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Technical note

Use of larder beetles (Coleoptera: Dermestidae) to deflesh human jaws

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ABSTRACT

We describe new experimental data for the defleshing of human bones using larder beetles (*Dermestes haemorrhoidalis*) (Küster, 1852). Although the ability of larder beetles to feed on vertebrate remains has been, and still is, used by taxidermists to deflesh skulls and bones, this method has never been documented from a quantitative perspective and has over time become ignored in most forensic anthropology or odontology laboratories.

To promote the rational and efficient use of this method, we performed experiments to estimate the quantity of food consumed by larvae. From the 2nd instar to nymphosis, each larva consumed a mean of 0.13 ± 0.03 g of dry beef muscle. We then used 100 ± 50 *D. haemorrhoidalis* adults and 100 ± 50 larvae to deflesh human maxillae and mandibles sampled within a forensic context (victim identification). Each sample was weighed and photographed before, during and after the experiment. According to our experiments, 20–25 days were sufficient to completely deflesh all of the samples.

We concluded that a small number of larder beetles can be used to efficiently deflesh human jaws. According to this result, the use of larder beetles appears to be an inexpensive, simple and efficient way to clean mandibles and maxillae. Furthermore, this method is DNA-safe (compared to usual maceration techniques) and thus allows the samples to be used for subsequent DNA and drug analyses.

1. Introduction

Defleshing skulls and bones is a central question in forensic anthropology and odontology. Indeed, anatomical components need to be cleaned prior to their analysis. Although modern imaging methods (e.g. computed tomography) can be used for this purpose, these methods are expensive and are not available in all laboratories. Thus, simmering in hot water with dish detergent or bleach is commonly used to clean forensic samples prior to direct analysis [1]. However, such treatments alter DNA [2–9]. As DNA analysis can be requested several months after sampling and defleshing, a method of preserving DNA (i.e. DNA safe) should be preferred [2]. Here, we describe quantitative data for the defleshing of human maxillae and mandibles using the larder beetle *Dermestes haemorrhoidalis* (Küster, 1852) (Coleoptera: Dermestidae). The primary reason larder beetles are not widely used in forensic cases is likely due to a lack of knowledge with regard to their efficiency in cleaning specimens [9]. Nonetheless, these insects are frequently used by natural history museums to clean animal remains [10]. In this study, we report for the first time experimental data describing the food consumption of *D. haemorrhoidalis* larvae and their efficiency in removing soft tissue from human bones.

D. haemorrhoidalis is a commonly found necrophagous insect with a worldwide distribution. The adults exhibit a characteristic oval shape and dark colouration ranging from brown to black (Fig. 1). Both the larvae and adults feed on dry animal tissues. After mating, the females lay egg–batches of ten to hundreds of eggs in cracks or cavities of the tissues [11]; the larvae feed on the surface yet bury themselves in a safe place before each moult. After 7 to 8 larval moults, the larvae reach a sufficient weight for metamorphosis, stop feeding and dig pupation chambers in appropriate places [12]. The developmental time depends on temperature: the higher the temperature, the shorter the time of development [13].

Within a forensic context, larder beetles are commonly observed on dry human remains, particularly in indoor cases [14,15]. Indeed, the ability of larder beetles to feed on vertebrate remains has been, and still is, used by taxidermists to clean bones [16]. Various refinements, such as the use of formalin to prevent feeding on articulations, have been documented over the years [10,17]. Regardless, the quantitative aspects of this method have not been documented, particularly within a forensic context.

2. Material and method

Experiments were performed under controlled conditions to estimate the quantity of food consumed by *D. haemorrhoidalis*

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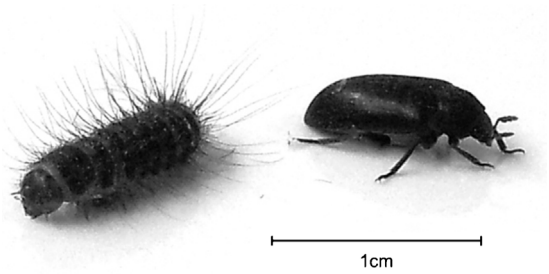

Fig. 1. *Dermestes haemorrhoidalis* larvae (left) and adult (right). Adults have an oval shape with dark-brown colour while hairy larvae are even more characteristic with their long dark bristle along the body.

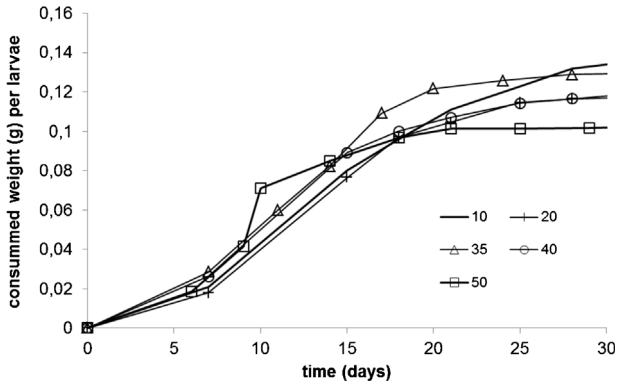

Fig. 2. Quantity of food (g) consumed per *Dermestes haemorrhoidalis* larvae during their development (2nd instar to nymphosis). Larvae were kept at 25 °C in the dark with a 10 g piece of dry beef muscle. Each curve corresponds to an initial number of larvae used for each experiment (10–50.).

larvae during their development. We also report the use of *D. haemorrhoidalis* larvae and adults to deflesh human jaws sampled within a forensic context (victim identification).

Breeding: *Dermestes haemorrhoidalis* from a local (Lille, France) wild strain were bred in a $40 \times 30 \times 40$ cm^3 plastic container filled with 3 cm of pine wood chips. The container (i.e. dermestarium) was kept at 20 ± 1 °C, 60 ± 5% relative humidity and daylight. A $20 \times 20 \times 20$ cm^3 piece of expanded polystyrene was provided for the molting and metamorphosis of the larvae. Larvae and adults were feed with beef muscle and a wet absorbent paper was also provided.

Food consumption under controlled conditions: 2–5 mm long 2nd *Dermestes haemorrhoidalis* larvae were collected from the breeding container. Zero (control), 10, 20, 35, 40 and 50 larvae were placed in $10 \times 15 \times 10$ cm^3 experimental plastic containers filled with 1 cm of pine wood chips and a $5 \times 5 \times 5$ cm^3 piece of expanded polystyrene. A piece of 10 ± 0.25 g of fat-free dry beef muscle and a wet absorbent paper were provided. The set-up was kept at 25 °C, 60 ± 5% r.h. in the dark. The piece of beef muscle was regularly weighed until the nymphosis of the larvae.

Maxilla and mandible defleshing: A total of 7 anatomical pieces were sampled within a forensic context for the dental identification of the decomposed human remains. These samples varied in weight and decomposition level. Detailed data for each case/individual are reported in Table 1. All samples were needed to be cleaned prior to analysis [1]. The jaws were weighed and photographed prior to the experiment and placed in the cleaning container.The samples were regularly weighed until flesh removal was complete. The clean jaws were then removed from the container, weighed and photographed. A control experiment was performed using the same set-up without larder beetles.

3. Results

3.1. Food consumption under controlled conditions

The survival rate (to the adult stage) ranged from 86 to 100%. At 25 °C, the larvae completed their development (1st instar to imago) in less than two months. The mean development time (2nd instar to imago) was 44.7 ± 6.9 days, and the mean duration of the pupal period was 10.35 ± 2.4 days. Thus, the larvae were actively feeding during a mean duration of 34.35 days. These data are consistent with those of Coombs (1979) for larvae bred under similar conditions (25 °C, 65% relative humidity).

During development, each larva consumed a mean of 0.13 ± 0.03 g of dry beef muscle. This per-larvae feeding quantity was independent of the initial number of larvae (Pearson correlation test, $\alpha = 0.05$, $p = 0.157$) (Fig. 2). As assessed with regard to the mean duration of larval (feeding) instar, each larva consumed a mean of 0.0038 g of dry muscle per day. The control experiment (without larvae) showed a weight loss of the dry piece of meat that was close to zero, with a decrease of only 0.34 g during the entire experiment.

3.2. Maxillae and mandibles defleshing

We observed a total removal of the flesh and skin on the maxillae and mandibles in a maximum of 22 days (Figs. 3 and 4). The jaws used for this study ranged from 116 to 253 g prior to the experiment, and from 83 to 192 g after cleaning by the larder beetles. The total weight loss ranged from 23.9 (A) to 38.5 (B), with a mean of 30.2 ± 6.8% of the initial weight. Variability was mainly due to the initial decomposition/drying stage of the samples and the extent of excision from the cadaver. In contrast, the control mandible (without larder beetles) only lost 19% of its initial weight. The statistical comparison of the theoretical (estimated from the control) and observed weight loss indicates a significant effect of larder beetle feeding on the total weight loss (χ^2 test, $\alpha = 0.05$, $p < 0.0001$).

Regarding the kinetics of weight loss, the first step was a rapid drying and it occurred during the first 5 days (see the control in Fig. 3). The action of the larder beetles then became visible, with a slower phase of weight loss characterised by visible defleshing (Fig. 3). In all cases, the larder beetles completely removed the dry tissues, leaving clean and bare bones (Fig. 4).

Table 1
Detailed information of the 7 samples defleshed by *Dermestes haemorrhoidalis*. md is used for mandibles and mx for maxillas. PMImax is the time between the last time the victim was seen alive and the discovery of the remains.

Sample	Sex	Age (years)	Type	Weight before (g)	Weight after (g)	PMImax (days)	Corpse location	Cause of death
A	F	51	md + mx	116.4	88.6	2	House	Burning
B	F	40–65	md + mx	135.4	83.3	Unknown	Forest	Unknown
C	M	64	md + mx	157.8	105.6	211	Apartment	Suicide by gunshot
D	F	44	md + mx	200.8	151.8	252	Forest	Suicide by hanging
E	M	39	md + mx	208.9	131.4	164	Apartment	Suicide by gunshot
F	M	73	md + mx	253.8	192.2	41	Garden	Suicide by hanging
Control	M	21	md	197.5	159.9	63	Garden	Homicide by blunt trauma

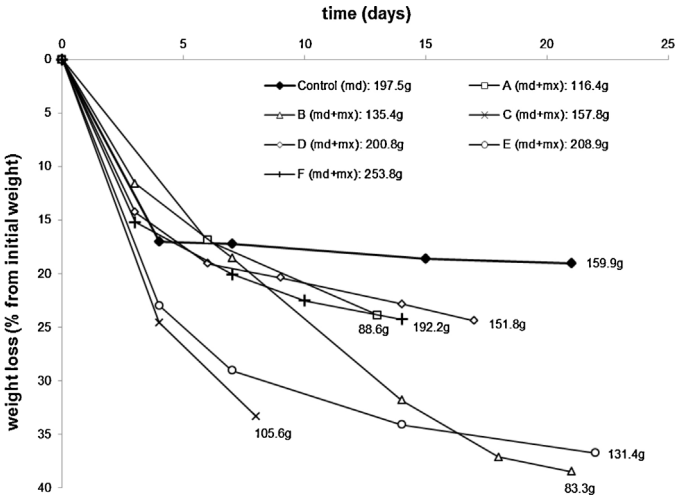

Fig. 3. Weight loss of human jaws samples (md: mandible, mx: maxillas) during larder beetles feeding (*Dermestes haemorrhoidalis*). The mandibles and maxillae, sampled for victim identification, were placed in a dermestarium with adults and larvae. Total defleshing occurs in less than 25 days. Total weight loss ranged from 24 to 38.5% of initial weight. Regarding control experiment (mandible without larder beetles), weight loss was only due to drying and did not exceed 19% of the initial weight.

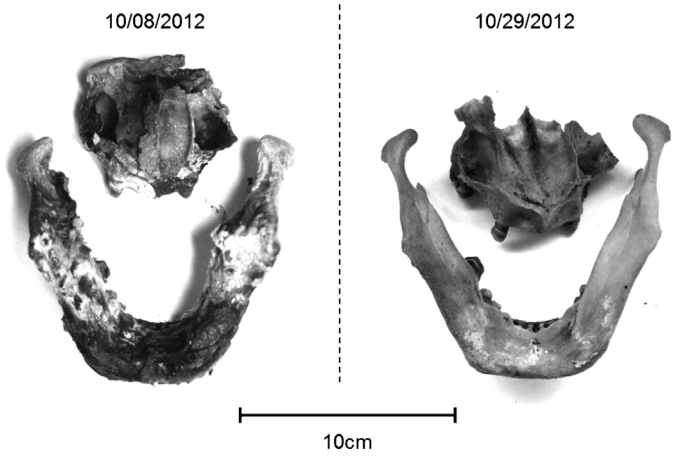

Fig. 4. Picture of mandible and maxilla before (left) and after (right) defleshing by *Dermestes haemorrhoidalis*. Experiment B, initial weight: 135.4 g, final weight: 83.3 g, time = 20 days.

4. Discussion

Modern imaging tools are powerful methods to analyse human forensic mandible or maxilla samples. However, these are expensive, only available in some laboratories and, due to their cost and limitations, cannot fully substitute direct observations. Accordingly, the cleaning of forensic samples is necessary most of the time. Although simmering and the use of detergent or bleach are inexpensive, these techniques require handling and are not DNA safe [1–9]. Lastly, the use of scalpels or cleaning scissors to remove soft tissues can create bone artefacts similar to *antemortem* lesions.

The data reported in this study clearly show the ability of *D. haemorrhoidalis* to deflesh human remains. At 25 °C, a dermestarium population of 100 ± 50 adults and 100 ± 50 larvae fully cleaned human jaws in 2 weeks, a duration that can be regarded as long within a forensic context and compared to other methods. However, according to larval feeding experiments, the number of larvae can be adapted to the quantity of the muscles to be defleshed and the time available. Indeed, our feeding experiment results provide a per-larva consumption rate that can be used to adjust the defleshing setup. For example, a bone sample including 25 g of dry muscle (i.e. approximately 100 g of fresh muscle) would be completely defleshed by 500 larvae in 2 weeks or by 1000 larvae in a single week. As the breeding of *D. haemorrhoidalis* is simple, inexpensive and does not require much time or skills, any lab can maintain a colony of hundreds of individuals. Adults can be obtained from field trapping, and starter kits can even be found on the Web. Furthermore, contrary to other defleshing methods, only a few human actions are needed during the cleaning process: handling is limited to placing and removing the bones from the dermestarium. From this perspective, the use of larder beetles can be regarded as a time-saving method.

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