Blaptica dubia Serville (Blattodea, Blaberidae) a biodeteriorating agent of photographic materials

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Abstract

We report results of a study carried out to investigate the damage that *Blaptica dubia* Serville (Blattodea, Blaberidae) could cause to various kinds of photographic materials, drawn from a range of historical periods. The damages were expressed in terms of percentage of eroded weight. The overall objective was to identify the most easily damaged materials among the photographic supports which, because made of both organic and inorganic materials of natural and synthetic origin, are easily subject to biodeterioration. The results revealed that tested materials showed different vulnerability, confirming *B. dubia* as a serious biodeteriorating agent. These insects are able either to cause marked erosions to photographs and to cause unaesthetic alterations such as unsightly stains due to their excretions (excrement and/or regurgitations). In preservation environment, control of cockroaches is mainly realized using modified atmospheres, pesticides, traps, baits and gel baits. In this area radiation technologies have found a new impulse so that they can be considered an alternative method to disinfest/disinfect because of their well-known physical properties to penetrate materials, without noticeably altering chemical-physical characteristics of substrate. The absence of induced radioactivity as well as of chemical residues, enables handling of irradiated materials immediately after process, without any risks to operators, environment and users.

Keywords: biodeterioration, *Blaptica dubia*, photographs material, damage, cultural heritage

1. Introduction

Insects (booklice, carpet beetles, clothes moths, cockroaches, silverfish, termites, and woodworms) are an important group of biodeteriogens for materials stored in museums, archives and libraries since they can cause damage such as holes, burrows, erosion, and various unsightly stains. In order to set up an appropriate Integrated Pest Management (IPM) program against insects that may be found in storage environments, it is important to know both the different stored heritage susceptibility to attacks of different pests and the damage inflicted. It is often possible, within some limits, to identify specific insect pests responsible for deterioration. Cockroaches often cause serious damage to papery materials. In this work we present the results obtained from examining samples of different photo typologies widely distributed in the world and which date from a range of historical periods.

2. Materials and Methods

2.1. Entomological test

The orange-spotted cockroach, *Blaptica dubia* (Serville) (Blaberidae, Blattodea) (Fig. 1), was

chosen to carry out these experiments. *B. dubia* is a medium-sized species (around 4.0-4.5 cm) with sexual dimorphism: adult males have full wings covering the body (although they rarely fly) while females have only rudimentary forewings (corresponding to a fourth of the body length) and lack the muscles required to fly. Adult coloration ranges from dark brown to black with lighter orange spot/stripe sometimes visible only in bright light. This can slightly differ from one colony to another, in relation to environment and diet conditions. *B. dubia* is ovoviviparous, producing live young ranging from 20 to 40 nymphs per month under suitable conditions. Its ideal temperature range is 24-35°C: it does not breed below 20°C and does not moult successfully when the humidity values are too low. These insects are very widely distributed and considered particularly harmful to library and archival heritage, since they can erode and leave stains (deriving from their bodily excretions) on the materials they come into contact with. Moreover they can cause public health problems such as allergies, asthma and sometimes even transmit infective diseases. Low numbers of cockroaches can produce significant amounts of allergens that often remain longer than 6 months, even with aggressive cleaning (Eggleston, 2003). In addition Brenner (1995) and Baumholtz et al. (1997) have provided extensive reviews of literature on the pathogens associated with cockroaches, including viruses, bacteria, fungi and molds.

2.2. Experimental test

In order to evaluate damage caused by *B. dubia* and thus the vulnerability of the different sample typologies, the photos were singly placed directly on the bottom of boxes in which the insects were bred at temperature ranging from 27 to 30°C, and relative humidity between 45% and 75%. In each box 20 specimens, divided into adult males (3), females (7) and nymphs (10), were bred. During the experiment, number and the stage of insects in the different boxes was kept rigorously constant, removing new-born individuals and replacing any dead specimens. The insects were fed with minimal food (in pellet form; slices of apple were included in the minimal diet, too) in order to induce them to eat the photographic samples as a nutritional supplement. The samples, before being individually inserted into boxes (the experimental phase lasted four weeks) were weighed every week, then scanned using digital technology. The erosion degree was calculated by noting weight differences in photos over a four week period. Recorded values were each the mean values of five different samples for each photo typology.

2.3. Photographic samples

Two groups of photographic prints were chosen: I) photos without secondary support (i.e. mount cardboard) in order to avoid any possible interference caused by components used in the mounting process, such as adhesives with erosive action of insects. It consisted of: albumen prints dating from the late 19th century **(A)**; silver gelatin prints dating from the late 19th century **(G**); photomechanical prints (collotype) dating from the early 20th century **(C**); chromogenic colour prints dating from the 1960s **(CG**); chromogenic colour prints (resin coated) dating from the 1990s **(CGrc**). II), and photos provided with mount cardboard. It consisted of: albumen prints dating from the late 19th century **(Am**); silver gelatin prints dating from the early 20th century **(Gm**); photomechanical prints (offset) dating from the early 20th century **(Pm**). All samples, originating from private collections of the authors, were free from stains and/or erosions attributable to biological deterioration.

Figure 1 *Blaptica dubia*: colony (left); male, female and nymph (right).

3. Results and Discussion

A visual inspection showed all samples were damaged by erosions and stains due to cockroach excretions (excrement and/or regurgitations). The most significant images are presented below. Because of different weights and dimensions of the samples, it was decided to quantify damage as percentage of eroded weight in order to better compare the results. Table 1 and 2 show the weight in grams before and after four weeks under exposure to *B. dubia* specimens and percentages of the eroded material, both for sample without mount cardboard and samples provided with mount cardboard.

Figure 4 reports for the two groups of photos the respective weight eroded percentages average and standard deviations. Data revealed a variability among the eroded percentages in the different material typologies. With reference to the first group, (without mount cardboard) the photomechanical prints (collotype) (**C**) and the albumen prints (**A**) were more palatable to the cockroaches in comparison to the other photo typologies and in particular to the chromogenic colour prints (resin coated) (**CGrc**). In the second group (with mount cardboard) the photomechanical prints (offset) (**Pm**) and albumen prints (**Am**) resulted in more erosion than the silver gelatin prints (**Gm**). The damage is located mainly on the image layer, perhaps due to the presence of glue used to adhere primary to secondary support. Probably the greatest resulting thickness may facilitate the insect to practice a superficial erosion.

Generally, obtained results confirm that cockroaches are harmful biodeteriorating agents since they are able to feed on photographic materials (potentially they can completely destroy them), as well staining them due to the habit of regurgitating food and leaving physiological excretions on the object surface (Adamo et al., 2009, 2011a, 2012; Ruschioni et al., 2009). The damages observed in tested samples manifest themselves as erosions of variable dimensions and depths, and stains that are usually elongated and brown in color. The erosions started at the photographs edges and moved inwards; however, eroded areas were also found in central surfaces of some prints (**Gm** and **Am**) destroying much of the layer image.

Table 1 Weight in grams at the beginning of the experiment (time 0) and after 4 weeks under exposure to *B. dubia*, and percentage of eroded material (samples without mount cardboard).

Types of photographic prints	Sample	Starting weight (g)	Weight after four weeks (g)	% eroded by *B. dubia*
A - albumen prints	1 A	3.53	3.23	850
	2 A	3.85	3.70	3.90
	3 A	2.80	2.50	10.71
	4 A	4.88	4.30	11.89
	5 A	9.02	8.70	3.55
G - silver gelatin prints	1 G	1.27	1.27	0.00
	2 G	1.21	1.20	0.83
	3 G	1.60	1.60	0.00
	4 G	2.01	1.98	1.49
	5 G	1.27	1.27	0.00
C – photomechanical prints (collotype)	1C	3.56	1.40	60.67
	2C	3.39	3.25	4.13
	3C	3.59	2.95	17.83
	4C	3.75	2.75	26.67
	5C	3.89	3.35	13.88
CG - chromogenic colour prints	1CG	2.68	2.60	2.99
	2 CG	2.76	2.70	2.17
	3 CG	2.68	2.54	5.22
	4 CG	2.70	2.63	2.59
	5CG	2.91	2.86	1.72
CGrc - chromogenic colour prints (resin coated)	1 CGrc	3.58	3.54	1.12
	2 GCrc	3.52	3.47	1.42
	3 CGrc	3.67	3.65	0.54
	4 CGrc	4.45	4.42	0.67
	5 CGrc	3.65	3.63	0.55

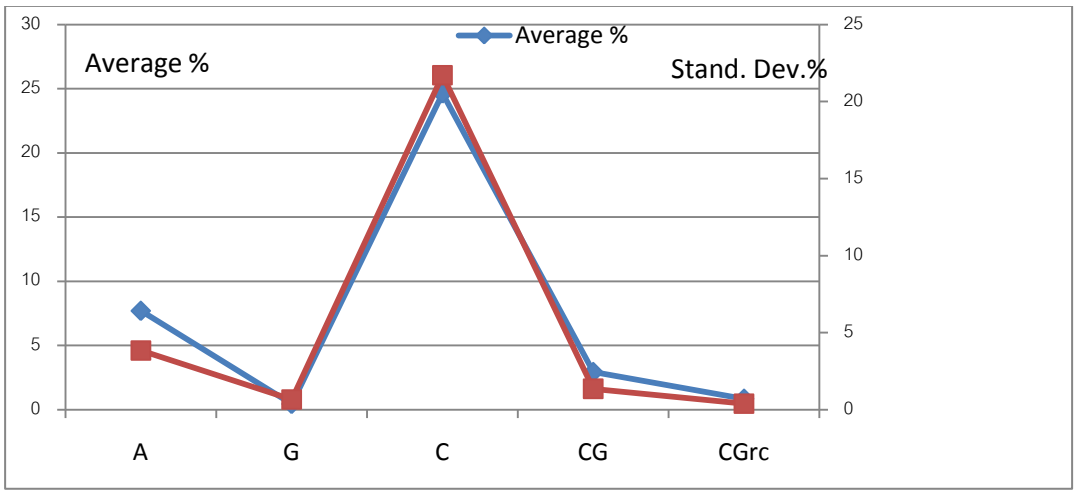


Figure 2 Weight eroded percentages average and standard deviation (samples without mount cardboard).

Table 2 Weight in grams at the beginning of the experiment (time 0) and after 4 weeks under exposure to *B. dubia*, and percentage of eroded material (samples with mount cardboard).

Types of photographic prints	Sample	Starting weight (g)	Weight after 4 weeks (g)	% eroded by *B. dubia*
Am – albumen prints with cardboard mount	1 Am	15.60	14.17	9.17
	2 Am	15.31	14.26	6.86
	3 Am	14.61	13.46	7.87
	4 Am	17.54	15.94	9.12
	5 Am	15.24	13.54	11.15
Gm- silver gelatin prints with cardboard mount	1Gm	9.15	8.95	2.19
	2Gm	12.03	11.78	2.08
	3Gm	20.60	19.30	6.32
	4Gm	10.28	10.06	2.15
	5Gm	7.37	6.67	9.38
Pm - photomechanical prints (offset) with cardboard mount	1Pm	15.30	13.69	10.52
	2 Pm	15.50	14.28	7.87
	3 Pm	16.79	15.00	10.66
	4 Pm	16.51	14.96	9.39
	5 Pm	16.33	15.30	6.31

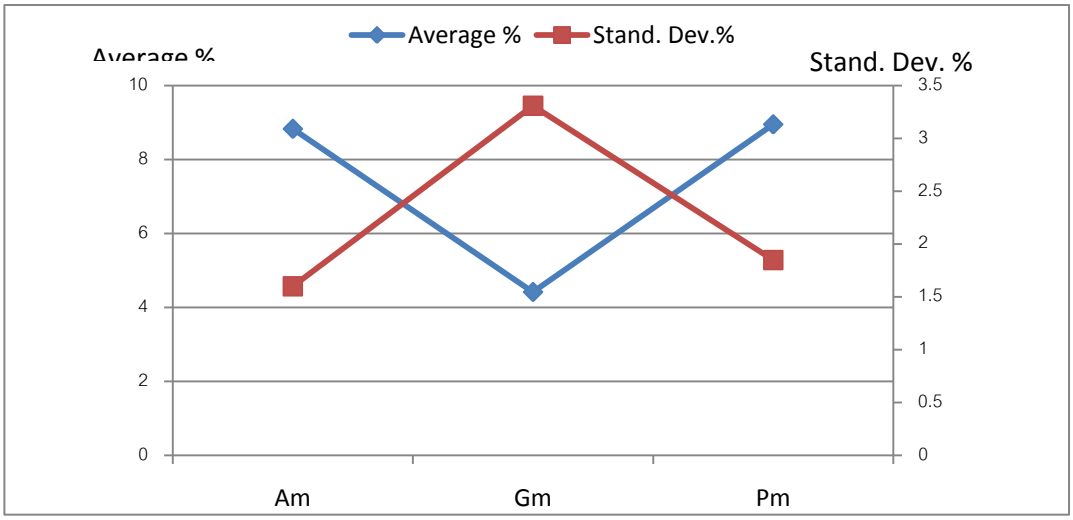


Figure 3 Weight eroded percentages average and standard deviation (samples with mount cardboard).

Examining damage expressed as percentage of weight loss, after 4 weeks, the value can vary from a minimum of 0 in class **G** (samples 1, 3, 5 of silver gelatin prints) to a maximum of 60.7% of **C** (sample 1 of photomechanical prints-collotype). The resin coating (i.e. plastification) seemed to act as a deterrent, giving a protective effect to **CGrc** (chromogenic colour prints-resin coated) in fact their eroded percentages result very low. Furthermore it is interesting to note how the **G** prints, despite not being resin coated, appear to be the materials that are least susceptible to erosion.

With reference to the second group of photos, although albumen is considered a material very sensitive to biodeteriogens, **Am** prints seemed to show some particular differences when compared to **Pm** and **Gm**. The results confirm **Gm** to be less vulnerable to *B. dubia* despite the fact that sample **Gm** 5 shows erosions of 9.38%. This type of binder could be less attractive (Adamo et al., 2012).

4. Main methods to control cockroaches in preservation environments

4.1. Modified atmospheres

This technology has been widely used in the food industry and now many museums have adopted the technology as well. Generally modified atmospheres can be applied in a traditional fumigation chamber or in a portable fumigation bubble, but it is necessary to pack materials in low-permeability plastic bags in order to maintain the desired atmosphere. Two or three weeks under exposure are considered sufficient to kill all stages and species of insect pests when operating at 25°C and above but longer periods may be required for lower values; a temperature under 20°C is not recommended. When small objects have to be disinfested, it is possible to seal them in bags together with oxygen scavenger of gaseous O_2 (the best known is Ageless®). The materials to be treated have to be enclosed in a well-sealed O_2-barrier packages (polyethylene film). Three weeks at 25°C are sufficient to kill all stage of insect pests (Pinniger, 2001; Trematerra and Pinniger, 2014).

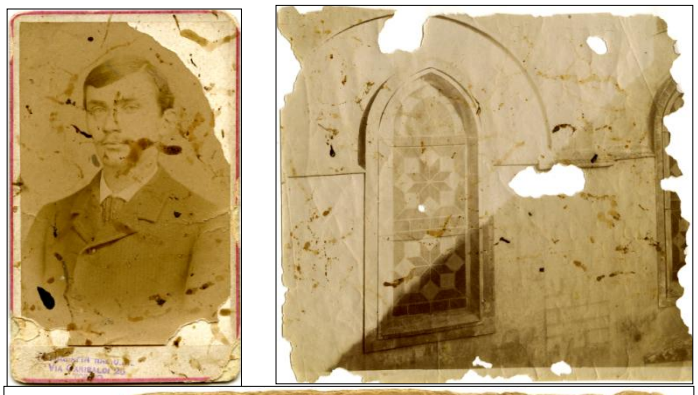
4.2. Pesticides

Dry powder or aerosol formulations are mostly useful for treatment of hollow walls, cracks and crevices, i.e. mainly cockroach hiding places that cannot easily be reached. Synthetic pyrethroids (deltamethrin, permethrin) have been used because of their good residual life and flushing ability. Other effective insecticides are: organophosphates (diazinon that provides both vapor and contact action, chlorpyrifos trade name Dursban®), carbamates (bendiocarb trade name Ficam®, propoxur trade name Baygon® and Raid® are probably the insecticides most commonly used to control cockroaches).

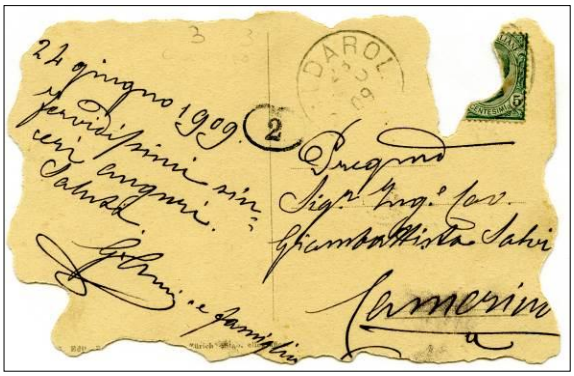
4.3. Traps, bites and gel bites

Traps are usually placed on the floor, and most importantly in corners. Traps need to be checked at regular intervals. Dust can build up on the adhesive and render it ineffective. Sometimes the attractive action of the traps is enhanced by the addition of synthetic pheromones. Pheromone traps are one of the most useful new tools for pest management in museums (Trematerra, 2012). Commercially the most widely used aggregation pheromones are associated with poisoned baits (bait-stations). Bait containing an attractive food base along with an insecticide, are the primary pesticides used to treat cockroach infestations. However female cockroaches, with egg cases (ootheca) feed very little and avoid open spaces so they are less likely to be affected by a bait. The advantage of bait stations is the possibility to confine insecticides to a small area rather than to disperse them.

Bumen print with mount cardboard dating from late 19th century (**Am**); albumen print without mount cardboard dating late 19th century (**A**)



Photomechanical print (offset) dating from the early 20th century (**Pm**)



Photomechanical print (collotype) dating from the early 20th century (l *recto*, r *verso*) (**C**)

Chromogenic colour prints dating from the 1960s (**CG**)

Figure 4 Photographic materials damaged by *Blaptica dubia*.

Gel baits can be very active for crack and crevice treatments but their action is most effective in indoor areas. Available commercial baits may contain abamectin, boric acid, fipronil, hydramethylnon, indoxacarb or imidacloprid mixed with a food base. Their effectiveness varies according to cockroach species. Fipronil immediately kills the individuals that have ingested it and, due to the habit of these insects of feeding on feces and carcasses the insecticide can be transferred. For prophylactic treatments in areas subject to re-infestation, it is advisable to use gel baits based on imidacloprid since this product has a strong insecticidal action towards nymphs. Three general strategies are applicable for resistance management: insecticide rotations, insecticide mixtures and IPM program. Generally cockroaches do not remain inside infested materials but if a serious infestation occurs, direct treatments such as ETO or gamma rays can be required.

4.4. Gamma radiation

To date, disinfestation of biodeteriorated material is usually performed with ETO, but because of its toxicity, environmental concerns, and in some case even for cultural heritage itself (Lindblom Patkus, 2014), this fumigant has been banned in many countries. Hence, radiation is receiving increased interest. Gamma radiation is able to kill living organisms by the irreversible denaturation or cleavage of nucleic acids, devitalizing simultaneously and indiscriminately all living organisms present on and inside the treated material. If properly applied, gamma radiation can be used to disinfest/disinfect cultural heritage artefacts since it does not cause any noticeably chemical-physical alterations of the substratum. The low radiation energy and the complete absence of chemical residues in the irradiated goods allow direct and immediate handling after treatment with minimal risks. This process allows treatment of large amounts of materials in a short time. It could be used to stop the biodeterioration processes in waterlogged materials or to disinfect artefacts contaminated with animal excretions (cockroaches, mice, birds). Many experimental trials have been carried out at the laboratories of ENEA Casaccia (Italy) to identify any damage caused by radiation to cellulose, permanent paper, photographic paper, glossy paper and colour fastness (Adamo et al., 1998, 2001, 2011b, 2013a,b; Rocchetti et al., 2002; Baccaro et al., 2013). Results obtained following standard procedures show that gamma radiation, using a suitable dose for an efficient disinfection treatment (up to 10 kGy), does not cause any contra-indication for the material itself. If the aim of the treatment is to eliminate insects at any stage, a dose of < 2 kGy can be used. Trials are in progress to characterize by chemical-physical analysis (FTIR, EPR) gamma radiation effects on some typologies of photographic prints.

5. Conclusions

This study examined a wide range of photographic materials to better characterize damage typologies and to investigate different levels of susceptibility of these vulnerable artefacts when exposed to the action of chewing insects. It provided data for developing strategies aimed at improving preventive conservation of this vulnerable and complex category of documentary cultural heritage. The simple investigation method used in the experimental trials highlights the different vulnerability of tested photographic papers and, since it varies according to pests and constitutive materials of artefacts, a deep knowledge of damage typologies could be useful in creating a database in order to better identify infesting agents. The different amount of eroded material within the same photo typology could be clarified after chemical analysis and supports and further investigation and tests to develop an appropriate strategy under an IPM program.

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