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Identification of the Life Cycle Rate of Flies in the Carcass of Rattus Norvegicus that is Exposed and Not Exposed to Sunlight in Determining the Post Mortem Interval

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Abstract

Background: The discovery of corpses represents the most common criminal case category in Indonesia, accounting for 35.46% or approximately 3,698 cases from early 2024 to September 20, 2024. Determining the post mortem interval (PMI) is therefore essential in forensic investigations. One method used to estimate PMI is forensic entomology through the analysis of insect life cycles developing on corpses, particularly flies. Environmental factors, such as sunlight exposure, may influence the development rate of flies and affect the accuracy of PMI estimation.
Objective: This study aimed to identify differences in the development rate of the fly life cycle on Rattus norvegicus carcasses exposed and not exposed to sunlight.
Methods: This study employed a quasi-experimental method using a posttest-only non-equivalent control group design. Observations were conducted twice daily to record and collect specimens from each developmental stage of flies, including eggs, larvae, pupae, and adult flies, on carcasses exposed and not exposed to sunlight.
Results: The findings demonstrated significant differences in the development rates of second instar larvae, third instar larvae, pupae, and adult flies between carcasses exposed to sunlight and those not exposed, with p-values < 0.05.
Conclusion: Sunlight exposure significantly affects the development rate of the fly life cycle on Rattus norvegicus carcasses. These findings indicate that environmental exposure should be considered in forensic entomology analysis to improve the accuracy of PMI estimation.

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INTRODUCTION

As time goes by, forensic experts are increasingly faced with the discovery of bodies in various places. The latest analysis of the National Police's DORS SOPS application shows that from January to September 20, 2024, the police have cracked down on 10,428 cases that disturb public order and security in various regions of Indonesia. These cases include a wide variety of violations. Based on the data obtained, the discovery of corpses is the most common type of case, reaching 35.46% or around 3,698 cases (Pusiknas, 2024). The difficulty of determining an accurate time of death in the case of the discovery of a dead body requires investigators to conduct a thorough investigation and identification so as to reveal *the Post Mortem Interval* (Sutton & Byrd, 2020; Pittner et al., 2020).

The Post Mortem Interval is the time that passes from death to the discovery of the body and is one of the main keys in assisting the investigation process (Franceschetti et al., 2023). The

longer the body is found, the greater the difficulty of identification and the chance of error in determining *the Post Mortem Interval*. One of the methods used and well known in forensic science to ensure *Post Mortem Interval* is by analyzing the development of insects around the corpse or what is called forensic entomology (Mona et al., 2019; Siva Prasad & Aneesh, 2022).

Forensic entomology is the use of insects and other arthropods in the legal context, especially in the medicolegal aspect. After 48-72 hours, forensic entomology is usually the only method used to determine the *Post Mortem Interval*, as insects arrive at the scene minutes after the discharge of blood and other bodily fluids (Mona et al., 2019). Species of fly-like necrophages is the insect species that lands on the corpse the fastest and plays an important role in determining *the Post Mortem Interval* (DiMaio & Molina, 2021).

Flies play an important role in the early stages of decomposition by initiating the process of decomposition of body tissues after death. Flies lay their eggs in open openings, such as wounds, mouths, nostrils, and ears (DiMaio & Molina, 2021; Alyasiri, 2026). Identification of flies at different stages of their life cycle, such as eggs, larvae, pupa, and adults, can determine *the Post Mortem Interval* (Franceschetti et al., 2023). The life cycle of flies takes place sequentially according to the stage of decomposition, starting from the fresh stage, the bloating stage, the decay stage, the post-decay stage, and the skeletonization stage (Wadhawan & Singh, 2025). However, there are several factors that affect the development of flies, one of which is lighting.

Lighting will affect the decomposition process of the corpse and become a determining factor for the existence of flies. Flies detect objects to be used as food sources, places to lay eggs, and resting places by utilizing the reflection of sunlight (Anderson, 2019; de Barros et al., 2024). When entering the adult phase, flies only need an optimal source of water, light, and temperature to create relative humidity, thus accelerating the development of fly larvae in reaching their single life cycle (Ramadan et al., 2018; Yahya, 2021).

This research uses a form of experimental research that requires an illustration of a forensic case. The use of human remains as samples is considered incompatible with research ethics so they will use *Rattus norvegicus* as a sample. *Rattus norvegicus* will be given treatment, then the carcass will be placed on an exposed medium and not exposed to sunlight. The focus of this study is the identification of the life cycle rate of flies in the carcass *of Rattus norvegicus* which is influenced by exposure to sunlight.

METHOD

Data analysis techniques in this study begin with descriptive statistical analysis, which is used to provide an overall description of the data obtained. This analysis involves calculating the mean, standard deviation, minimum value, and maximum value. The descriptive statistics are applied to travel time data (in hours) for each stage of fly development, starting from the egg stage until reaching the adult stage, in groups of carcasses exposed and not exposed to sunlight.

The next stage is the assumption test, which must be conducted before hypothesis testing to determine whether parametric or non-parametric statistical methods will be used. This test includes both the normality test and the homogeneity test. The normality test is used to determine whether the data is normally distributed, with hypotheses H0: data is normally distributed and H1: data is not normally distributed. Because the sample size is less than 50, the Shapiro-Wilk test is applied, where a significance value < 0.05 leads to rejection of H0 (not normally distributed), while a value ≥ 0.05 leads to acceptance of H0 (normally distributed).

The homogeneity test is then carried out to assess whether the variance between groups is equal, using Levene's Test, provided that the data has met normality assumptions. The hypotheses used are H0: variance is homogeneous and H1: variance is not homogeneous, with the decision rule that a significance value < 0.05 means H0 is rejected (heterogeneous), while ≥ 0.05 means H0 is accepted (homogeneous). After the assumption tests, hypothesis testing is conducted using an independent t-test to determine whether there is a difference in the life cycle rate of flies in carcasses of *Rattus norvegicus* exposed and not exposed to sunlight. The hypotheses are H0: no difference in fly life cycle rate between the two groups, and H1: there is a difference. The decision rule is that if the significance (2-tailed) > 0.05, H0 is accepted (no difference), while if < 0.05, H0 is rejected and H1 is accepted (there is a significant difference).

RESULTS AND DISCUSSION

Result

Data Description

This study identified the life cycle rate of flies in *Rattus norvegicus* carcasses that were exposed and not exposed to sunlight in determining *the Post Mortem Interval*. This research was conducted on May 1-13, 2025 on the Agricultural Land of Pasir Eurih Village, Kalong Liud Village, Nanggung District, Bogor Regency.

In this study, *the Rattus norvegicus* strain of Wistar used was two to three months old, weighed between 150 and 200 grams, showed normal behavior, and had no anatomical abnormalities. Sampling was carried out by *non-probability sampling, then* the euthanasia *process was carried out* by the cervical dislocation method. Next, the samples were divided into an experimental group (exposed to sunlight) and a control group (not exposed to sunlight). The number of samples used was 10 *Rattus norvegicus*. The use of minimal samples was chosen to reduce the use of experimental animals and reduce research costs. Data was obtained through direct observation of each group of carcasses by recording the duration of time it takes for flies to complete their entire life cycle, from eggs to adult flies.

Environmental Conditions During Observation

During the observation process which took place from May 1 to 13, 2025, environmental conditions were measured routinely every day in both groups in the morning (08.00-11.00) and afternoon (15.00-18.00). Parameters noted include light intensity (lux), ambient temperature (°C), and humidity level (%). The measurement data is presented in the following table:

Table 1. Exposed Groups

Date	Observed Phases	Light Intensity (lux)	Temperature (°C)	Humidity (%)
01 May 2025	Euthanasia	2158	30	72
02 May 2025	Eggs	- 3036	- 30.1	- 76
		- 2205	- 30	- 72
03 May 2025	Larva instar 1	- 3551	- 27.1	- 81
		- 2813	- 27	- 80
04 May 2025	Larva instar 2	- 3099	- 27.2	- 81
		- 2154	- 27	- 80
05 May 2025	Larva instar 2	- 3891	- 28	- 80
		- 2760	- 30	- 81
06 May 2025	Larva instar 3	- 3408	- 27.3	- 79
		- 2511	- 28	- 80
07 May 2025	Larva instar 3	- 3374	- 27.2	- 79
		- 2476	- 27.3	- 79
08 May 2025	Red	- 3890	- 30	- 82
		- 2870	- 30	- 80
09 May 2025	Red	- 3446	- 29	- 79
		- 2856	- 29.3	- 80
10 May 2025	Adult flies	- 3154	- 32	- 79
		- 2307	- 30	- 77

Table 2. Unexposed Groups

Date	Observed Phases	Temperature (°C)	Humidity (%)
01 May 2025	Euthanasia	30	72
02 May 2025	Eggs	- 30.1	- 76
		- 30	- 72
03 May 2025	Larva instar 1	- 27.1	- 81
		- 27	- 80
04 May 2025	Larva instar 2	- 27.2	- 81
		- 27	- 80

05 May 2025	Larva instar 3	-	28	-	80
		-	30	-	81
06 May 2025	Larva instar 3	-	27.3	-	79
		-	28	-	80
07 May 2025	Larva instar 3	-	27.2	-	79
		-	27.3	-	79
08 May 2025	Larva instar 3	-	30	-	82
		-	30	-	80
09 May 2025	Larva instar 3	-	29	-	79
		-	29.3	-	80
May 10, 2025	Red	-	32	-	79
		-	30	-	77
11 May 2025	Red	-	30	-	82
		-	31	-	80
May 12, 2025	Red	-	29	-	80
		-	29.3	-	81
13 May 2025	Adult flies	-	27	-	80
		-	28.5	-	80

Observation Results of Each Phase

Observations are carried out regularly to ensure the accuracy of the development time from eggs to adult flies. Each stage of development was found, taken and stored in a specimen container containing 70% alcohol, and the time of retrieval was recorded as a basis for determining the difference in the speed of development of the life cycle of flies between groups of carcasses observed.

Table 3. Results of Morning Observations (in Hours)

Groups	Eggs	Larva 1	Larva 2	Larva 3	Red	Flies
Exposed	16	39	65	112	158	208
Exposed	17	40	66	114	160	207
Exposed	18	41	64	113	161	210
Exposed	17	40	64	114	161	209
Exposed	16	41	65	112	159	210
Not Exposed	17	40	66	89	208	280
Not Exposed	17	41	67	90	210	279
Not Exposed	16	42	66	88	210	282
Not Exposed	18	41	65	89	209	281
Not Exposed	17	41	66	90	208	280

Table 4. Afternoon Observation Results (in hours)

Groups	Eggs	Larva 1	Larva 2	Larva 3	Red	Flies
Exposed	24	49	72	121	168	216
Exposed	24	49	72	121	168	216
Exposed	24	49	72	121	168	216
Exposed	24	49	72	121	168	216
Exposed	24	49	72	121	168	216
Not Exposed	24	49	72	121	168	216
Not Exposed	24	49	72	121	168	216
Not Exposed	24	49	72	121	168	216
Not Exposed	24	49	72	121	168	216
Not Exposed	24	49	72	121	168	216

Data Analysis Results

The results of the observation used in data processing are morning observations because the phase of fly development is always identified in the morning so that the morning data is considered more representative. The result of data processing with SPSS Version. 30.0. shows variations in each phase of development.

Descriptive Statistical Analysis

Table 5. Results of Descriptive Statistical Analysis of Egg Phase

Descriptive Statistics

	N	Rank e	At least one	Maximum	Mean	Std. Deviation	Variance	Skewness		Kurtosis	
Statistic		Statistic	Statesmen c	Statesmen c	Statistic	Statesmen c	Statistic	Statistic	Hours. Error	Statis tic	Hours. Error
Time	10	2	16	18	16.90	.738	.544	.166	.687	-.734	1.334
Kelompok	10	1	1	2	1.50	.527	.278	.000	.687	-2.571	1.334
Valid N (listwise)	10										

The results of descriptive statistical analysis on the oviposition process showed an average time of 16.9 hours with a standard deviation of 0.738, as well as a minimum value of 16 hours and a maximum of 18 hours. The distribution of the data was symmetrical with a skewness of 0.166 and a kurtosis of –0.734, indicating that the time data tended to be symmetrical and a flatter distribution.

Table 6. Results of Descriptive Statistical Analysis of Instar Larval Phase 1

Descriptive Statistics

	N	Ranked	At least one	Maxim um	Mean	Hours Deviated ion	Variance	Skewness		Kurtosis	
Statistic		Statistic	Statesmen c	Statesmen c	Statistic	Statesmen c	Statistic	Statis tic	Hours . Error	Statistic	Hours . Error
Time	10	3	39	42	40.60	.843	.711	-.389	.687	.370	1.334
Kelompok	10	1	1	2	1.50	.527	.278	.000	.687	-2.571	1.334
Valid N (listwise)	10										

The results of descriptive statistical analysis in the larval phase of instar 1 showed an average time of 40.6 hours with a standard deviation of 0.843, as well as a minimum value of 39 hours and a maximum of 42 hours. The skewness value of –0.389 and the kurtosis of 0.370 indicate almost symmetrical time data and a distribution that is not flat (has a higher peak).

Table 7. Results of Descriptive Statistical Analysis of Instar 2 Larval Phase

Descriptive Statistics

	N	Rank e	At least one	Maxim um	Mea n	Hours Deviate d ion	Varia nce	Skewness		Kurtosis	
Statis tic		Statis tic	Statesm en c	Statesm en c	Statis tic	Statesm en c	Statist ic	Statis tic	Hour s . Err or	Statis tic	Hour s . Err or
Time	10	3	64	67	65.40	.966	.933	-.111	.68 7	-.623	1.3 34
Kelom pok	10	1	1	2	1.50	.527	.278	.000	.68 7	-2.571	1.3 34

Valid N (listwise)	10

The results of descriptive statistical analysis in the larval phase of instar 2 showed an average time of 65.4 hours with a standard deviation of 0.966**,** as well as a minimum value of 64 hours and a maximum of 67 hours. The values of skewness -0.111 and kurtosis -0.623 indicate that the time data tend to be symmetrical and have a flatter distribution.

Table 8. Results of Descriptive Statistical Analysis of Instar Larval Phase 3

Descriptive Statistics

	N	Rank e	At least one	Maximum	Mean	Hours Deviated ion	Variance	Skewness		Kurtosis	
Statistic		Statistic	Statesmen c	Statesmen c	Statistic	Statesmen c	Statistic	Statistic	Hours. Error	Statistic	Hours. Error
Time	10	26	88	114	101.10	12.574	158.100	.003	.687	-2.537	1.334
Kelompok	10	1	1	21.50		.527	.278	.000	.687	-2.571	1.334
Valid N (listwise)	10										

The results of descriptive statistical analysis in the larval phase of instar 3 showed an average time of 101.1 hours with a standard deviation of 12.574, as well as a minimum value of 88 hours and a maximum of 114 hours**.** The skewness value of 0.003 and kurtosis –2.537 indicate that the time data tends to be symmetrical and has a flat distribution.

Table 9. Results of Descriptive Statistical Analysis of Pupa Phase

Descriptive Statistics

	N	Rank e	At least one	Maximum	Mean	Hours Deviated ion	Variance	Skewness		Kurtosis	
Statistic		Statistic	Statesmen c	Statesmen c	Statistic	Statesmen c	Statistic	Statistic	Hours. Error	Statistic	Hours. Error
Time	10	52	158	210	184.40	25.954	673.600	-.002	.687	-2.559	1.334
Kelompok	10	1	1	21.50		.527	.278	.000	.687	-2.571	1.334
Valid N (listwise)	10										

The results of descriptive statistical analysis in the pupa phase showed an average time of 184.4 hours with a standard deviation of 25.954, as well as a minimum value of 158 hours and a maximum of 210 hours. The skewness values **were –**0.002 and kurtosis –2.559, indicating that the time data tended to be symmetrical and had a flat distribution.

Table 10. Results of Descriptive Statistical Analysis of Fly Phase

Descriptive Statistics

	N	Rank e At least one	Maximum	Mean	Hours Deviated ion	Variance	Skewness		Kurtosis	
Statis tic		Statistic	Statesmen c	Statesmen c	Statistic	Statesmen c	Statistic	Statistic	Hours. Error	Statistic	Hours. Error
Time	10	75	207	282	244.60	37.754	1425.378	.000	.687-	2.565	1.334
Kelompok	10	1	1	21.50		.527.278		.000	.687-	2.571	1.334
Valid N (listwise)	10										

The results of descriptive statistical analysis in the adult fly phase showed an average time of 244.6 hours with a standard deviation of 37.754, as well as a minimum value of 207 hours and a maximum of 282 hours. Skewness values of 0.000 and kurtosis –2.565 indicate symmetrical time data and a flat distribution.

Normality Test

Table 11. Egg Phase Normality Test Results

Tests of Normality

		Kolmogorov-Smirnova			Shapiro-Wilk		
	Groups	Statistic	df	Say.	Statistic	df	Say.
Time	exposed	.231	5	.200*	.881	5	.314
	Not exposed	.300	5	.161	.883	5	.325

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

From the above results, it can be seen that the significant value of the exposed group = 0.314 and the control group = 0.325 shows ≥ 0.05, normal or H0 distributed data is received.

Table 12. Results of the Instar 1 Larval Phase Normality Test

Tests of Normality

		Kolmogorov-Smirnova			Shapiro-Wilk		
	Groups	Statistic	df	Say.	Statistic	df	Say.
Time	Exposed	.231	5	.200*	.881	5	.314
	Not Exposed	.300	5	.161	.883	5	.325

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

From the above results, it can be seen that the significant value of the exposed group = 0.314 and the control group = 0.325 shows ≥ 0.05, normal or H0 distributed data is received.

Table 13. Results of the Instar 2 Larval Phase Normality Test

Tests of Normality

		Kolmogorov-Smirnova			Shapiro-Wilk		
	Groups	Statistic	df	Say.	Statistic	df	Say.
Time	Exposed	.231	5	.200*	.881	5	.314
	Not Exposed	.300	5	.161	.883	5	.325

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

From the above results, it can be seen that the significant value of the exposed group = 0.314 and the control group = 0.325 shows ≥ 0.05, normal or H0 distributed data is received.

Table 14. Results of the Instar 3 Larval Phase Normality Test

Tests of Normality

		Kolmogorov-Smirnova			Shapiro-Wilk		
	Groups	Statistic	df	Say.	Statistic	df	Say.
Time	Exposed	.241	5	.200*	.821	5	.119
	Not Exposed	.231	5	.200*	.881	5	.314

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

From the above results, it can be seen that the significant value of the exposed group = 0.119 and the control group = 0.314 shows ≥ 0.05, normal or H0 distributed data is received.

Table 15. Pupa Phase Normality Test Results

Tests of Normality

		Kolmogorov-Smirnova			Shapiro-Wilk		
	Groups	Statistic	df	Say.	Statistic	df	Say.
Time	Exposed	.221	5	.200*	.902	5	.421
	Not Exposed	.241	5	.200*	.821	5	.119

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

From the above results, it can be seen that the significant value of the exposed group = 0.421 and the control group = 0.119 shows ≥ 0.05, normal or H0 distributed data is received.

Table 16. Results of the Fly Phase Normality Test

Tests of Normality

		Kolmogorov-Smirnova			Shapiro-Wilk		
	Groups	Statistic	df	Say.	Statistic	df	Say.

Time	Exposed	.221	5	.200*	.902	5	.421
	Not Exposed	.237	5	.200*	.961	5	.814

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

From the above results, it can be seen that the significant value of the exposed group = 0.421 and the control group = 0.814 shows ≥ 0.05, normal or H0 distributed data is received.

Homogeneity Test

Table 17. Egg Phase Homogeneity Test Results

Tests of Homogeneity of Variances

		Levene Statistic	df1	df2	Say.
Time	Based on Mean	.590	1	8	.464
	Based on Median	.333	1	8	.580
	Based on Median and with adjusted df	.333	1	8.000	.580
	Based on trimmed mean	.621	1	8	.454

From the results of the homogeneity test, the results of Levene's Statistic were obtained of 0.590 with a significant value of 0.464, showing ≥ 0.05. The research data had a homogeneous variant or accepted H0.

Table 18. Instar Larval Phase Homogeneity Test Results 1

Tests of Homogeneity of Variances

		Levene Statistic	df1	df2	Say.
Time	Based on Mean	.590	1	8	.464
	Based on Median	.333	1	8	.580
	Based on Median and with adjusted df	.333	1	8.000	.580
	Based on trimmed mean	.621	1	8	.454

From the results of the homogeneity test, the results of Levene's Statistic were obtained of 0.590 with a significant value of 0.464, showing ≥ 0.05. The research data had a homogeneous variant or accepted H0.

Table 19. Instar 2 Larval Phase Homogeneity Test Results

Tests of Homogeneity of Variances

		Levene Statistic	df1	df2	Say.
Time	Based on Mean	.590	1	8	.464
	Based on Median	.333	1	8	.580
	Based on Median and with adjusted df	.333	1	8.000	.580
	Based on trimmed mean	.621	1	8	.454

From the results of the homogeneity test, the results of Levene's Statistic were obtained of 0.590 with a significance value of 0.464, showing ≥ 0.05. The research data had a homogeneous variant or accepted H0.

Table 20. Instar Larval Phase Homogeneity Test Results 3

Tests of Homogeneity of Variances

		Levene Statistic	df1	df2	Say.
Time	Based on Mean	.330	1	8	.582
	Based on Median	.400	1	8	.545
	Based on Median and with adjusted df	.400	1	7.692	.545
	Based on trimmed mean	.317	1	8	.589

From the results of the homogeneity test, the results of Levene's Statistic were obtained of 0.330 with a significance value of 0.582, showing ≥ 0.05. The research data had a homogeneous variant or accepted H0.

Table 21. Pupa Phase Homogeneity Test Results

Tests of Homogeneity of Variances

		Levene Statistic	df1	df2	Say.
Time	Based on Mean	.526	1	8	.489
	Based on Median	.286	1	8	.608
	Based on Median and with adjusted df	.286	1	6.759	.610
	Based on trimmed mean	.480	1	8	.508

From the results of the homogeneity test, the results of Levene's Statistic were obtained of 0.526 with a significance value of 0.489, showing a ≥ of 0.05. The research data had a homogeneous variant or accepted H0.

Table 22. Fly Phase Homogeneity Test Results

Tests of Homogeneity of Variances

		Levene Statistic	df1	df2	Say.
Time	Based on Mean	.188	1	8	.676
	Based on Median	.167	1	8	.694
	Based on Median and with adjusted df	.167	1	7.784	.694
	Based on trimmed mean	.172	1	8	.689

From the results of the homogeneity test, the results of Levene's Statistic were obtained of 0.188 with a significance value of 0.676, showing ≥ 0.05. The research data had a homogeneous variant or accepted H0.

Hypothesis Test

Table 23. Egg Phase Hypothesis Test Results

Independent Samples Test

	Levene's Test for Equality of Varianc en	t-test for Equality of Means		
		They mean this		95% Confidence Interval of the Difference

		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference	Lower	Up
Watch over	Equal variances assumed	.590	.464	-.408	8	.347	.694	-.200	.490	-1.330	.930
	Equal variances not assumed			-.408	7.784	.347	.694	-.200	.490	-1.335	.935

The results of the hypothesis test on the travel time of oviposition obtained a significance value (2 tailed) of 0.694 indicating > 0.05, there was no difference between the group of carcasses that were exposed and not exposed to sunlight in the process of fly oviposition, so H0 failed to be rejected**.**

Table 24. Instar Larval Phase Hypothesis Test Results 1

Independent Samples Test

		Levene's Test for Equality of Variance		t-test for Equality of Means							
						They mean this				95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Differen this	Low er	Up
Watch over	Equal variances assumed	.590	.464	-1.633	8	.071	.141	-.800	.490	-1.930	.330
	Equal variances not assumed			-1.633	7.784	.071	.142	-.800	.490	-1.935	.335

The results of the hypothesis test on the travel time of the instar 1 larval phase obtained a significance value (2 tailed) of 0.141 indicating > 0.05, there was no difference between the group of carcasses that were exposed and not exposed to sunlight in reaching the larval phase of instar

1, so H0 failed to be rejected**.**

Table 25. Instar 2 Larval Phase Hypothesis Test Results

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference	Lower	Upper
Watch over	Equal variances assumed	.590	.4649	-2.449	8	.020	.040	-1.200	.490	-2.330	-.070
	Equal variances not assumed			-2.449	7.784	.020	.041	-1.200	.490	-2.335	-.065

The results of the hypothesis test on the travel time of the instar 2 larval phase obtained a significance value (2 tailed) of 0.040 indicating < 0.05, there was a difference between the group of carcasses that were exposed and not exposed to sunlight in reaching the instar 2 larval phase, then H0 was rejected.

Table 26. Instar Larval Phase Hypothesis Test Results 3

Independent Samples Test

		Levene's Test for Equality of Variances	t-test for Equality of Means

						They mean this				95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference this	Lower	Up
Watch over	Equal variances assumed	.330	.582	40.817	8	<.001	<.001	23.800	.583	22.455	25.145
	Equal variances not assumed			40.817	7.758	<.001	<.001	23.800	.583	22.448	25.152

The results of the hypothesis test on the travel time of the instar 3 larval phase obtained a significance value (2 tailed) < 0.001 indicating < 0.05, there was a difference between the group of carcasses that were exposed and not exposed to sunlight in reaching the instar 3 larval phase, so H0 was rejected.

Table 27. Pupa Phase Hypothesis Test Results

Independent Samples Test

		Levene's Test for Equality of Varianc en		t-test for Equality of Means							
						They mean this				95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference this	Lower	Up
Watch over	Equal variances assumed	.526	.489	-66.953	8	<.001	<.001	-49.200	.735	-50.895	-47.505

	Equal variances not assumed		-66.953	7.496	<.001	<.001	-49.200	.735	-50.915	-47.485

The results of the hypothesis test on the travel time of the pupa phase obtained a significance value (2 tailed) < 0.001 indicating < 0.05, there was a difference between the group of carcasses that were exposed and not exposed to sunlight in reaching the pupa phase, so H0 was rejected**.**

Table 28. Results of the Fly Phase Hypothesis Test

Independent Samples Test											
		Levene's Test for Equality of Variances		t-test for Equality of Means							
						They mean this				95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Side d p	Two-Side d p	Mean Difference	Std. Error Difference this	Lowe r	Up
Watch over	Equal variances assumed	.188	.676	-92.435	8	<.001	<.001	-71.600	.775	-73.386	-69.814
	Equal variances not assumed			-92.435	7.860	<.001	<.001	-71.600	.775	-73.392	-69.808

The results of the hypothesis test on the travel time of the fly phase obtained a significance value (2 tailed) < 0.001 indicating < 0.05, there was a difference between the group of carcasses that were exposed and not exposed to sunlight in reaching the fly phase, so H0 was rejected**.**

Discussion

The development of flies on carcasses is strongly influenced by environmental factors, particularly sunlight exposure, which affects temperature, humidity, and light intensity. Flies are phototrophic insects that rely on light to identify nutrient sources and oviposition sites (Putra & Budiarti, 2022). Light intensity and temperature interact to influence relative humidity, which subsequently affects oviposition behavior (Hans et al., 2019). Previous studies reported that more

flies are attracted to carcasses exposed to sunlight, resulting in faster oviposition under illuminated conditions (Lutz et al., 2019; Park et al., 2025). However, the findings of this study demonstrated no significant difference in the oviposition process between carcasses exposed and not exposed to sunlight ($p > 0.05$). This finding may be explained by chemical factors, particularly the foul odor produced during decomposition by anaerobic bacterial activity, which attracts flies regardless of light conditions. Consequently, oviposition occurred relatively similarly in both groups.

The absence of significant differences also continued during the transition from eggs to first instar larvae ($p > 0.05$). Light intensity regulates environmental temperature and humidity, where moderate light intensity and lower temperatures can create optimal humidity conditions for embryonic development and egg hatching (Hans & VanLaerhoven, 2024). Firoozfar et al. (2018) reported that the highest hatching rate occurs at approximately 80% humidity. In this study, the similar hatching duration between groups may have been influenced by simultaneous oviposition in both carcass conditions, resulting in nearly identical incubation periods and minimizing developmental differences between the observed groups (Otárola-Jiménez et al., 2024).

Significant differences began to appear during the development from first instar to second instar larvae and continued into the pupal and adult fly stages ($p < 0.05$). Carcasses exposed to sunlight experienced higher temperatures, accelerating larval metabolism and feeding activity, thereby promoting faster development from first instar to second instar larvae (Gao et al., 2023). These findings are consistent with Bosly (2021), who demonstrated that larval weight and body length increased significantly at higher temperatures, particularly around 30°C. The pupation process was also significantly affected by sunlight exposure. High light intensity tends to reduce environmental humidity, influencing larval migration and pupation behavior during the post-decay stage when larvae seek drier environments for pupation (Alyasiri, 2026; Hans et al., 2019; Yahya, 2021). Jiang et al. (2023) further reported that light-dark cycles accelerate larval development into pupae, supporting the results observed in this study.

Interestingly, during the transition from second instar to third instar larvae, carcasses not exposed to sunlight demonstrated faster larval development despite the significant difference between groups ($p < 0.05$). Although higher temperatures generally accelerate larval growth (Monika et al., 2020), excessive sunlight exposure may surpass the larvae's tolerable light intensity threshold, particularly above 2000 lux, causing larvae to avoid the carcass and reduce feeding activity (Lambiase & Tarone, 2021). Similar findings were reported by Bosly (2021), who observed that larvae maintained at 30°C showed lower body weight and length during the third instar stage compared to larvae at 20°C and 25°C. These findings suggest that excessive sunlight exposure may become a stressor that inhibits optimal larval development.

The adult fly emergence phase was also significantly influenced by sunlight exposure ($p < 0.05$). The duration of the pupal stage depends greatly on environmental conditions, particularly light intensity, which functions as a biological time marker regulating circadian rhythms and determining the timing of adult emergence (Chapman et al., 2013; Holmes et al., 2017). Holmes et al. (2017) demonstrated that pupae exposed to light for eight hours required fewer accumulated degree hours to hatch compared to pupae maintained in complete darkness. Similarly, the present study found that pupae on carcasses exposed to sunlight developed into adult flies more rapidly. Overall, these findings indicate that sunlight exposure significantly influences multiple stages of fly development and should therefore be considered an important factor in forensic entomology for improving the accuracy of post mortem interval estimation.

CONCLUSION

The conclusion of this study shows that there is no difference between carcass groups exposed and not exposed to sunlight in the processes of fly oviposition and the hatching of eggs into first instar larvae. However, differences were found in several subsequent developmental stages, namely from first instar larvae to second instar larvae, from second instar larvae to third instar larvae (where development in carcasses not exposed to sunlight occurs faster), as well as in the pupation process and the emergence of adult flies from pupae. Overall, the differences in

development time at each stage between exposed and unexposed carcasses can be used to determine the Post Mortem Interval (PMI) in forensic cases, particularly in situations where a body is found in an open environment.

In addition, this study provides several recommendations. The public is encouraged to promptly report the discovery of carcasses or bodies so that investigations can be conducted before the insect life cycle progresses too far. For the Faculty of Medicine at UKI, it is expected to continue supporting the development of forensic science, especially forensic entomology in determining the time of death. Future research is recommended to include additional factors such as humidity, fly species, and the use of larger animal carcass models, as well as increasing the number of openings in enclosed cages to allow more flies to enter and providing an acclimatization period for experimental animals to ensure more stable sample conditions. Meanwhile, forensic investigation teams are advised to further optimize forensic entomology analysis by paying attention to lighting conditions at crime scenes, as sunlight exposure has been shown to influence the fly life cycle rate, and to enhance collaboration with entomologists to improve the accuracy of estimating the time of death.

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AUTHOR CONTRIBUTION STATEMENT

Author 1 conceptualized the research framework, conducted the systematic literature review, performed the bibliometric analysis, and drafted the manuscript. Author 2 provided critical intellectual revisions, validated the methodological approach, and supervised the overall study. Both authors reviewed and approved the final manuscript for submission.

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