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SHORT NOTE

Solenopsis saevissima (Smith) (Hymenoptera: Formicidae) Activity Delays Vertebrate Carcass Decomposition

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Abstract

Ants are among the insects involved in cadaveric decomposition processes, as they exhibit predatory and necrophagous behavior. Fire ants exhibit an aggressive behavior, which impacts carcass colonization, accelerates or delays the decomposition rates and potentially confounds interpretation of the post-mortem interval. Here, we estimated the effects of *Solenopsis saevissima* (Smith) activity on the decomposition rate in domestic pig carcasses. We placed two pig carcasses close to *S. saevissima* nests, and two other pig carcasses (controls) in other locations 50 m away from the nest. Decomposition processes were delayed by at least three days for carcasses on the nest compared to those without direct exposure to ants. Our results showed that predatory activity of *S. saevissima* interfered with carcass colonization by scavenger insects, functioning as an ecological barrier to the establishment of immature Diptera. Such results highlight the importance of considering ecological processes that may interfere with mechanisms determining post-mortem intervals.

In addition to climatic conditions, such as temperature and rainfall, the presence of and ecological interactions between insect guilds play a key role in the decomposition rate of vertebrate carcasses (Simmons et al. 2010; Santos & Alves, 2016). Ants (Hymenoptera: Formicidae) are among the insects involved in decomposition processes, and exhibit both predatory and necrophagous behavior (Carvalho et al. 2004; Cruz & Vasconcelos, 2006). Furthermore, they interact with other arthropods around decomposing bodies (Rámon & Donoso, 2015).

Due to their aggressive behavior, ants from the genus *Solenopsis* can reduce the number of eggs and larvae in cadaver-occupying species, impacting carcass colonization (Stoker et al., 1995) and either accelerating or delaying the rate of decomposition (Andrade-Silva et al. 2015). Therefore, these ants may potentially confound interpretation of the post-mortem interval (PMI).

Despite their relevance in forensic entomology, little is known about the effects of *Solenopsis* spp. on the process of cadaveric decomposition. Most studies conclude that these ants alter insect succession patterns and decomposition processes, but do not indicate specifically how these factors are altered (Zara & Caetano, 2010; Andrade-Silva et al. 2015; Maciel et al. 2015). Here, we analyzed qualitative effects of *Solenopsis saevissima* (Smith) presence on decomposition rates of domestic pig (*Sus scrofa* L.) carcasses. Also, we sought to better understand the ant interactions with other insects, as well as the presence of post-mortem lesions throughout the decomposition process. This information may help to increase the accuracy of PMI estimates, thereby improving the quality of crime evidence based on forensic entomology.

The study was conducted between January and February 2013 - at the beginning of the rainy season, in an urban remnant of Amazon forest located within the Universidade

Federal do Maranhão (02° 33' 36" S, 44° 18' 33" W). This area has an altitude of less than 100 m a.s.l., climate tropical hot and humid, annual rainfall between 1,900 and 2,200 mm and an average annual temperature above 26 °C (Alvares et al., 2013). The environmental characteristics indicate high degree of anthropogenic intervention in the original vegetation (ICMBIO, 2014), which has been reduced to low capoeira due to the expansion of the university's campus.

Four domestic pigs weighing between 20 and 25 kg were sacrificed from close range shot (<30cm; pistol .40) to the head (carried out by a Criminal Examiner). We placed two carcasses (10 m apart) close to *S. saevissima* nests, and the other two (without exposure) were placed about 50 m from the other carcasses to guarantee the independence of the samples. Carcasses were observed daily between the hours of 12:00 and 13:00. Decomposition phase was determined following classifications by Payne (1965): fresh (S1), bloated (S2), active decay (S3), advanced decay (S4), and dry/remains (S5).

Throughout the study, the carcasses were protected from large animals by metal cages surrounded by wire mesh (5 cm diameter) installed into the ground. The ants were obtained from carcasses by active collection. Identification of subfamily and genera followed Baccaro et al (2015) and species were confirmed by the Laboratório de Mirmecologia (CPDC) at the Centro de Pesquisa da Lavoura Cacaueira (CEPLAC) in Bahia, where voucher specimens were deposited.

During stage S1, we found little odor caused by the decomposition of the carcasses and observed a low number of ants in the first hours of decomposition, mainly for the carcasses unexposed to the nests. In S2, we observed marks on the carcasses resulting from the activity of *S. saevissima*, which also presented eggs and small and punctual (mouth and muzzle) masses of Diptera larvae. The S3 phase was characterized by masses of large larvae throughout the carcass, except for those exposed to the ant nests, where mass was very reduced. In addition to the strong odor of decomposition at this stage, liquids resulting from this process were perceptible around the carcasses, especially for the carcasses not exposed to the *S. saevissima* nests. The S4 phase was characterized by a great reduction in the resource offered by the carcass and the beginning of its skeletonization. There was also a decrease in the size of larval mass seen in the previous phase. In the S5 phase we observed an absence of larvae mass, and completely dry and fragmented carcasses, with exposed bones.

We recorded differences in the duration of the decomposition phases between carcasses exposed to ant nests and controls. The ant-exposed carcasses lasted three additional days in the S3 and S4 phases, and more than 10 days in the final phase (Fig 1). *Solenopsis saevissima* displayed the following behaviors on the carcasses: production of tissue lesions visible in early decomposition (Fig 2-A); predation on dipteran eggs, larvae, and adults (Figs 2 B-D); and feeding on

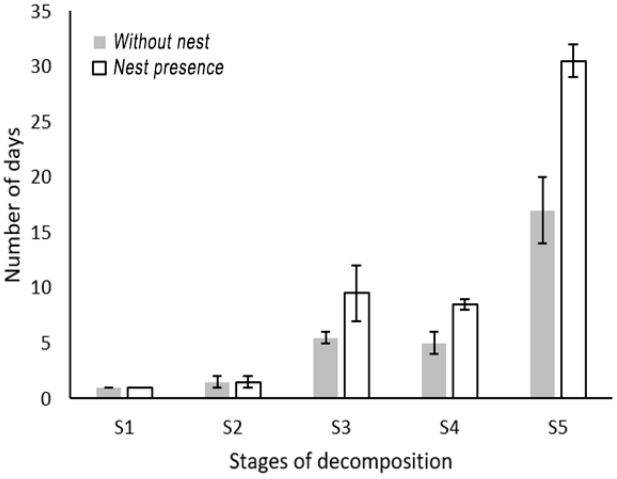

Fig 1 - Average duration (number of days) of decomposition phases for domestic pig carcasses with and without exposure to *Solenopsis saevissima* nest in an urban Amazon forest remnant in São Luís, Maranhão, Brazil. S1: Fresh; S2: Bloated; S3: Active decay; S4: Advanced decay; S5: Dry and remains.

exudates released by the carcass. These ant behaviors likely led to differences in fly larval biomass between experimental (carcasses on the ant nest) and control groups (Figs 2E-F). Although in very small densities, other ant species such as *Camponotus rufipes* (Fabricius), *Dorymyrmex brunneus* Forel, *Ectatomma brunneum* Smith and *Pheidole synarmata* Wilson, were collected from the carcasses.

Carcasses are a limited and ecologically expensive resource, because many organisms (e.g. flies, beetles, bees, ants, and others) compete for them (Noll et al., 1996; Alves et al., 2014; Santos et al., 2014). The presence of *S. saevissima* reduces fly larval populations and makes oviposition by adults more difficult, which reduces colonization and can decrease associated entomofauna, therefore, decreasing the rate of decomposition (Wells & Greenberg, 1994; Moura et al., 2005). When acting as necrophages, ants, such *Solenopsis*, cause lesions that can lead to errors in criminal investigations (Patel, 1994). In the short term these lesions can darken, which may lead to the diagnosis of pre-mortem mutilations, thereby compromising interpretations by crime experts.

The higher larval biomass from the control carcasses suggests that the end of the S3 phase is strongly influenced by ecological factors, specifically by the activity of fly larvae. Consequently, factors that prevent or delay oviposition by adult flies or hatching of immatures can alter the timing of carcass decomposition. Some studies have emphasized the possibility of variation in decomposition rates and insect succession patterns in the same location (Shean et al., 1993; Joy et al., 2006; Sharanowski et al., 2008; Santos & Alves, 2016), as well as visible lesions in the first few weeks of decomposition (Campobasso et al., 2009). Although we did not observe them here, two genera of ants, *Camponotus* and *Pheidole*, have been known to remove eggs, larvae, and pupae

Fig 2 - Marks (A), predation to eggs (B), larvae (C) and adults (D) of Diptera caused by *Solenopsis saevissima* activity and difference in mass of fly larvae present in *Sus scrofa* carcasses with (E) and without (F) exposure to *Solenopsis saevissima* nest.

from decomposing carcasses (Barros et al., 2008).

Our results showed that the predatory activity of *S. saevissima* interfered with carcass colonization of flies, by effectively functioning as an ecological barrier for the establishment of immatures. As a consequence, the first stages of decomposition were extended by three days, when ants were present on carcasses. We emphasize the importance of considering ecological processes (e.g. interspecific interactions) and abiotic factors on decomposition when estimating the postmortem interval. Studies of this nature will limit underestimation and improve the accuracy of PMI estimates, as well as reinforce the importance of investigating ant behavior on carcasses within the field of forensic entomology.

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References

Alvares, C.A., Stape, J.L., Sentelhas, P.C., Gonçalves, J.L.M., Sparovek, G. (2013). Köppen's climate classification map for Brazil. Meteorologische Zeitschrift, 22: 711-728. doi: 10.1127/0941-2948/2013/0507

Alves, A.C.F., Santos, W.E., Farias, R.A.C.P., Creão-Duarte, A.J. (2014). Blowflies (Diptera, Calliphoridae) associated with pig carcasses in a Caatinga area, northeastern Brazil. Neotropical Entomology, 43: 122-126. doi: 10.1007/s13744-013-0195-4.

Andrade-Silva, J., Pereira, E.K.C., Silva, O., Santos, C.L.C., Delabie, J.H.C., Rebêlo, J.M.M. (2015). Ants (Hymenoptera: Formicidae) associated with pig carcasses in an urban area. Sociobiology, 62: 527-532. doi: 10.13102/sociobiology.v62i4.795

Baccaro, F.B., Feitosa, R.M., Fernandez, F., Fernandes, I.O., Izzo, T.J., Souza, J.L.P., Solar, R. (2015). Guia para os gêneros de formigas do Brasil. Manaus: Ed. INPA, 388 p. doi: 10.5281/zenodo.32912

Barros, A.S., Dutra, F., Ferreira, R. (2008). Insects of forensic importance from Rio Grande do Sul state in southern Brazil. Revista Brasileira de Entomologia, 52: 641-646.

Campobasso, C.P., Marchetti, D., Introna, F., Colonna, M.F. (2009). Postmortem artifacts made by ants and the effect of ant activity on decompositional rate. The American Journal of Forensic Medicine and Pathology, 30: 84-87. doi: 10.1097/PAF.0b013e318187371f

Carvalho, L.M.L., Thyssen, P.J., Goff, M.L., Linhares, A.X. (2004). Observations on the succession patterns of necrophagous insects on a pig carcass in an urban area of Southeastern Brazil. Anil Aggrawal's Internet Journal of Forensic Medicine and Toxicology, 5: 33-39.

Cruz, T.M., Vasconcelos, S.D. (2006). Entomofauna de solo associada à decomposição de carcaça de suíno em um fragmento de mata atlântica de Pernambuco, Brasil. Biociências, 14: 193-201.

ICMBio. Instituto Chico Mendes de Conservação da Biodiversidade. 2014. Encarte 3. Available at: http://www.icmbio.gov.br/portal/images/stories/imgs-unidades-coservacao/05ENCARTE3.pdf

Joy, J.E., Liette, N.L., Harrah, H.L. (2006). Carrion fly (Diptera: Calliphoridae) larval colonization of sunlit and shaded pig carcasses in West Virginia, USA. Forensic Science International, 164: 183-192. doi: 10.1016/j.forsciint.2006.01.008

Maciel, T.T., Castro, M.M., Barbosa, B.C., Fernandes, E.F., Santos-Prezoto, H.H., Prezoto, F. (2015). Foraging behavior of fire ant *Solenopsis saevissima* (Smith) (Hymenoptera: Formicidae) in *Felis catus* Linnaeus (Carnivora: Felidae) carcass. Sociobiology, 62: 610-612. doi: 10.13102/sociobiology.v62i4.736

Moura, M.O., Carvalho, C.J.B., Monteiro-Filho, E.L.A. (2005). Heterotrophic succession in carrion arthropod assemblages. Brazilian Archives of Biology and Technology, 48: 473-482.

Noll, F.B., Zucchi, R., Jorge, J.A., Mateus, S. (1996). Food collection and maturation in the necrophagous stingless bee, *Trigona hypogea* (Hymenoptera: Meliponinae). Journal of the Kansas Entomological Society, 69: 287-293.

Patel, F. (1994). Artefact in forensic medicine: postmortem rodent activity. Journal of Forensic Sciences, 39: 257-260.

Payne, J.A. (1965). A summer carrion study of the baby pig *Sus scrofa* Linnaeus. Ecology, 46: 592-602. doi: 10.2307/1934999

Rámon, G., Donoso, D.A. (2015). The role of ants (Hymenoptera: Formicidae) in Forensic Entomology. Revista Ecuatoriana de Medicina Y Ciencias Biológicas 36: 19-26.

Santos, W.E., Alves, A.C.F. (2016). Registro de besouros (Coleoptera) em carcaça bovina e rápida decomposição sob condições naturais em ambiente semiárido, nordeste do Brasil. Entomotropica, 31: 105-108.

Santos, W.E., Carneiro, L.T., Alves, A.C.F., Creão-Duarte, A.J., Martins, C.F. (2014). Stingless bees (Apidae: Meliponini) attracted to animal carcasses in the Brazilian dry forest and implications for forensic entomology. Sociobiology, 61: 490-493. doi: 10.13102/sociobiology.v61i4.490-493.

Sharanowski, B.J., Walker, E.G. Anderson, G.S. (2008). Insect succession and decomposition patterns on shaded and sunlit carrion in Saskatchewan in three different seasons. Forensic Science International, 179: 219-240. doi: 10.1016/j.forsciint.2008.05.019

Shean, B.S., Messinger, L., Papworth, M. (1993). Observations of differential decomposition on sun exposed v. shaded pig carrion in coastal Washington State. Journal of Forensic Sciences, 38: 938-49.

Simmons, T., Adlam, R.E., Moffatt, C. (2010). Debugging decomposition data-comparative taphonomic studies and the influence of insects and carcass size on decomposition rate. Journal of Forensic Science, 55: 9-13. doi: 10.1111/j.1556-4029.2009.01206.x

Stoker, R.L., Grant, W.E., Vinson, S.B. (1995). *Solenopsis invicta* (Hymenoptera: Formicidae) effect on invertebrate decomposers of carrion in central Texas. Environmental Entomology, 24: 817-822. doi: 10.1093/ee/24.4.817

Wells, J.D., Greenberg, B. (1994). Effect of the red imported fire ant (Hymenoptera: Formicidae) and carcass type on the daily occurrence of post feeding carrion-fly larvae (Diptera: Calliphoridae, Sarcophagidae). Journal of Medical Entomology, 31: 171-174.

Zara, F.J., Caetano, F.H. (2010). Mirmecologia e formigas que ocorrem em carcaças. In Gomes, L. (Ed.), Entomologia forense: novas tendências e tecnologias nas ciências criminais. (pp. 237-269). Rio de Janeiro: Technical Books