The effect of body size on the rate of decomposition in a temperate region of South Africa

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Abstract

Forensic anthropologists rely on the state of decomposition of a body to estimate the Post-Mortem-Interval (PMI) which provides information about the natural events and environmental forces that could have affected the remains after death. Various factors are known to influence the rate of decomposition, among them temperature, rainfall and exposure of the body. However, conflicting reports appear in the literature on the effect of body size on the rate of decay. The aim of this project was to compare decomposition rates of large pigs (*Sus scrofa;* 60 - 90 kg), with that of small pigs (< 35 kg), to assess the influence of body size on decomposition rates. For the decomposition rates of small pigs, 15 piglets were assessed three times per week over a period of three months during spring and early summer. Data collection was conducted until complete skeletonization occurred. Stages of decomposition were scored according to separate categories for each anatomical region, and the point values for each region were added to determine the total body score (TBS), which represents the overall stage of decomposition for each pig. For the large pigs, data of 15 pigs were used. Scatter plots illustrating the relationships between TBS and PMI as well as TBS and Accumulated degree days (ADD) were used to assess the pattern of decomposition and to compare decomposition rates between small and large pigs. Results indicated that rapid decomposition occurs during the early stages of decomposition for both samples. Large pigs showed a plateau phase in the course of advanced stages of decomposition, during which decomposition was minimal. A similar, but much shorter plateau was reached by small pigs of >20 kg at a PMI of 20-25 days, after which decomposition commenced swiftly. This was in contrast to the small pigs of <20kg, which showed no plateau phase and their decomposition rates were swift throughout the duration of the study. Overall, small pigs decomposed 2.82 times faster than large pigs, indicating that body size does have an effect on the rate of decomposition.

KEYWORDS: Forensic anthropology, post-mortem-interval, decomposition, total body score, body size

1. Introduction

Due to the vast areas of desolated fields in South Africa, human remains are often discovered in advanced stages of decomposition. Therefore, the ability to accurately estimate the post-mortem-interval (PMI) is essential in a case involving decomposed human remains. By obtaining an accurate PMI estimate, the potential pool of individuals that the remains could belong to can be reduced and therefore contribute to the possible identification of the individual. Studies involving decomposition can answer questions concerning how, where and when the victim died. Also, this information is useful in excluding possible assailants and to substantiate witness testimonies. Forensic anthropologists often rely on the state of decomposition to estimate the PMI as this can provide information about the natural events and environmental forces that were likely to have affected the remains after death [1].

Various authors [1-3] have suggested that it is necessary to develop quantitative methods in order to produce PMI estimates applicable to varying geographical regions and seasons. Quantitative studies using decomposing pig carcasses to evaluate time since death have been done in South Africa, however, these studies mostly focused more on entomological evidence to determine PMI than on stages of decomposition [4]. One exception is the study of Myburgh [2], who used Accumulated Degree Days (ADD) to assess the post-mortem-interval.

Standardized methods to estimate PMI are not available as there are many factors that influence human decomposition. The longer the PMI, the more difficult it is to assess the time of death [5]. However, as more knowledge is gained from experimental studies, forensic anthropologists come closer to deriving models that encompass all taphonomic parameters which may influence decomposition.

According to Vass [6] there are four main factors influencing the decomposition process, namely temperature, moisture, pH and partial pressure of oxygen. Environmental variables influence the decomposition processes the most, as factors such as temperatures and rainfall are highly variable and cannot be controlled [6]. By making use of ADD the variables associated with temperatures can be standardized. Temperature units known as ADD have been suggested as a viable method to quantify the rate of decomposition [1, 7]. ADD are heat energy units which represent the accumulation of thermal energy needed for the chemical and biological reactions that take place in the body during decomposition, thus representing chronological time and temperature combined. By using ADD the effect of temperature is standardised, thereby allowing studies to be compared with one another [3].

The study done by Megyesi [1] incorporated mixed methods whereby both qualitative and quantitative approaches were retrospectively used to calculate a PMI estimate. The qualitative data on decomposition was converted into quantitative scores from three regions in the body, namely the head and neck, trunk and limbs. These regions were scored separately as not all stages of decomposition apply equally to all parts of the body, as for example, limbs do not bloat. The point value allocated to each region was added to produce a total body score (TBS) [1].

Myburgh [2] made use of ADD to estimate PMI in a South African setting. She concluded that the results of her study broadly agreed with those found by Megyesi and associates [1] and that this model can be successfully applied in a South African setting. However, even with the new formulae developed specifically for a South African setting, validations done on an independent sample indicated that decomposition is very variable and the estimates not very accurate [8]. Various factors may have contributed to the relatively low levels of accuracy when validated, of which seasonality may be one. Myburgh [2] studied decomposition over a period of two extreme seasons, and found that seasonality played a major role in the decomposition process.

Furthermore, rates of decomposition are influenced by a number of factors such as the condition of the remains, scavenging activity and so forth. To better understand some of these variables that affect decomposition, large-scale studies have been conducted at institutions like the University of Tennessee's Anthropological Research Facility located in Knoxville. However, very few studies emphasized the effect that body size would have on the decomposition process. According to Archer [9], bodies of infants are occasionally found in circumstances which require PMI estimations. PMI estimations for infants and smaller bodied individuals are, however, problematic as there are scant data available on their decomposition patterns.

Mann and colleagues [10] also indicated that body size is important in the rate of decomposition. They concluded that obese bodies lose body mass more rapidly due to liquefaction of body fats, than compared to skinny individuals [10]. They also found that bodies weighing more than 110 kg decompose much more rapidly than bodies weighing approximately 65 kg. This is supported by the study done by Campobasso and associates [11] who observed that putrefaction is slower in foetuses and newborns, and that obese corpses decompose more rapidly due to greater amounts of liquid in the tissue.

Archer [9], however, suggested that newborn babies decompose three to five times the rate of adults. This was proposed to be due to the difference in body size and also the difference in bone composition. Archer [9] proposed that large pigs retain substantially more flesh and fat during the onset of butyric fermentation, whereas in small pigs, very little tissue remains. This may be due to differences in fat stores and flesh volume between the small and large pigs. Tracqui [12] proposed that heat loss is slower in obese bodies due to the greater body mass and because fat may act as insulator. By slowing down heat loss, the decomposition rate is greatly affected as post-mortem cooling is inhibited.

In a study done by Simmons [3] on the influence of insects and carcass size on the rate of decomposition, they found that smaller carcasses decomposed faster than larger carcasses. According to this study the slower decomposition rate in larger carcasses could be attributed to the greater body mass for insects to consume, hence prolonging the time to skeletonization. Body size was found to be a significant factor when carcasses are accessible to insects; when insects were excluded carcass size did not seem to influence the decomposition rate.

These results are supported by the findings of Spicka [13] who observed that a relationship exists between carcass mass and the rate of decomposition. Carcasses weighing 20 kilograms (kg) decomposed more rapidly than larger carcasses for the initial 6 days post-mortem. However, by 11 days post-mortem, the initial carcass weight had no effect on the percentage of carcass mass remaining.

From the literature cited, it is clear that consensus could not be reached by scholars on the effect of body size on the rate of decomposition. The aim of this study was therefore to compare the rates of decomposition between smaller and larger bodies, specifically in a temperate region of the world where rainfall is episodic and relatively low. If differences were observed, it was specifically attempted to establish during which stages of decomposition the most differences occur. This study is therefore valuable to understanding the contribution of body size to the rate of decay.

2. Materials and Methods

This study was conducted at the Forensic Anthropology Body Farm (FABF) on the Miertjie le Roux Experimental Farm belonging to the Faculty of Natural and Agricultural Sciences of the University of Pretoria. This 570 hectare farm is located in the Cullinan District, Gauteng Province. The Miertjie le Roux Experimental Farm is situated on the central Highveld plateau of South Africa, with warm summer days. Even in winter temperatures rarely fall below 0˚C. Rainfall mainly occurs during the summer months, at approximately 700 mm annually [14], and vegetation mostly consists of sour veldt grasslands.

An enclosure was constructed on half a hectare during August 2008 and comprised of a 50 m x 50 m, 1.2 m high chicken wire fence with a gate to allow for access when transporting carcasses. *Sus scrofa*, or domestic pig carcasses, were used in this study as their pattern of decomposition appears to resemble that of humans the most. Pigs are omnivorous and have a digestive track and intestinal flora similar to humans. Their skin resembles that of humans and putrefaction proceeds approximately at the same rate as human bodies with similar weights [11].

Pig carcasses were donated from a local farmer, and placed within 12 hours after death. An increase in the rate of insect colonization has been shown at sites of trauma and or visible external wounds, which may result in an accelerated decomposition rate [11]. Therefore, only pigs that died of natural causes, had known dates of death and showed no signs of external wounds or trauma were included in the study. Death in commercial pig farms is usually caused by *E. coli* (Escherichia coli) and Salmonellosis (*Salmonella choleraesuis*) infection. As disease can influence the rate of decay, all pigs in this study was received from the same farmer and exposed to similar conditions, therefore disease should not have a significant effect on any observed differences in decomposition rates.

Fifteen pigs classified as Piglets (weighing less than 35 kg and being less than 14 weeks old) were used for the sample of small pigs. All the small pigs in this study had a weight range of between 3 and 35 kg (Table 1), but could further be divided into 3 weight ranges with 5 pigs each. The smallest of the small pigs weighed between 3 and 5 kg (pigs 7, 8, 10, 11, 12), medium-sized small pigs weighed between 6 and 20 kg (pigs 2, 4, 13, 14, 20) and the larger of the small pigs weighed between 22 and 35 kg (pigs 1, 3, 5, 6, 9). Their rates of decomposition were compared with those of 15 large pigs, weighing between 60 and 90 Kg (Porkers and Baconers)

Table 1

Summary of the date of death, weight and metric dimensions of the sample of small pigs.

Pig	Date of placement	Sex	Weight (kg)	Height (cm)	Length (cm)	Width (cm)	Belly height (cm)
1	11/10/2011	F	33	35	88	17	27
2	11/10/2011	F	20	31	78	16	19
3	18/10/2011	F	22	28	81	18	20
4	19/10/2011	F	8	28	61	11	16
5	19/10/2011	F	35	38	93	23	28
6	03/11/2011	F	23	32	79	17	21
7	05/12/2011	F	3.2	13	33	7	5
8	03/11/2011	F	5	20	46	9	8
9	03/11/2011	F	35	43	98	19	30
10	07/11/2011	F	4.5	16	38	9	10
11	07/11/2011	F	4.8	15	38	8	10
12	05/12/2011	M	4.3	16	36	8	7
13	06/12/2011	M	6	19	42	9	10
14	16/11/2011	M	7.5	20	49	9	9
15	16/11/2011	F	20	32	77	16	19

[2, 8]. The assessment of decomposition rates of large and small pigs was done separately, i.e. during different summers.

The pigs were placed approximately 10 meters apart to ensure that insect colonization from one pig did not influence another. Pigs were numbered in sequence of arrival at the farm. Fresh pigs were placed between pig already in advanced stages of decomposition in order to minimize the effect of insect migration, as certain insects are often associated with specific stages of decomposition [15, 16].

Apart from the enclosed study area, additional steel cages were constructed and placed over the fifteen carcasses in order to prevent scavengers from access to the carcasses. In comparison to the large pig sample used by Myburgh [2], some of the carcasses used in this study were very small and easily dismembered and or removed by scavengers. Scavengers and carnivores seen in the area during the study include domestic dogs, black-backed jackals, suricates, crows and cattle egrets. These cages were constructed from galvanised meshed wire and steel which did not prevent access of insects to the bodies and neither interfered with temperatures and rainfall. The length of the cages differed as 10 cages were 1,2 m in length and 600 cm in width for the larger carcasses and 5 cages were 600 cm by 600 cm for the smaller bodied pigs.

Ethical approval for this study was granted from both the Student Ethics Committee of the Faculty of Health Sciences, and the Environmental Biohazard Committee of the Faculty of Natural and Agricultural Sciences, University of Pretoria.

Data collection was conducted 3 times per week until complete skeletonization has been reached. The longitudinal study was conducted over a period of 3 months starting from 11 October 2011 to 29 December 2011. Data collection for Myburgh's [2] study, which was used as baseline study to compare decomposition rates between the small and large pigs, took place from 13 August 2008 to 02 April 2009.

Each pig was weighed and their height, length, pelvic width, belly height and thoracic width measured prior to placement in an open veldt (Tables 1, 2 and 3). These measurements gave an estimation of body size. Each was allocated a number, the date of death, date of placement, height, weight, length, width, sex and belly height were measured and recorded.

The degree of decomposition for each pig was observed, photographed and recorded using three separate scoring guidelines developed by Megyesi [1]. The three separate categories for scoring decomposition were developed for each anatomical region (head and neck, trunk and limbs) with point values as indicated in Fig. 1.

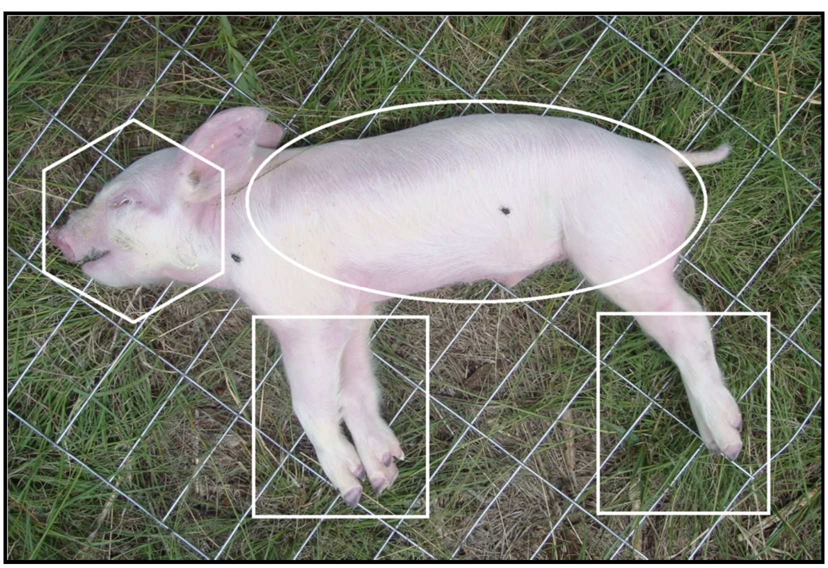

Fig. 1. Scoring of the three anatomical regions to calculate TBS (Hexagon = Head and neck, Oval = Trunk, Rectangular = Limbs).

Table 2

Summary of the date of death, weight and metric dimensions of the sample of large pigs.

Pig	Date of death/ placement	Sex	Weight (kg)	Height (cm)	Length (cm)	Width (cm)	Belly height (cm)
1	13/08/2008	M	82	74	131	23	38
2	19/08/2008	F	75	68	130	28	34
3	20/08/2008	M	60	51	109	33	37
4	20/08/2008	F	55	56	118	21	21
5	25/08/2008	F	63	64	133	22	21
6	29/08/2008	F	83	82	134	24	36
7	29/08/2008	M	38	52	102	24	27
8	02/09/2008	M	68	55	121	26	32
9	25/09/2008	M	80	51	132	29	39
10	10/10/2008	M	80*	57	152	28	36
11	13/10/2008	F	59	45	128	26	37
12	16/10/2008	M	85	38	143	29	32
13	16/10/2008	F	80*	50*	130*	30*	40*
14	24/10/2008	M	74	62	115	25	30
15	27/10/2008	M	80*	80	148	26	32
16	27/10/2008	M	65*	63	136	30	33
17	14/11/2008	F	75*	70*	130*	25*	30*
18	14/11/2008	F	65*	61	131	29	32
19	17/11/2008	M	80*	50*	130*	30*	40*
20	24/11/2008	M	65*	45*	125*	25*	35*
21	09/02/2009	M	65*	53	137	26	31
22	09/02/2009	M	70*	46	138	27	30
23	10/02/2009	F	75*	50*	140*	30*	40*
24	10/02/2009	F	75*	50*	140*	30*	40*
25	12/02/2009	M	85*	67	149	28	39
26	12/02/2009	M	68	54	144	27	34
27	23/02/2009	F	70*	52	113	30	40

28	23/02/2009	M	91	68	133	43	48
29	23/02/2009	F	89	60	120	32	38
30	23/02/2009	M	80*	55	130	39	42

(**estimation*) (Myburgh, 2010)

Table 3

Minimum, maximum and averages of the pig weights and measurements for small and large pig data sets (S=Small pigs (3.2 to 35 kg), L=Large pigs (60 to 90 kg)).

Measurement	Weight (kg)		Height (cm)		Length (cm)		Width (cm)		Belly height (cm)	
	S	L	S	L	S	L	S	L	S	L
Minimum	3.2	38	13	38	33	102	7	21	5	21
Maximum	35	82	43	82	98	152	23	43	30	48
Average	15.42	71.3	25.73	58.9	62.46	130.3	18.46	28.1	15.93	34.1

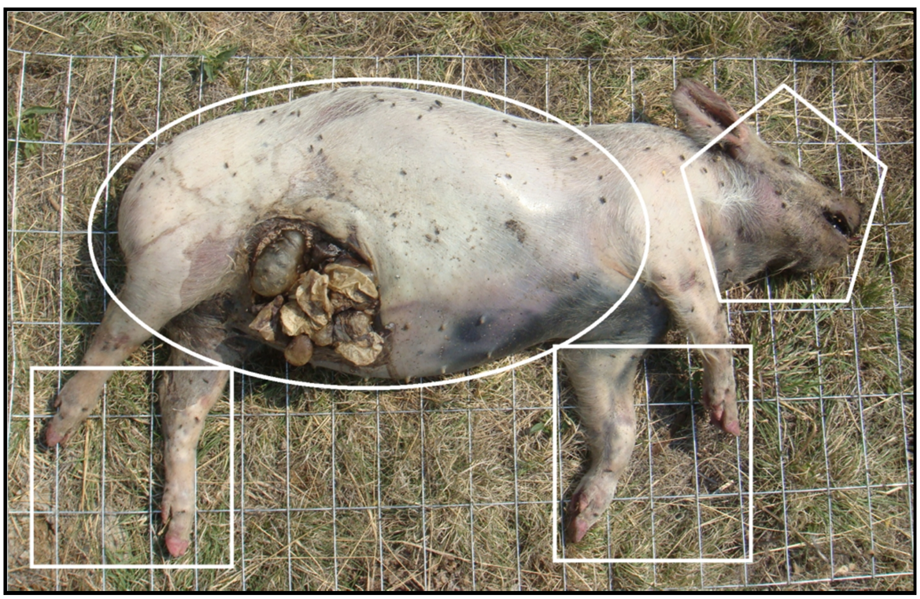

Fig. 2. An example of a pig in advanced stages of decomposition (Head and neck = 6, Trunk = 5, Limbs = 5 for a combined TBS of 16).

The qualitative descriptions of the stages of decomposition were converted into quantitative scores from these three regions in the body. The allotted point value of each region was then added to determine the TBS which represents the overall stage of decomposition of each pig from a minimum of 3 to a maximum of 35 points [1]. For example, as seen in Fig. 2, the head and neck exhibited brown to black discoloration, the trunk was in a stage of post bloating following release of abdominal gases with black discolouration, and the limbs showed brown to black discolouration. Scores of 6 (head), 5 (trunk) and 5 (limbs) were allocated resulting in a TBS value of 16.

An additional observer recorded the stages of decomposition for the head and neck, trunk, limbs and the resulting TBS of the first 10 piglets. This conforms to the same methods used by Myburgh [2] for the first 10 large pigs in her study which were scored by a secondary observer without influence from the primary investigator. This was performed as a means to determine the repeatability of the proposed method of scoring.

Accumulated degree days were calculated by adding together the daily average temperature received from a nearby National Weather Service Station (Wonderboom National Airport). By using ADD, the effect of temperatures on the rate of decomposition was standardised and allows various, similar studies to be compared.

To illustrate the progression of decomposition and compare the rates of decomposition between small and large pigs, TBS was plotted against PMI and then compared to the scatter plots of pigs with known bodyweights in the study done by Myburgh [2].

3. Results

Scatter plots of TBS vs. PMI for all pig specimens indicated two distinct decomposition patterns. The majority of specimens decomposed following a sigmoid curve during the decay process. As can be seen in Fig. 3, decomposition occurred rapidly in all pigs of the small pig sample, with TBS values of 15 to 18 observed within 8 days after placement. However, a distinct plateau phase was observed in the larger of the small pigs weighing between 22 and 35 kg, similar to what was seen in the large pigs (60 – 90 kg) during the advanced stages of decomposition. During the advanced period decomposition was minimal or absent. A similar, but much shorter plateau was reached by the small pigs of <20 kg at a PMI of 20 - 25 days, after which decomposition continued to progress relatively swiftly.

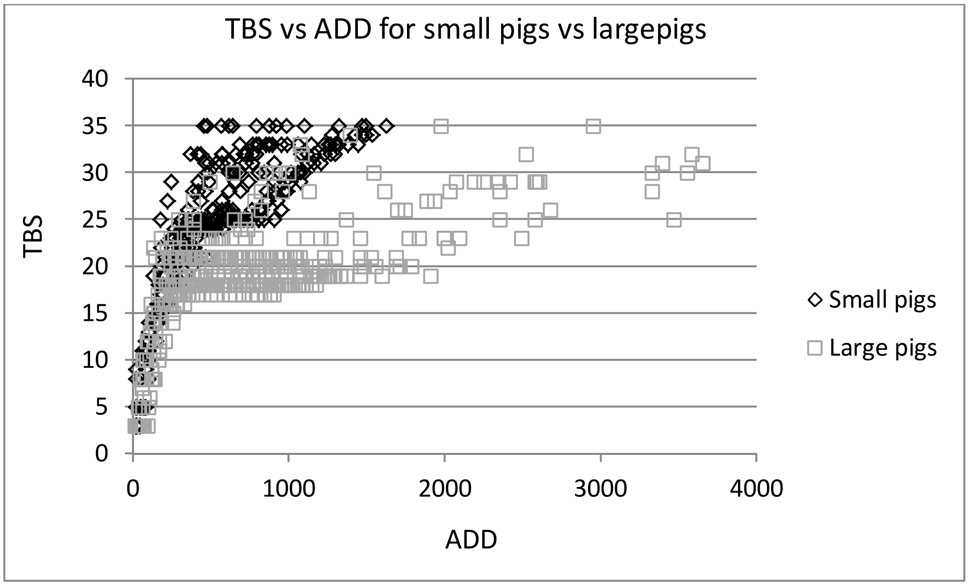

Fig. 3. Scatter plot of TBS vs. ADD for both pig data sets (N=30).

During the plateau phase observed in the larger pigs, the soft tissue became desiccated and little or no maggot activity was observed. This phenomenon may be unique to dry, temperate regions. Only 2 days with rainfall was observed during this period of the study. The larger of the small pigs in the sample (22 – 35 kg) had already reached the plateau phase when these 2 days of rainfall occurred, therefore the moisture could have aided in the rehydration of the flesh although they continued to decompose slowly. Rehydration of dried remains by rainfall may sometimes allow re-colonisation of carcasses by maggots.

Table 4
Summary statistics by group.

Group	Observations	Geometric Mean *	95% Confidence Interval
≥60kg	15	2400.852	(1787.283 ; 3225.058)
≤35kg	15	875.3806	(696.2507 ; 1100.597)

* Geometric means are reported due to skewed distribution in ADD

The differences in the rate of decomposition between the complete sample of small pigs (3 – 35 kg) and the large pigs (60 – 90 kg), as indicated by the geometric mean number of ADD to reach skeletonization, was measured and compared (Table 4). Overall, small pigs decomposed much faster, reaching greater TBS values relative to the same ADD in large pigs, suggesting that body size does have a distinct effect on the rate of decomposition. The mean ADD it took for the small pigs to reach skeletonization was 875.38ADD, compared to that of the large pig group of 2400.85ADD.

By fitting a negative binomial regression to the ADD, it follows that the incidence rate ratio (IRR) is equal to 2.82 (95% ci: 2.08 to 3.81). Therefore, it shows that small pigs (weighing between 3 and 35 kg) decompose 2.82 times faster than large pigs (weighing between 60 and 90 kg).

4. Discussion

Few studies which systematically studied the effect of body size on the rate of decomposition have been conducted. The purpose of this research was to compare decomposition rates of large pigs (*Sus scrofa;* 60 - 90 kg), with the decomposition rate of small pigs (≤ 35 kg), and less than 14 weeks old [17] to assess the influence of body size on decomposition rates within a controlled environment. To achieve this aim, data on TBS and ADD were collected. The results from this study indicate that a relationship between carcass mass and the rate of decomposition exists, as smaller bodies decompose faster. This is in contrast to the results obtained from Hewadikaram and Goff [18] who demonstrated, using a 15.1 kg and an 8.4 kg carcass, that the pattern of decomposition remains similar but that the rate of decomposition is different. They observed that the larger carcass decomposed at a faster rate during the early decay stage while the difference in the rate of decomposition during the later stages was less pronounced. However, the small sample size of Hewadikaram and Goff [18] may not have provided an accurate view of decomposition rates due to the variability of the process.

Denno and Cothram [19] indicated in their study that the size of the carcass can be directly related to the density of the fly population. During this study, blow-flies (Diptera) were observed within minutes after placing the piglets. Diptera were in abundance in the natural body openings (mouth, nose, and anus) to begin oviposition. The nose and mouth emit odours that attract flies and are therefore often the first areas to be colonised by insects [16]. This is in line with the observations made in a study by Lopes de Carvalho [20], with the Diptera (Calliphoridea) more abundant during the earlier stages of decomposition, whereas the omnivorous species were predominant during the later stages of decomposition. In the current study, similar oviposition was observed on carcasses irrespective of size and weight.

Furthermore, high temperatures promote intense insect activity which results in rapid depletion of the soft tissue on the carcass. After most of the soft tissue has been consumed, the remaining tissue eventually becomes dry and unaccommodating, resulting in less tissue consumption as well as arrested decomposition. This may contribute to the shorter period it takes to reach skeletonization in smaller pigs as no drying out stage occurs.

In the current study it was found that there was a considerable difference in the rate of decomposition of small and large pigs. In both groups, decomposition (as reflected by the TBS) initially progressed in a linear fashion relative to the ADD, but became more variable in the later stages. However, the small pigs weighing less than 20 kg decomposed at a much faster rate and had a much less obvious plateau in later stages of decomposition. Their rapid rate of decay from early decomposition until skeletonization may be ascribed to their differences in weights, and smaller body mass to consume by insects as the soft tissue was consumed before the tissue could become desiccated. Some of the larger of the small piglets in the sample (weighing between 22 – 35 kg) showed a plateau phase during the advanced stages of decomposition, similar to that observed in the much larger pigs weighing more than 60 kg. However, some variability was observed as this phenomenon was not observed equally in all pigs in this weight range. This indicates that other factors, for example rainfall, also play a role.

Some variability in the decomposition pattern was also observed in the smallest of the piglets. Two pigs weighing < 5 kg showed little or no insect activity during the decay process, although the early stages of decomposition of discolouration and bloating were observed and from there decomposition progressed rapidly. It seems possible that the body size was too little to attract much insect activity, and decomposition was probably mostly the result of micro-organisms.

This study reflects a relatively controlled test environment and provides valuable information about the decomposition process for smaller bodied individuals. A greater understanding of decomposition variables will enable better PMI estimates. As stated by Amendt [21], it should be emphasized that determining the exact PMI is exceedingly difficult, if not impossible, due to human biological variation. PMI can therefore only be estimated. The longer the PMI, the less accurate the estimation of the interval will be [22]. The process of decay is influenced by a number of aspects, for example, the complexity of integrating all factors affecting insect development [21]. It is therefore advisable that when PMI estimations are required, a multi-disciplinary approach be followed whereby i.e. forensic- entomologists, pathologists and anthropologists are involved.

Temperature and insect activity are variables that are related to aspects of decomposition, as temperature is considered the most important variable [10] and insects the most significant environmental decomposer [3]. The presence and developmental rates of insects will have a significant effect on the decomposition process. Insects hasten liquefaction and disintegration of carcasses by digestive juices they secrete, and the process of tunnelling through the body. Thus hot and dry temperatures and high rates of maggot activity allowed for rapid rates of decomposition, but as seen in the case of the two very small piglets decomposition can sometimes progress rapidly even in the absence of much insect activity. These results generally supported by the findings of Vass [7]; Simmons [3] and Spicka [13].

It can be concluded that carcass mass does affect the rate of decomposition. The results also indicate that smaller carcasses do not necessarily follow the same progression associated with larger carcasses during the decomposition process. In this study especially the pigs weighing less than 20 kg seemed to follow a distinctly different pattern. Therefore PMI estimates based on larger carcasses should not be used as PMI estimates for smaller carcasses less than 35 kg.

A similar sample size and information from all seasons of the year would be valuable in order to build a database on decomposition. Because of the variability in decomposition, it is imperative that further research be conducted in other regions and other seasons where temperatures and other environmental factors differ from those of the central Highveld plateau. By having comparative experimental data from different regions, PMI estimates can be improved and applied to actual forensic science cases.

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