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Comparative Study of Early Postmortem Changes in *Sus Scrofa Domestica* Models in the Savannah Region of Cross River State, Nigeria

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Abstract
Post-mortem changes could be separated into early post-mortem changes which include algor mortis, rigor mortis, and livor mortis, and late stages of decomposition characterized by putrefaction. There is limited understanding of how the interplay between body size, mode of death, and depositional environment influences the early postmortem changes in cadavers. Therefore, this study was aimed at comparing early post-mortem changes using Sus scrofa domestica models based on body size, mode of death, and depositional environment. Twelve white male pigs, divided into juvenile (20-25 kg, ±4 months) and adult (45-50 kg, ±8 months) groups, were sacrificed using three modes of death: poisoning, sharp force trauma, and blunt force trauma, and placed in cages and suspended by ropes. Observations, including daily visible decomposition changes, climatic data, temperature changes, and Total Body Score (TBS), were recorded over 8 days. Line graphs and bar charts were used to determine the relationship between decomposition and the independent variables, which include atmospheric temperature, humidity, wind speed and duration of decomposition. Findings from the study showed that factors such as weight or size of the carcass affects the rate of decomposition as well as other early post mortem changes. Although there are extensive forensic taphonomic studies conducted to study how different variables affecting decomposition process, the correlation between different factors is yet to be uncovered in detail.

Keywords: Total body score, Post Mortem, Algor mortis, Rigor mortis, Livor mortis

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INTRODUCTION

Decomposition is a natural process that occurs for every organism that has died. Initially, the degradation may not be visible to the naked eye as the process starts at the cellular level. Slowly the changes will progress to macroscopic and form the post-mortem changes. This process continues even beyond the dry remains stage as the bones still undergo decomposition although at a much slower rate as previously seen (Hau *et al.,* 2024).
Post-mortem change is the term for the natural disintegration of the body that occurs following death, at the cellular level. The procedure involves complex cellular and biochemical processes. The immediate postmortem alterations persist for a significant duration, with varying rates for different organs (Elgawish *et al.,* 2021). Numerous internal and external factors affect the onset and degree of these changes. These alterations could be important for establishing or verifying the time of death, providing a clue to the method or cause of death, or suggesting that a body might have been moved after it passed away. An intimate understanding of the postmortem processes and the factors that affect them will aid in the estimation of the postmortem interval (PMI), sometimes referred to as time since death (Khalil *et al.,* 2024).

The body of the deceased experiences a series of chemical and physical changes right after death. These are progressive, permanent, and inescapable changes that happen in a rather consistent order across time. There are a few early stages that the body goes through during death that result in a significant change in the physical nature and/or appearance of the corpse before noticeable, gross decomposition adjustments begin. These modifications may cause confusion if they are not acknowledged because they have historically been utilized when estimating the PMI (Zongo *et al.,* 2023). However, the rate at which these changes occur can vary greatly depending on a wide range of environmental and contextual circumstances. The changes to a body that take place immediately following death are often more rapid than those occurring later during the decomposition process. Furthermore, an intimate understanding of the postmortem processes and the factors that affect them will aid in the estimation of the postmortem interval (Hauther *et al.,* 2015).

There are a few early stages that the body goes through during death that result in a significant change in the physical nature and/or appearance of the corpse before noticeable, gross decomposition adjustments begin. These modifications may cause confusion if they are not acknowledged because they have historically been utilized when estimating the PMI (Zongo *et al.,* 2023).

Rates of decomposition are influenced by a number of factors such as the condition of the remains, scavenging activity and so forth. Several studies have been conducted to better understand some of these variables that affect decomposition. However, very few studies emphasized the effect that body size would have on the decomposition process. According to Spaulding (2020) PMI estimations for infants and smaller bodied individuals are problematic as there are scant data available on their decomposition patterns.

Hanging is a form of asphyxia characterised by a constriction of the neck by a ligature tightened by the gravitational weight of the body or part of the body, which ultimately results in death of the individual (Lynch-Aird 2015). Where an individual has a strong suicidal intent and access to firearms is restricted by governmental legislation, hanging with its high chance of fatality is regrettably an increasingly common mode of attempted suicide (Cai *et al.,* 2022). In Nigeria, it has been reported hanging is the most violent and prevalent method of suicide compared with poisoning, and often results in death (Oyetunji *et al.,* 2021). Obun et a., (2023) found that the decomposition rate was slower in the hanging carcass and that each stage of decomposition was prolonged when compared with surface remains. This was attributed to the fact that bodies hanging outdoors will have a greater part of their surface area exposed to the drying effect of wind, which could in turn lead to rapid mummification.

Deaths due to poisoning and drug abuse are quite common throughout the world. One type of poison that is commonly found in cases of poisoning or suicide is pesticides (Hore *et al.,* 2017). The popular choice of poison for suicides in Nigeria is Sniper (Onyejike *et al.,* 2019). Sniper is a DDVP, 2,2-dichlorovinyl dimethyl phosphate compound produced by a Swiss-Nigerian chemical compound, as a synthetic organophosphorus (Uy *et al.,* 2022) but popularly used in Nigeria as an insecticide because of its effectiveness compared to other brands (Onyejike *et al.,* 2019). However, there have been several reports on homicides and suicides resulting from Sniper in Nigeria, this led to the ban on the manufacture of small bottle Sniper by the Federal Government of Nigeria in 2019 (Onyejike *et al.,* 2019). In cases of poisoning, the presence of poison in the body can change the rate of development and growth of the insects that land on the body. Toxins in the body can cause insects that land on them to also experience poisoning so that their developmental stage stops. The presence of poison can also reduce the number of insects that come to the body (Manik, 2019). Observation from some studies showed that poison or embalming fluid significantly delays the natural process of decomposition (Obun *et al.,* 2020). Taphonomic studies on factors affecting various decomposing vertebrate species, such as dogs, various rodents, birds, reptiles, and amphibians, has been carried out (Martin *et al.,* 2021). However, these findings may not be generalized to human remains to represent a typical forensic scenario. The purpose of this study was to compare early postmortem changes in pig models based on size, mode of death, and depositional Environment. The domestic pig (*Sus scrofa L.*) was used because many studies have shown that it possesses a pattern of decomposition that is similar to that of human (Connor *et al.,* 2018).

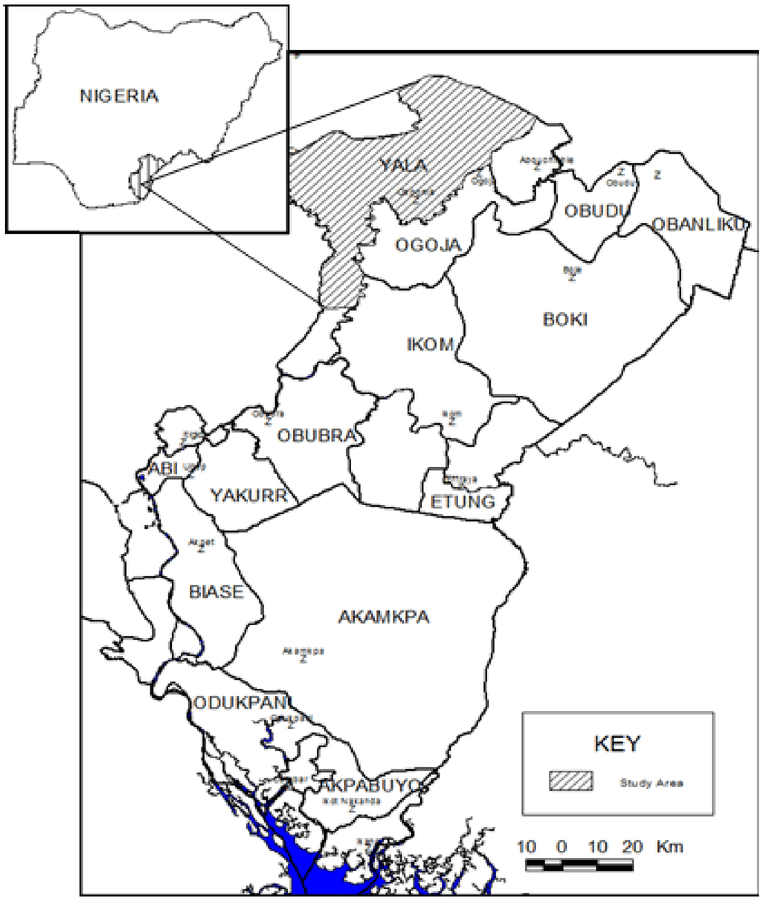
MATERIALS AND METHOD

Ethical Approval

Ethical approval was obtained from the Ahmadu Bello University Zaria, Ethics Committee on Animal Use and Care. Approval number: ABUCAUC/2024/018

Study Location

The study took place at the Taphonomy Research Facility within the Department of Human Anatomy, Cross River University of Technology (CRUTECH) in Okuku, Yala, Northern Cross River State, Nigeria, located about 274 km north of Calabar (6°35′35″N, 8°38′01″E). The region features savannah plains and semi-arid vegetation, with soil that is a blend of warm, sandy, and reddish clay. The humid tropical climate includes a wet season (April–October) and a dry season (November–April), with temperatures ranging from 15°C to 32°C and annual rainfall of 1300–3000 mm. Conducted from April to July 2024, this study was set amidst diverse habitats, including grasslands and semi-arid shrubs, with local fauna such as wild rats, squirrels, snakes, and birds. Weather data were collected from the closest point to the site and cross-referenced with prior studies (Simon, 2010).



6°35′35″N, 8°38′01″E

Study Design

Domestic pig (sus scrofa) models were used as analogues for human cadavers. This animal is considered to be an excellent model in decomposition studies and is frequently used in taphonomy experiments.

Twelve (12) male pigs of white breed were obtained from the abattoir having met all veterinary health standards were housed in the pen house of the Department of Human Anatomy (Cross River University of Technology) and grouped into two (2) groups containing three (3) animals each. Group 1, were the juvenile group and group 2 were the adult group. For the juvenile group, the pigs will have an average weight of ±20-25kg and aged ±4 months. For the adult group, the pigs will have an average weight of ±45-50kg and aged ±8 months. For each of the two groups, each animal will have a distinct representation as presented in Table 2.0.

The animals were sacrificed with three modes of death namely poisoning, sharp force trauma and blunt force trauma left on designated surfaces. Climatic observations were also taken for period of 7 days (Morning, Noon and Evening(s).

Table 1: Animal grouping

	JUVENILE CARRION		
JUVENILE	Blunt force	Stabbed	Poisoned
	Surface (SJB)	Surface (SJS)	Surface (SJP)
	Hanged (HJB)	Hanged (HJS)	Hanged (SJP)
	ADULT CARRION		
ADULT	Blunt force	Stabbed	Poisoned
	Surface (SAB)	Surface (SAS)	Surface (SAP)
	Hanged (HAB)	Hanged (HAS)	Hanged (HAP)

Data Collection
To reveal seasonal differences in daily weather conditions, data were obtained on-site and from the Nigeran Meteorological Agency (NiMet) station located in Calabar which were compared. To reveal differences between forests in ambient air (1 m above ground) and ground-level temperature and humidity, measurements would be made using a digital humidity/temperature meter with a data logger (CENTER 314, Center Technology Cor., Taiwan). Weather conditions during the experimental period. Daily mean temperatures, total precipitation, and hours of sunshine per day were recorded and plotted.

To estimate the time of death using decomposition changes and the Accumulated Degree Hour (ADH) method, the stages of decomposition were first observed: pallor mortis (paleness of the skin), algor mortis (body cooling), rigor mortis (muscle stiffening), livor mortis (blood pooling), and putrefaction (onset of bloating and skin discoloration) (Krompecher *et al.,* 2017). Relevant changes, such as body temperature and skin color, were recorded. The ADH method was then applied by calculating the temperature difference between the body and its surroundings over time. Body and ambient temperatures were measured, and the temperature differences were summed for each hour since death to estimate the elapsed time. All observations and temperature readings were documented for forensic accuracy (Dekeirsschieter *et al.,* 2013).

RESULTS
The results showed that in the hanged pigs, the duration of the fresh stage was uniform in both the stabbed and blunt force pigs but showed slight variation in the poisoned pig as it lasted longer, in both adult and juvenile carcasses. It lasted for 24 hours. Of note, the eyes and nose of each hanging carcass were slightly open from the pressure of the noose tied around the neck. Onset of rigor mortis was first observed at the limbs 3 hours and 2 hours post mortem in the stabbed and blunt force pigs respectively. For the surface disposed carrions, The fresh stage for both carcasses, commenced directly after the animals were humanely killed, and it was associated with soft torsos and flexible limbs and no foul odor. They remained in the fresh stage for a very short period of time; It lasted from 0-1 day in both adult and juvenile pigs. Onset of rigor was evident on the limbs at 4hours post mortem in the blunt force pig, 5hours in the stabbed pig and 6hours in the poisoned pig. Livor mortis was first observed 3 hours post mortem in the blunt force pig and 4 hours in the stabbed pigs.

In the hanged pigs, Within the next seven hours post fresh stage, onset of bloating was evident in the adult carcass with greenish discoloration evident throughout the lower abdominal region. Following the onset of bloating, purplish red coloration was observed in the lower extremities of the adult indicating onset of livor mortis (36H post mortem). Rigor mortis was observed in the poisoned pig 12 hours post mortem and had spread to the head and neck in the stabbed and blunt force pigs. The duration of bloating was 84ADH post mortem, where it reached its peak. The poisoned pigs showed pronounced lividity around the neck and dependent part of the trunk at 15hours post mortem. Noticeably, rigor waned earlier in the juvenile pig with livor still prominent.

The bloat stage for the surface disposed pigs lasted for four days in the juvenile pig and it peaked in day 2. In the poisoned pig, it was characterized by a swelling of the abdomen region and gradual increase in the head and neck to the limbs. The duration of livor mortis was evident 36ADH in the poisoned pig 34ADH in the blunt force and 37ADH post mortem in the poisoned pig. By his time, rigor had waned completely in both stabbed and blunt force pigs. Rigor mortis was evident in the limbs of the poisoned pigs 30H post mortem.

The onset of active decay stage for the hanged animals which was indicated by the presence of first instar maggots at the marked the end of lividity. Rigor mortis had waned completely in the blunt force pig at 36 ADH and 42ADH in the stabbed pig. The poisoned pig experienced longer rigor at 52ADH. HJP showed the longest duration of lividity (93 ADH), while SAP has a shorter duration (77 ADH).

The surface disposed carrions showed onset of the active decay marked the end of all signs of lividity in all pigs. The active decay stage was characterized by maggot filled blisters and significant larval aggregations developing around the pigs

Figure 1: Images of Surface (A) Adult Pigs, with different modes of death showing Rigor Mortis (B) Juvenile Pigs, with different modes of death showing Rigor Mortis

Figure 2: Images of Hanging (A) Adult Pigs, with different modes of death showing Lividity (B) Juvenile Pigs, with different modes of death showing Lividity

Figure 3: Images of Surface (A) Adult Pigs, with different modes of death showing Rigor Mortis (B) Juvenile Pigs, with different modes of death showing Rigor Mortis

Figure 4: Images of Surface (A) Adult Pigs, with different modes of death showing Lividity (B) Juvenile Pigs, with different modes of death showing Lividity

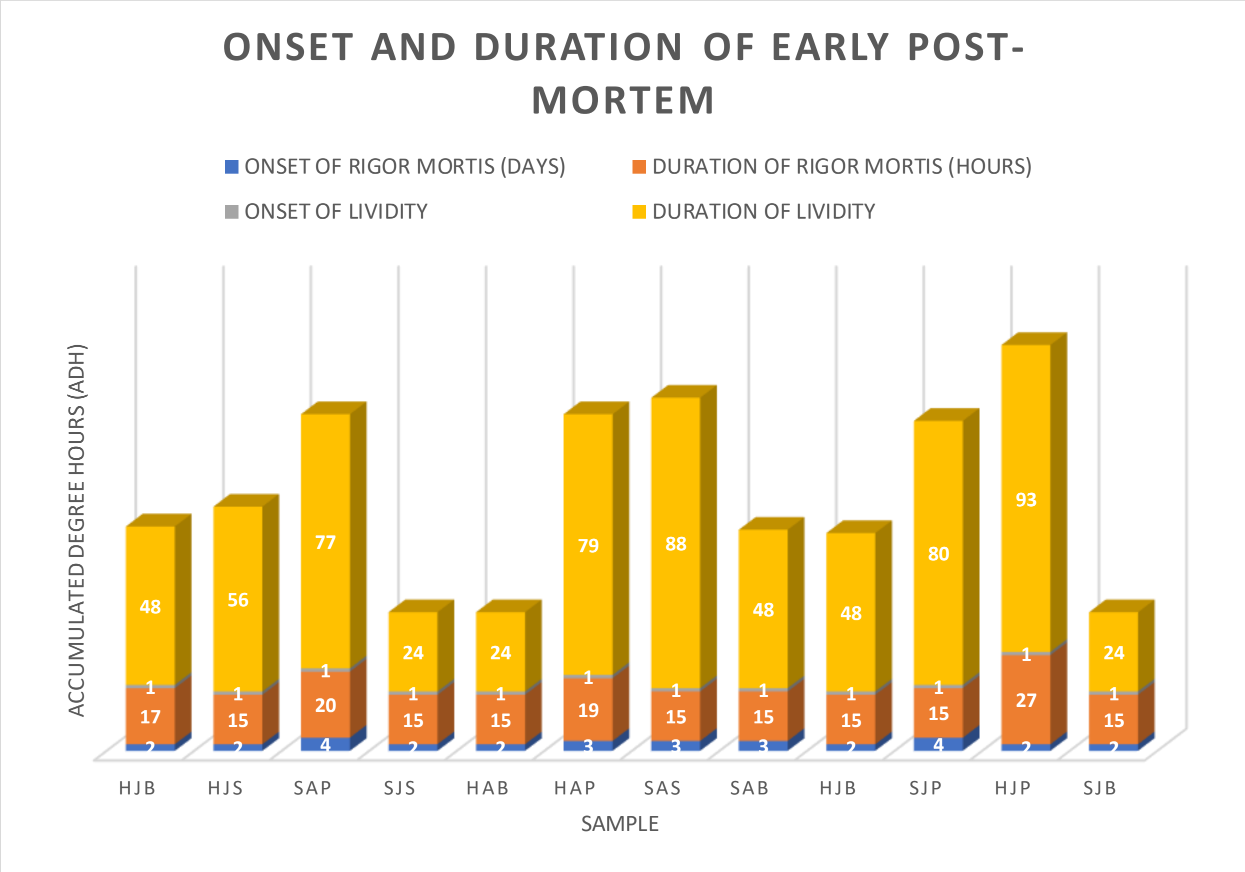


Figure 5: **Onset and duration of rigor mortis and lividity**

The graph illustrates the onset and duration of rigor mortis and lividity in various pig samples, measured in accumulated degree hours (ADH). Rigor mortis begins within 1-2 days across all samples, with its duration varying between 15 to 27 hours, depending on the sample. Notably, poisoning (HJP) shows the longest duration of rigor mortis (27 hours), compared to other samples with around 15-20 hours. Lividity sets in early, within 1-3 hours, and lasts significantly longer than rigor mortis, with durations ranging from 24 to 93 ADH. Sample HJP shows the longest duration of lividity (93 ADH), while SAP has a shorter duration (77 ADH). These variations suggest that the mode of death and other variables impact the progression of post-mortem changes, with poisoning showing distinctively prolonged post-mortem signs.

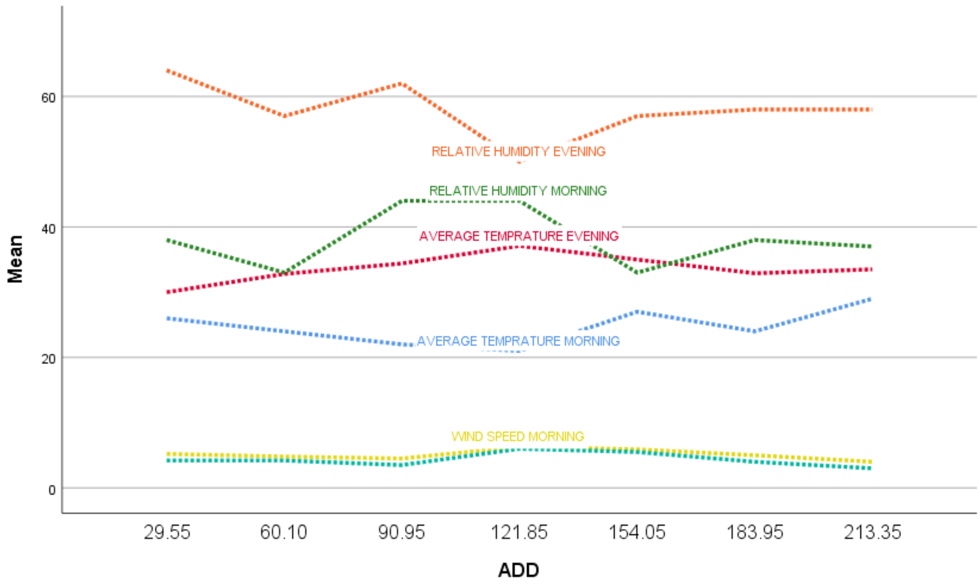


Figure 6: **Relationship between Accumulated Degree Days (ADD) and environmental factors**

The graph illustrates the relationship between Accumulated Degree Days (ADD) (x-axis) and environmental factors such as Relative Humidity, Average Temperature, and Wind Speed (y-axis as) measured during morning and evening periods. Relative Humidity varies significantly between morning and evening, suggesting diurnal effects or environmental changes over time. The average temperature is consistently higher in the evening than morning, as expected due to daily temperature patterns. Wind Speed is stable, likely indicating that it is less affected by diurnal or ADD-related changes.

DISCUSSION

The examination of early postmortem changes in pigs in this study revealed significant differences across the phases of decomposition—fresh, bloat, and active decay—depending on the mode of death (stabbing, poisoning, and blunt force trauma) and the size of the carcass (adult vs. juvenile).

In both hanging and surface-disposed pigs, the fresh stage revealed distinct patterns influenced by trauma type and environmental exposure. Surface-disposed carcasses transitioned quickly through the fresh stage (0–1 day), with rigor mortis onset varying by trauma: 4 hours postmortem in blunt force subjects, 5 hours in stabbed, and 6 hours in poisoned pigs. This early rigor onset aligns with Geissenberger et al., (2024), who noted rapid progression in open-air conditions due to increased microbial and insect activity. By contrast, in hanging carcasses, the fresh stage duration remained uniform in stabbed and blunt force subjects but was slightly prolonged in poisoned subjects, mirroring Madea (2023), who reported that toxins can slow autolytic processes and delay rigor.

Hanging subjects exhibited signs of livor mortis earlier (3–4 hours postmortem) compared to those in other studies where restrained positioning was shown to affect blood pooling (Lee et al., 2024). The findings also align with Petrus (2023), which suggested that blunt force trauma accelerates rigor due to muscle trauma-induced changes, as evident in the blunt force pigs that exhibited earlier rigor onset in both hanging and surface conditions.

The bloat stage displayed notable differences between hanging and surface-disposed pigs, with poisoned carcasses in both conditions showing prolonged bloating. Hanging poisoned subjects, for example, exhibited extended livor mortis at 15 hours, consistent with Khalil et al. (2024), which found that toxins prolong vascular congestion and bloating. The duration of bloating in surface-disposed pigs was more variable: four days in juvenile subjects, with adult poisoned pigs showing extensive abdominal swelling, this supports findings by Carlson et al. (2023) and Khalil (2024), who documented that surface-exposed conditions promote faster bloating due to microbial and insect colonization.

In both depositional settings, livor mortis manifested distinctly across trauma types. Livor mortis in poisoned subjects persisted up to 37 ADH in surface conditions, aligning with Janaway et al. (2009), who found that toxins delay vascular decompression. Moreover, the juvenile carcasses demonstrated earlier dissipation of rigor, suggesting that smaller body sizes lead to faster heat loss and thus a quicker transition through the bloat phase.

The active decay stage, indicated by extensive maggot activity in surface-disposed pigs, showed marked differences based on environment and trauma type. The extensive larval colonization and blistering in surface-disposed pigs align with Dawson et al., (2024), who highlighted that outdoor conditions facilitate rapid insect colonization, thereby accelerating decay. In contrast, hanging carcasses showed delayed insect colonization, consistent with Cogswell & Cross (2021) findings that restrained positions limit insect access and thus slow decay onset.

Poisoned pigs particularly in the hanging position, displayed prolonged rigor up to 52 ADH, which may indicate that toxins slow muscle decomposition, as suggested by Madea (2023) In both environments, the onset of active decay marked the cessation of livor mortis, yet poisoned pigs exhibited signs of extended lividity, aligning with findings by Chandy et al., (2020) who observed that chemical agents influence blood stasis.

Across depositional environments and trauma types, poisoned pigs consistently showed prolonged rigor and livor mortis, corroborating Lynch-Aird, et al (2015), who observed that toxins impact decomposition through slowed autolysis and altered blood settling. This extended livor mortis in poisoned subjects suggests that toxic agents affect vascular and muscular systems differently compared to physical trauma alone. Comparatively, surface-disposed conditions accelerated the decomposition stages across all trauma types, particularly evident in the juvenile subjects, where rigor dissipated earlier.

The presence of maggots in surface-disposed pigs, contrasted with delayed colonization in hanging pigs, underscores environmental access as a key determinant of decomposition rate, supporting Dawson (2020). Moreover, the accelerated decay observed in surface-disposed carcasses highlights how open-air exposure facilitates rapid transition through stages.

CONCLUSION

The degradation process from a fresh cadaver to dry skeletal remains until the destruction of bone elements takes time from years if not centuries, if variations such as mummification and adipocere occur. However, the decomposition process itself is subject to various intrinsic such as age, weight, ante mortem condition, presence of trauma, drugs or toxins and extrinsic factors such as environment setting, temperature, moisture level, sun exposure, layers and type of clothing, coffin and bedding and accessibility of insect. The condition of corpses in real crime scenes is often diverse and numerous variables may have taken part in leading to the point of decomposition process before the arrival of experts. Therefore, it is difficult to compare studies and real cases due to differences in climate, geographical location, subject or model used and setting of the study. Although there are extensive forensic taphonomic studies conducted to study how different variables affect the decomposition process, the correlation between different factors is yet to be uncovered in detail.

It generally is impossible to draw any definite conclusion concerning the time of death by the appearance of a single postmortem change, or conversely, to predict what postmortem changes are to be expected in a given case after a particular postmortem interval has elapsed. Nevertheless, in the very early postmortem interval (approximately within 24 hours after death), in some distinct cases, particularly the presence and picture of several postmortem changes may, when analyzed combined with the temperature of the deceased, give the death investigator valuable hints concerning the time frame in which the subject most probably has died. The presented tables summarizing the chronologic order of appearance and sequence of events of distinctive postmortem changes such as livor mortis and rigor mortis will prove useful in forensic casework to give an approximate estimation of the time since death.

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