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Allergenic Properties of Hair Portion of House Dust Mites

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ABSTRACT

Aims: to propose the house dust mite's hair or setae contribution of causing allergy in vulnerable people, and starting with its biological positioning among other insect.

Discussion: House dust mites (HDM) are allergogenic arthropods for atopic individuals. The most common species of HDM are *Dermatophagoides farinae*, *Dermatophagoides pteronyssinus*, and *Euroglyphus maynei*. with preference to humid, warm and temperate climates, that responsible for allergy episodes in atopic individual. Beside their feces, allergenic properties also found in house dust mites's shed skin and decaying bodies. Along their shedding exoskeleton, its hair or setae perhaps also contributes to or even augment the allergogenic propertis. Insect setae, which are hair-like structures on the insect's body, have a wide range of functions beyond simple sensory perception. These functions include defense, locomotion, camouflage, and pheromone dispersal. In the context of house dust mites, at least there are three condition that might facilitate the setae's potency to cause allergy, including easily to detach, anatomical location and its homeostatic function. Further study need to be conducted in order to explore the mechanism of its setae in causing or at least contributing to its allergogenic properties.

Keywords: setae, sensilla, bristles, allergogenic, sensory, protective, *Dermatophagoides farinae*, *Dermatophagoides pteronyssinus*,

1. INTRODUCTION

House dust mites (HDM or DM) possess allergenic properties [Aggarwal & Senthilkumaran, 2022]. It is a predominant source of indoor aeroallergens [Thao et al., 2023]. Some of the allergic diseases that have been associated with the HDM are allergic rhinoconjunctivitis [Imoto et al., 2024], allergic asthma [Caraballo, 2024], and atopic dermatitis [Bumbacea et al., 2020]. This insects's excrements and body parts contain proteins that act as allergens [Vrtala, 2022], triggering allergic reactions in hypersensitive atopic individuals [Krupka Olek et al., 2024], particularly through inhalation; HDM, either proteolytically active or inactive, acts as an adjuvant favouring allergic reaction to other substance such as egg white [Benedé et al, 2025] a condition of which simultaneous sensitization to two or more allergens occur at the same time [Sideneus et al., 2001].

People are primarily exposed to these allergens by inhaling them when dust is disturbed, such as during bed-making or vacuuming [Wilson & Platts-Mills, 2018]. When inhaled, these allergens can trigger an immune response in sensitive individuals, leading to various allergic symptoms [Thao et al., 2023; Imoto et al., 2024; Caraballo, 2024; Bumbacea et al., 2020].

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Dust mite allergens can persist in the environment, especially in areas with high humidity [Arlan et al., 1999] and dust accumulation in conjugation with lost human epidermis [Strzelczyk, et al., 2020], making them a whole season attention. Avoidance of allergens is actually a recommended environmental method in the prevention of inhaled allergy symptoms [12].

House dust mites produce allergens primarily concentrated in their feces [Rutten, 2018], which contain proteins that are highly allergenic [Rutten, 2018; Tovey et al., 1981]. Dust mite excrements contain undigested food particles and digestive enzymes [Sarwar, 2020; Rutten, 2018; Thomas, 2015; Bessot & Pauli, 2011], which are highly potential to trigger allergic reactions [Miller, 2019]. Their small size facilitates their spread, making them to become airborne effortlessly, and also enabling them to be readily inhaled. These proteins can also be found in their body parts and shed exoskeletons [Aggarwal & Senthilkumaran, 2023, Thomas, 2015].

Beside their feces, allergenic properties also found in house dust mites's shed skin and decaying bodies [Sarwar, 2020; Sidenius et al., 2002]. These allergens can become airborne when disturbed [de Blay et al., 1991] and increased the risk of exposure [Eggleston, 2005] and also inhaled, which can further causing allergic reactions. The body, legs and mouth apparatus actually bear various hairs [Bergmann, 2022], which are differently noticeable in all dust mite species [Sarwar, 2020]. The possible functional significance of the hairs has still debatable to date and this paper aimed to proposed its hair contribution of causing allergy in vulnerable people, and starting with its biological positioning among other insect.

2. SHORT DESCRIPTION ON THE BIOLOGY OF HOUSE DUST MITE

Any attempt to describe the house dust mites would lower than complete without a brief overview of its classification and also its biological positioning relationship to other arthropods. The subphylum Arthropoda is generally classified into four extant subphyla: Chelicerata (arachnids, horseshoe crabs, etc.), Crustacea (crabs, lobsters, etc.), Hexapoda (insects, springtails), and Myriapoda (centipedes, millipedes) [sollai, et al., 2024]. An additional subphylum needed to be mention was the unfortunate extinct subphylum, Trilobitomorpha, includes the trilobites in rock enroll [Chipman & Drage, 2023].

House dust mites are arthropods belonging to the subphylum Chelicerata, class Arachnida, order Acari, suborder Astigmata. Other suborders of mites can be further classified into Mesostigmata, Metastigmata (ticks), Prostigmata, and last but not least Oribatida [Arlan & Platts-Mills, 2001]. The chelicerae that belongs for the house dust mite are pincer-like and armed with both movable and fixed digits [Chang & Kaufman, 2005]. For comparison, other chelicerates have either stylet-like chelicerae adjusted for piercing (eg, spider mites and chiggers) [Mullen & Vetter, 2019] or sickle-shaped chelicerae function in grasping, cutting and also tearing [Schmidt & Melzer, 2024] which dangerously making the host skin's vulnerable (e.g., as the one used by ticks to reach under the host's skin) [Richter, et al., 2013]. In addition to the mites, the subphylum Chelicerata also accommodate such familiar groups as spiders, scorpions, mites, and ticks, as well as an array of bizarre and unfamiliar forms [Sharma, 2018]. On the other hand, some classifications used to group insects, centipedes, and millipedes all belong to the subphylum Uniramia [Ramzan, 2024], but unfortunately this classification is not always universally accepted. But at least on that account, some experts postulate that mites can be considered not intimately related to insects. Mites, while often resembling insects in very basic and general form, exhibit distinct differences in morphology and physiology feature [Chown & Terblanche, 2006]. In particular, guanine is the main nitrogenous waste excreted by arachnids, including mites [Pauli et al., 1988], whereas terrestrial insects excretion largely consists of uric acid [Ren et al., 2022], as a break down of purine. Because of the

85 differences in physiology, some common insecticides and growth regulators applied
86 successfully to control insect populations [Singh & Kumar, 2024] are unfortunately lack in
87 effectivity for controlling dust mite populations [Downing, et al., 1990].

88 in the natural environment, the acari are actually a very variegated group of organisms that
89 have exploited some unusual microenvironments where their adaptations include specialized
90 feeding habits that modify its morphology adaptation [Liu et al., 2021], host's condition
91 [Retzinger & Retzinger, 2024] resistance to harsh conditions [Rojas-Cabeza, et al., 2025], and
92 compensatory behavioral mechanisms to enhance resource utilization [Tian, et al., 2020]. For
93 instance, some species infect:

94 1. human, e.g., inhabit the hair follicles of humans [Smith, et al., 2020] and the human skin
95 due to scabies mites [Paichitrojana, 2022],

96 2. animal, e.g., the nasal passages of birds and mammals [Hilario Perez, 2016], the trachea
97 of insects such as found in ground beetle (Carabidae) [Gudowska, et al., 2016], the skin
98 scales of reptiles [Mendoza-Roldan, et al., 2020], the feathers of birds [Doña, et al., 2019],
99 and the list still continue.

100 3. Plant (as a plant parasites which commonly starts as spontaneous vegetation as reservoir
101 for predatory mites) some of which are major pests for mango [Abo-Shnaf, et al., 2022],
102 apple [Rode, et al., 2024], strawberry [Zhou, et al., 2020], citrus [Affandi & Corpuz-Raros,
103 2005], rice [Kayal, et al., 2021], and the list continue.

104 The abundance and variation of its preference are very enormous. Many species of mites are
105 actually blood- or fluid-feeding ectoparasites of poultry [Ribeiro, et al., 2023], mammals, and
106 reptiles [Wang, et al., 2022] and can transmit diseases, such as Lyme disease (ticks) [Gulia-
107 Nuss, et al., 2016] and scrub typhus (chiggers) [Elliott, et al., 2019]. Some live in root, leave
108 and soil litter [Bluhm, et al., 2019], where they are function as natural predators that play a
109 significant role in soil ecosystems as predators of other soil-dwelling organisms [Beretta, et
110 al., 2022], and also function as trophic interaction with fungal and detritus feeders [Velez, et
111 al., 2018].

112 In the context of our focus, the house dust mites belong to the suborder Astigmata and family
113 Pyroglyphidae [Bergmann, 2022]. Nonetheless, mites belonging to other families are also
114 present in house dust, and they often referred to as "domestic mites" [Cui, 2014] and include
115 mites from the Glycyphagidae [Wurst & Pfister, 1990], Acaridae [Skelton, et al., 2007] and
116 Chortoglyphidae families [National Center for Biotechnology Information, 2025]. Beside that,
117 predatory mites (Cheyletidae) [Zhou, et al., 2022] may also be present in domestic setting.

118 Astigmatid mites are atypical in the condition of lacking well organized respiratory systems
119 and associated external openings for ventilation [Bergmann, 2022]. Even though they are
120 aerobic organisms but unfortunately they don't have specialized organs for gas exchange and
121 apparently exchange O₂ and CO₂ through their general body surface by passive diffusion
122 across their cuticle [Portnoy, et al., 2013]. Anatomically, All mites (Acari) belong to the
123 arthropods (arthropods) and here to the arachnids (Arachnida: Chelicerata), are divided into
124 a variety of orders especially under the aspect of the formation of their respiratory openings:
125 Astigmata (none), Prostigmata (anterior), Cryptostigmata (hidden), Mesostigmata (middle),
126 Metastigmata (posterior). Domestic mites all have well-developed and sophisticated systems
127 of respiration, digestion and water balance, enabling them to live and survive in the various
128 habitats of houses.

129 Astigmatid heteromorphic nymphs also lack a mouth, and so oral feeding is not possible. Still,
130 feeding as a parasite can occur during phoresy via the attachment organ suckers, anus or
131 genital papillae [Sendi, et al., 2025]. Their favourite and primary source of food came ultimately

on human or pets skin scales and other organic detritus that collects in homes [Sarwar, 2020; Bergmann, 2022]. At least there are several species have been found in house dust, three of which are very common in homes worldwide and are the major source of mite allergen [Krzysztof, 2011]. The most common of these species are *Dermatophagoides farinae*, *Dermatophagoides pteronyssinus*, and *Euroglyphus maynei* [Sarwar, 2020], with preference to humid, warm and temperate climates [Gwiazdowicz, 2021].

In tropical setting, the storage mite *Blomia tropicalis* (Family Echymyopodidae) can be an endemic mite in house setting dwellings [Guilleminault & Viala-Gastan, 2017], also along with other Pyroglyphid mites [Sánchez, et al., 2017; Sarwar, 2020]. In addition to the previously mentioned species, other astigmatid mites (storage mites) may be isolated in homes and are a potent source of allergens [Thao, et al., 2023; Krzysztof, 2011]. Most notable are species in the families Acaridae (*Tyrophagus putrescentiae* and *Acarus siro*), Glycyphagidae (*Glycyphagus domesticus* and *Lepidoglyphus destructor*), and Chortoglyphidae (*Chortoglyphus ancutatus*) [Fernández-Caldas, et al., 2007]. Predaceous mites (e.g., Cheyletus spp) [Henszel, et al., 2010] may also be found in homes. The significance of these as sources of indoor allergens [Thao et al., 2023; Aggarwal & Senthikumar, 2023; Bumbacea, et al., 2020; Vrtala, 2022] is yet to be clearly determined.

House dust mites are typically about 0.1–0.4 mm in size, and as a consequence of their small, diminutive size, mites (Acari) are able to exploit specific habitats and ecological niches unavailable to larger arthropods [Mullen & O Connor, 2019]. Storage mites can grow to approximately 0.6 mm in size [Vrtala, 2022] and as their counterparts the house dust mite, both are thus pragmatically unnoticed to the naked eye.

A prominent characteristics of the mites is the extensive abolition of the segmentation of their bodies, a significant reduction in external segmentation, particularly in the adult stage, which is characteristic of arthropods (e.g., insects). As the consequences, the clear boundaries between the head (caput), thorax, and hindquarters (abdomen) is impossible to be delineated [Bergmann, 2022]. Adults and nymphs have four pairs of legs, larvae only three pairs of legs. The legs are composed of six limbs. The basal limb is fused to the body. The soles of the feet have great absorbcency, allowing the mites to hold many times their body weight even on smooth surfaces [Waldvogel, et al., 2025]. The body, legs and mouth apparatus bear numerous hairs, which are differently pronounced in all mite species [Bergman, 2022] and will be briefly discussed in the next section.

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166 3. COMMON FUNCTION OF INSECT'S HAIR

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Hair-like shape and composition are ubiquitous throughout insect's biology properties and frequently function to sense or adjust or even alter interactions with an organism's environment [Seale, et al., 2018]. The universal shape of a hair is basically plains: a cylindrical, straight, long, filamentous structure that originated from the inner part of the superficial facet of an organism; it is actually hair structure that affecting hair appearance [Nagase, 2019]. Hair commonly consists of hierarchical fibers in a cortex surrounded by cuticle scales [Yang, et al., 2020] and this typical consistency may provide a wide array of functions, due to its flexibility and large superficial portion that it usually retains and covers. Due to this straightforward structural basis, a slight modifications in hair geometry, such as flexure, caliber, shaft and also inter-hair spacing, may enhance its mechanical capabilities, which adding functions such as attachment capabilities [Eimüller, 2008], mechanosensing [Chaklam, et al., 2020], physical barriers used for defence and protection [Sugiura & Yamazaki, 2014] and last but not least also motion or gesture which already stimulate the scholars to apply it in the advancement of mechanosensing in artificial systems, such as robotics. [Boublil, 2021].

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182 In the context of higher insect, insect hairs, also known as setae or sensilla, are varied between
 183 species. Most arthropods have many hairs, often packed together at an unusually high density.
 184 Functional explanations for this high density depend on the type of hair [Casas, et al., 2010].
 185 It was proven that the abundant density of small setae in the foot of many insects ensure full
 186 contact establishment [Ji, et al., 2011] which results in increased adherence which is
 187 advantageous for their survival [Rajabi, et al., 2021], whereas a huge integer of aquatic
 188 arthropods such as marine crustaceans also use hairs for sensing and feeding [Hood et al.,
 189 2019] and terrestrial arthropods apply hair as biological machine for particle capture, flying or
 190 swimming [Seale et al., 2018].
 191 Setae or sensilla has a variety of functions, basically as (1) sensory functions, (2) protective
 192 functions and (3) other non sensory-protective function, which will be described further as
 193 follows:
 194 3.1. Sensory Function
 195 3.1.1 Mechanoreception: Setae which are sensory apparatus [Vittori, et al., 2018] widely used
 196 to detect mechanical stimuli like touch, taste, smell [Winterton, 2009], vibration, and air
 197 currents [Boublil, et al., 2021] are called tactile hair [Barth, et al., 2004]. They can be
 198 specialized to perceive different types of stimuli, such as benign touch [French &
 199 Torkkeli, 2009], wind velocity [Palmer, et al., 2021] and direction [Palmer, et al., 2023],
 200 or even sounds [Boublil, et al., 2021].
 201 3.1.2 Chemoreception: Some setae are chemoreceptors, allowing insects to detect chemicals
 202 in the environment [Fonseca et al., 2024; Sokolinskaya, et al., 2020]. These can be
 203 olfactory which means the capability to sense airborne chemicals [Rieder, 1987] or
 204 gustatory which refers to the ability to perceive chemicals in food or liquids [Garm, et
 205 al., 2003].
 206 3.1.3 Thermoreception: Setae can also be used to sense temperature changes and practically
 207 for the blood-sucking arthropods utilize multimodal information for sensing and
 208 recognising its potential hosts. The specific heat discharged by the body of endothermic
 209 vertebrates constitutes a major cue for correct orientation [Lazzari, 2019].
 210 3.1.4 Proprioception: Proprioception or the sense of physical self is an important feature of
 211 living organism. This proprioceptive sensing maintenance by setae, which can help
 212 insects sense the position and movement of their own body parts, contributing to
 213 balance and coordination [Gebhart, et al., 2022].
 214 3.2. Protective function
 215 3.2.1 Defense: Setae can be modified to provide physical protection against its enemies [Yano
 216 & Shiotsuka, 2013]. Some setae are barbed [Ruzzier, et al., 2020] or poisonous [Poinar
 217 & Vega, 2019] and sometime called urticating hair [Battisti, et al., 2011], while others
 218 species generate a physical barrier that is difficult to penetrate or in other words
 219 principally as physical protection against predators. For example, *Hylesia metabus*, a
 220 species of moth, endemic mainly in the region of northeastern Venezuela. Female
 221 moths apply their abdominal setae to cover their egg masses. Exposure with these
 222 setae surely can produce a severe dermatitis in vulnerable humans. Setae from males
 223 actually do not cause these type of symptoms. Rodriguez, et al., reported that egg
 224 masses not covered by setae were examined and transported by Pheidole ants,
 225 whereas covered eggs were largely avoided [Rodriguez, et al., 2009]. The morphology
 226 of the S3 and S4 setae types suggests that these may be related to the urticating
 227 properties reported for the moth. Ant avoidance of setae covered eggs suggests that
 228 these protect the eggs from at least some predators. In the context of self-defence,
 229 setae also help regulate body temperature. Setae, like the hairs or bristles found on
 230 some insects, can reduce the rate of convective heat exchange, but they do not

eliminate it entirely. They primarily act as insulators, slowing down heat transfer through convection, but failed to block it completely [Casey, 1992].

3.2.2 Camouflage: The arrangement and structure of setae can help an insect blend into its environment, providing camouflage [Lianos, et al., 2022].

3.2.3 Grooming: Some type of setae can do the self-cleaning, e.g., like the one in Gecko, a type of lizard [Hu, et al., 2012], removing debris and preventing fouling which facilitated by its hydrophobicity properties [Bello, et al., 2022]

3.3. Other non sensory-protective function

3.3.1 Locomotion: Setae which located on legs and other body parts of insect can facilitate its grip and traction [Voigt, et al., 2017], aiding in movement on various surfaces [Federle & Labonte, 2019].

3.3.2 Dispersal: Setae can aid the dispersal of pheromones [McKinney, et al., 2015] or other important chemical signals, by playing a crucial role in their basic communication and behavior. These hair-like structures, located on various body parts, house chemosensory neurons that detect specific chemical signals and trigger appropriate responses [Fleischer & Krieger, 2018].

3.3.3 Glandular-like secretory Function: Some setae are associated with glands and may have other functions like lubrication to reduce friction [Cheng, et al., 2022] or secretion of substances [Urbanek, et al., 2011].

3.3.4 Support and Flight: In insects, setae can play a role in supporting flight, detecting airflow patterns, and preventing stall [Bloublil, et al., 2021]. Hairs specialized to detect airflow and trigger mechanosensory responses are often called sensory hairs or filiform hairs. These hairs are highly sensitive to even slight air movements and are found in various animals, including insects and bats. When deflected by air, they stimulate receptor cells at their base, sending a signal to the nervous system.

As previously mentioned, insect hairs, particularly those found on caterpillars and other arthropods, can indeed be allergenic, causing a range of reactions from mild skin irritation to severe, life-threatening anaphylaxis. These hairs, often barbed or needle-like, can penetrate the skin and release toxins, leading to inflammation, itching, and pain. The possible functional significance of the hairs of house dust mite has not been clarified to date but we proposed its allergenic potency in the next section.

3. PROPOSED ALLERGENIC POTENCY OF THE HAIR OF HOUSE DUST MITES

House dust mites (HDM) are a major cause of indoor allergies, with their allergenic potency stemming from specific proteins. These proteins, particularly Der p 1 and Der p 2, are the most common triggers for allergic reactions in sensitized individuals [Thomas, 2015;Thao, et al., 2023]. The allergenic potency of HDM extracts can vary, and is often measured in terms of the concentration of these major allergens and their ability to induce an allergic response.

The main source of allergens in house dust mites (HDM) is their feces, shed skin and decaying body parts [Sarwar, 2020; Sidenius et al., 2002]. These microscopic particles, containing previously mentioned specific proteins [Thomas, 2015], which become easily airborne when disturbed and can trigger allergic reactions in susceptible individuals.

Dust mite excrements sepcifically contain mixed undigested food particles and digestive enzymes [Sarwar, 2020; Rutten, 2018; Thomas, 2015; Bessot & Pauli, 2011], which are highly

276 allergogenic [Miller, 2019]. These specific allergenic proteins can also be found in their body
277 parts and shed exoskeletons [Bergmann, 2022].
278 House dust mites have specialized bristle-like hairs called setae. These setae are important
279 for identification and are used to distinguish between different species of mites, including the
280 common house dust mites, *Dermatophagoides pteronyssinus* and *Dermatophagoides farina*
281 [Thao, et al., 2023]. The setae on the dorsal (upper) side of the mite are typically long and
282 serrated, while the ventral (lower) side has different arrangements of setae, including anal
283 setae, which can be used to differentiate between male and female mites.
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286
287 Fig. 1. Setae of house dust mites, made from fresh dust sample (courtesy of Dept. of
288 Parasitology, Faculty of Medicine, Universitas Kristen Indonesia, Jakarta-Indonesia
289
290

291 House dust mites possess stiff, bristle-like hairs called setae, which are visible under a
292 microscope. These setae are a key feature of their external structure and help in identification.
293 The setae are distributed across the mite's body, with some longer than others. Hair or setae
294 of the house dust mites also has the potency to precipitate even to augment the allergenic
295 response in atopic individuals. The reasons for the statement are as follows:

- 296 1. Easily to detach: Dust mites, like other arthropods, molt as they grow, shedding their outer
297 layer of skin or exoskeleton as they become mature. This process releases various
298 components, including its setae. During shedding off their skin (ecdysis), their setae
299 (bristles or hairs) on the part of detach skin can also detach from their bodies [Bergmann,
300 2022; Sarwar, 2020; Rutten, 2018; Thomas, 2015; Bessot & Pauli, 2011]. These shed tiny
301 microscopic parts, along with their feces, are a crucial component of house dust and
302 commonly mixed together thus making it a perfect allergen for atopic individuals [Thao, et
303 al., 2023; Miller, 2019]. Their small size facilitates their spread, making them to become
304 airborne easily, and also enabling them to be readily inhaled [Strzelczyk, 2020]. Even after
305 fifty years of storage, abandoned dust kept from the early study of house dust mite at the
306 year of 1964, and in 2014 it is still detected, both the mites and also the allergens
307 [Bergmann, et al., 2014]

308 2. Anatomical location: House dust mite's setae, which are bristle-like structures on the mite's
309 body, are primarily located on the legs, particularly on the tarsi (the last segment of the
310 legs). They also appear on other parts of the body, including the dorsal (upper) surface and
311 around the genital and anal openings in both male and female mites. The structure and
312 arrangement of setae vary between the sexes and are used in identification. Setae are
313 found on all legs, with the subtarsal seta being replaced by a pectinate (comb-like) seta on
314 the tarsi. While on the dorsal surface, dorsal setae are found and described as long and
315 serrated (whip-like), except for one specific seta (d2). Setae of the genital region are
316 present around the genital opening, which is located between coxae III and IV (leg
317 segments) while setae of the anal region of female house dust mites, there are 6 pairs of
318 anal setae, while males have 3 pairs. Setae can also be found on other parts of the body,
319 contributing to the overall structure and function.

320 3. Homeostatic function: Setae play a crucial role in the mite's ability to move, sense its
321 environment, and reproduce. The specific structure of setae, such as the pectinate seta on
322 the tarsi, helps the mite grip surfaces and move around effectively. The sensory setae likely
323 help the mite detect changes in its environment, such as humidity and temperature, which
324 are important for its survival. The genital setae are important for reproduction. In the context
325 of homeostasis of house dust mites, their setae also play an indirect role in causing
326 allergies.

327
328 The three statements above still needs to be studied in more depth, especially in the context
329 of the allergenic content of setae, how fragile and easily detached the setae are and whether
330 setae in certain anatomical positions (for example near the anal region) play a role in triggering
331 secretion.

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334 4. CONCLUSION

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336 Insect setae, which are hair-like structures on the insect's body, have a wide range of functions
337 beyond simple sensory perception. These functions include defense, locomotion, camouflage,
338 and pheromone dispersal. In the context of house dust mites, further study need to be
339 conducted to explore the potency of its setae in causing or at least contributing to its
340 allergogenic properties.

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342

343 DISCLAIMER (ARTIFICIAL INTELLIGENCE)

344

345 Author(s) hereby declare that NO generative AI technologies such as large language models
346 (chatGPT, COPILOT, etc.) and text-to-image generators have been used during writing or
347 editing of this manuscript.

348

349 COMPETING INTERESTS

350

351 Authors have declared that no competing interests exist

352

353 AUTHORS' CONTRIBUTIONS

354

355 'Author FES' designed the study, performed the literatur analys and wrote the first draft of the
356 manuscript. 'Author R' managed the isolation of house dust mites from fresh dust sample and
357 conduct detailed analyses of the study. 'Author EY' and 'author JL' taking the microscopic

358 appearance of house dust mites and managed the literature searches. All authors read and
359 approved the final manuscript."

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361

362 **CONSENT (WHERE EVER APPLICABLE)**

363

364 Not needed

365

366 **ETHICAL APPROVAL (WHERE EVER APPLICABLE)**

367

368 Not needed

369

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731 **APPENDIX**

732

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