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and 0.936 at 25, 30, and 35 °C, respectively), with rate constants (k) of 0.0173, 0.0625, and 0.1131 per day and half-lives ($t_{1/2}$) of approximately 40.1, 11.1, and 6.1 days (Table 5). Based on the linear regression equations, a 25% decline from the initial fat content is estimated to occur at around day 4.2 at 35 °C and day 6.4 at 30 °C, whereas a 50% decline is estimated at around day 8.2 and day 12.1, respectively. The corresponding estimates for 25 °C (16.5 and 32.5 days) lie beyond the observed storage range and should be regarded as extrapolations.

Table 5. Linear Regression and First-Order Kinetic Parameters of Total Fat Decline at Each Storage Temperature

Temp	Linear equation (y = total fat, %; x = days)	R^2 (linear)	k (d^{-1})	R^2 (first-order)	$t_{1/2}$ (d)	Time to 25% decline (d)	Time to 50% decline (d)
25 °C	y = 5.299 - 0.082x	0.972	0.0173	0.964	40.1†	16.5†	32.5†
30 °C	y = 5.426 - 0.232x	0.932	0.0625	0.877	11.1	6.4	12.1†
35 °C	y = 5.309 - 0.328x	0.995	0.1131	0.936	6.1	4.2	8.2

Beyond the observed storage range (0-12 days); extrapolated value.

DISCUSSION

The main finding of this study is that the total fat content of durian seed is not stable during storage: it declined significantly as storage duration and storage temperature increased, and the significant temperature × duration interaction shows that higher temperatures steepened the decline. This overall pattern is consistent with the general principle widely reported for various oil-bearing seeds, namely that storage conditions, particularly temperature and humidity, strongly influence the rate of lipid deterioration (Corbineau, 2024). In soybean seed, for instance, storage without moisture-proof packaging and temperature control has been shown to significantly reduce physiological quality and nutritional composition compared with storage under controlled conditions (Coradi et al., 2020). A similar tendency has been reported for sesame seed, whose oil composition and stability decline significantly under suboptimal storage conditions, whereas storage at room temperature with low humidity better preserves fatty acid structure (Abdiani et al., 2024).

Mechanistically, the observed decline in total fat content is suspected to relate to residual lipase activity and lipid oxidation. Although the slices were dried to a moisture content below 10% before storage, residual endogenous lipase may still hydrolyze the ester bonds of triglycerides into free fatty acids and glycerol (hydrolytic rancidity), while lipids exposed to air in open containers may undergo oxidation. Both types of reaction generally proceed faster at higher temperatures, which is consistent with the much stronger decline observed at 35 °C than at 25 °C. Because the Soxhlet method measures the total fat that can be extracted by a non-polar solvent, the measured decline indicates a change in the lipid fraction soluble in n-hexane, whether due to hydrolysis, oxidation, or both, as has been documented for various commercial seed oils whose oxidative stability measurably declines during storage (Ahmed et al., 2024) and for watermelon seed oil, whose nutritional quality changes significantly under uncontrolled storage (Siol et al., 2025). A comparison of Soxhlet extraction systems for walnut kernel oil further confirms that extracted fat

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values are highly sensitive to raw material condition prior to extraction, including its storage history (Ahmed et al., 2019).

The rate of fat decline increased markedly with temperature. The average decline of 0.08, 0.23, and 0.33 percentage points per day at 25, 30, and 35 °C, and the increase of the first-order rate constant from 0.0173 to 0.1131 per day (about 6.5-fold) with a corresponding shortening of the half-life from 40.1 to 6.1 days between 25 and 35 °C, show that fat loss is strongly temperature dependent. At 25 °C the decline remained moderate (19.01% after 12 days), whereas at 30 and 35 °C more than half of the initial fat content (55.32% and 75.67%) was lost within the same period. The initial fat content (day 0) recorded in this study, 5.26%, is also reasonably consistent with values reported in studies of fresh and processed durian seed composition, such as the 4.80% fat content reported for peeled-and-boiled durian seed flour (Sovia et al., 2026), and the range of fat content reported across various durian seed varieties, from roughly 1% to more than 5% on a dry-weight basis (Alfayet et al., 2026; Nuryanti et al., 2024). The differences in absolute values across studies can reasonably be attributed to differences in variety, growing location, fruit maturity stage at harvest, and pretreatments applied prior to analysis (Baraheng & Karrila, 2019; Suharjo & Nadja, 2021).

The stage-wise decline also differed among temperatures. At 25 and 35 °C the decline per stage increased relatively steadily with storage time, whereas at 30 °C it was uneven, with 19.26% lost between day 3 and day 6, only 4.82% between day 6 and day 9, and 37.33% between day 9 and day 12. Nevertheless, Duncan's test showed that every successive storage duration differed significantly at each temperature, so the slower step at 30 °C should be regarded as a descriptive observation rather than a statistically distinct plateau. The larger standard deviations at 30 °C (up to 0.14, compared with maximum values of 0.06 at 25 °C and 0.08 at 35 °C) may have contributed to this irregularity. Whether it reflects a genuine shift in the dominant degradation mechanism, for example from enzymatic hydrolysis toward oxidation, requires further investigation with more closely spaced sampling intervals and complementary analyses such as free fatty acid content and peroxide value.

To the authors' knowledge, most publications on durian seed focus on characterizing processed products such as flour under various pretreatments, for example soaking in sodium metabisulfite solution to improve physicochemical and functional flour properties (Kumoro & Hidayat, 2018), or optimizing drying temperature and duration to obtain optimal chemical and organoleptic flour quality (Ananda et al., 2025), without specifically tracing how quality declines during storage before processing. The present study addresses this gap by showing that the storage time and temperature between seed separation from the fruit pulp and further processing are critical factors determining the final quality of durian-seed-based products, whether intended as a food filler (Sembor et al., 2023) or as a source of bioactive compounds with antioxidant potential (Charoenphun & Klangbud, 2022).

These findings carry important practical implications for efforts to valorize durian seed waste into value-added products, such as composite flour (Deh-ae et al., 2026), and into an alternative vegetable oil source increasingly explored in other tropical fruit seeds, such as rambutan seed (Azzatul et al., 2021; Chai et al., 2019; Minh, 2021) and papaya seed (Andriana & Broto, 2023). Given that total fat content declined by 55.32% at 30 °C and 75.67% at 35 °C within 12 days, whereas the decline at 25 °C was 19.01%, it is recommended that durian seed be processed immediately after

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separation from the fruit pulp and, if processing must be delayed, stored at a controlled low temperature (not exceeding 25 °C) for no longer than three days, consistent with general postharvest handling recommendations for oil-bearing seeds (Coradi et al., 2020; Corbineau, 2024). By comparison, freezing whole durian fruit has been shown to preserve fruit quality attributes over a much longer period (Prasetia et al., 2023; Sospeter et al., 2025), suggesting that prompt chilling or freezing after harvest may be a relevant mitigation strategy worth testing further on durian seed specifically, as an alternative to the freeze-drying approach already being explored for other durian-based products (Tran et al., 2024).

From a reaction-kinetics perspective, the first-order model fitted the data less well than the linear model at all three temperatures (R^2 = 0.964 vs 0.972 at 25 °C; 0.877 vs 0.932 at 30 °C; 0.936 vs 0.995 at 35 °C), indicating that the loss of extractable fat within 12 days is closer to a constant-rate decline than to an exponential decay, particularly at 35 °C. The poorer fit at 30 °C reflects the uneven stage-wise decline discussed above. Because this study was designed to simulate short-term storage conditions that are practically relevant to postharvest processors, the kinetic parameters (k and $t_{1/2}$) should be regarded as descriptive and valid only within the 0-12-day range. Longer storage periods, more closely spaced observation intervals, and more than three temperature levels are required to establish appropriate kinetic models and to estimate the temperature dependence of fat degradation reliably.

The consequence of fat loss during storage should also be considered from the standpoint of nutritional value and end-product economics. Fat is one of the main contributors to the energy value of durian seed, alongside the carbohydrate and protein content that has been extensively studied previously (Aziz & Jalil, 2019), so a decline of more than half within 12 days at 30-35 °C can be expected to reduce both nutritional value and the oil yield obtainable if the seed is processed into vegetable oil. For small and medium-scale processors that rely on durian seed waste as a value-added raw material, quantitative information on this rate of decline can serve as a basis for designing a more efficient raw-material collection and processing schedule, thereby minimizing potential losses from delayed processing while supporting the circular-economy approach to tropical fruit waste outlined in the introduction (Gamay et al., 2024; Tan et al., 2023).

This study has several limitations that warrant attention in future research. First, the Soxhlet method used measures only total extractable fat, without directly distinguishing the proportion of free fatty acids, peroxide value, or individual fatty acid profiles, which are in fact more sensitive for detecting the early stages of rancidity and could be further analyzed using gas chromatography approaches, as applied to durian seed from other regions (Guntarti et al., 2024). Second, this study used only one unidentified local durian seed variety from a single traditional market in Padang, so generalizing the results to other varieties, whose initial composition is known to vary considerably (Sujang et al., 2024; Yongyut et al., 2025), still requires verification through further research. Third, only three storage temperatures and five storage durations were examined, and relative humidity inside the incubators was not controlled or recorded, so their possible effects on fat degradation could not be separated. Future research is recommended to measure free fatty acid content and peroxide value in parallel with total fat content, and to test the effectiveness of pretreatments such as rapid drying or cold storage in slowing the rate of fat degradation in durian seed, in order to

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develop more comprehensive and applicable postharvest handling recommendations for durian-seed-waste processors.

CONCLUSIONS

Storage temperature, storage duration, and their interaction significantly affected the total fat content of durian seed (*Durio zibethinus* Murr.) as measured using the acid hydrolysis-Soxhletation method ($p < 0.05$). The best storage condition was no storage (day 0), which retained the highest total fat content (5.26%). If storage is unavoidable, durian seed should be kept at 25 °C for no longer than 3 days, and storage at 30 °C or higher should be avoided.

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