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House Dust Mites, Other Domestic Mites and Forensic Medicine

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1. Introduction

Many species of mites are the sources of potent allergens that sensitize and induce IgE-mediated allergic reactions in humans. Most of the mite allergens are proteins, and the allergic response mechanism to these allergens is the same as it is for allergens from other sources such as plant pollens, molds and foods (Arlian, 2002). Mites occurring in house dust, besides the ticks (Acari: Ixodida), are one of the most medically important group of mites. In total at least 150 species of mites have been found in dwellings, including plant parasites, animal parasites, predatory mites, oribatid mites and storage mites. But the most abundant mites in house dust are members of the family Pyroglyphidae (Astigmatina) (Wharton, 1976; Arlian, 2001; Arlian et al., 2002; Solarz, 2010). The three mite species, most often and most abundant found in house dust throughout the world, are *Dermatophagoides pteronyssinus*, *D. farinae* and *Euroglyphus maynei* (Arlian, 2001; Colloff, 2009; Pope et al., 1993). The house dust mites now constitute the most dangerous pests of temperate climate countries, causing both significant loss of human life and immense waste of resources. These mites are the major sources of indoor inhalant allergens facilitating both the sensitization of atopic subjects and asthmatic attacks in patients (Pope et al., 1993; Arlian, 2002; Colloff, 2009). For the first time, Voorhorst et al. reported that house dust contained mites of the genus *Dermatophagoides* and suggested that these were the source of the house dust allergen (Voorhorst et al., 1969). Therefore they are studied recently as causing atopic diseases in humans, known in medicine as house-dust-mite allergy or house-dust-mite atopy (Wharton, 1976; Van Bronswijk, 1981; Platts-Mills et al., 1992; Pope, 1993; Arlian, 2001; Colloff, 2009). These diseases are atopic asthma, atopic dermatitis (eczema) and allergic rhinitis, keratoconjunctivitis or oculorhinitis (Arlian & Platts-Mills, 2001; Arlian et al., 2008; Colloff, 2009). Many-faceted studies of house dust mites of the Pyroglyphidae family have been continued since 1964 in many countries of the world, including the surveys on their taxonomy and fauna, biology and ecology, epidemiology, allergenicity and control. To date, only 15 species were found in house-dust samples: *Dermatophagoides pteronyssinus*, *D. farinae*, *D. evansi*, *D. microceras*, *D. siboney*, *D. neotropicalis*, *Hirstia domicola*, *H. chelidonis*, *Malayoglyphus intermedius*, *M. carmelitus*, *Sturnophagoides brasiliensis*, *Hughesiella africana*, *Hu. valerioi*, *Euroglyphus maynei* and *Gymnoglyphus longior*. The house dust mites have been reported from human dwellings and a wide variety of other habitats associated with man and his environment, both indoor and outdoor (Van Bronswijk 1981; Fain et al., 1990; Solarz & Solarz, 1996; Arlian, 2002; Solarz, 2003; Solarz et al., 2007; Colloff, 2009; Perotti et al., 2009).

Most often they are found in habitats intimately associated with man, such as beds, bed linen, couches, sofas, other upholstery furnitures, clothing, curtains, window stills, floors and carpets (Van Bronswijk, 1981; Fain et al., 1990; Mehl, 1998; Colloff, 2009; Arlian & Platts-Mills, 2001; Arlian, 2002; Solarz, 2001a, b, 2004a, 2010). These domestic environments are very important locations for forensic investigations, but this richness of mite diversity has not been exploited by forensic investigators (Perotti et al., 2009). Next chapters are focused on the mites in a variety of indoor habitats. The natural sources of allergenic mites in dwellings or stores are still not quiet known (Solarz et al, 2007). The possible sources of these mites in house dust are nests of synanthropic birds and stored products (Hughes, 1976; van Bronswijk, 1981; Fain et al., 1990). In Poland, the knowledge of their occurrence in house dust is still poor and the number of faunistic surveys on dust acarofauna is anywhere from ten to twenty. So, exists indispensability of these surveys in Poland, especially in Upper Silesian region, where air vitiation may to have stimulating influence to sensitization of human beings with house dust allergens. It is also commonly known that certain industrial dusts may cause chronic lung diseases in occupational populations, including also coal workers (Solarz & Solarz, 1996). It cannot be excluded that apart from coal dust itself, certain constituents of biological origin may also contribute to the pathogenic effect. Our previous results reveal the occurrence of allergenic mites in samples of dust and debris from coal-mines of the Upper Silesian region (Solarz & Solarz, 1996; Solarz, 2003). Thus they should all be regarded as a potential source of mite allergens in this environment. Our studies suggest also that the allergenic mites belonging to Acaridae, Glycyphagidae, Pyroglyphidae and Tetranychidae should be considered as occupational risk factors contributing to the occurrence of respiratory and dermal diseases among workers of ZOO gardens (Solarz et al., 2004a, b). As the occurrence and concentration of mites in samples from different places may vary to a considerable extent, further studies are highly desirable. An understanding of the seasonal dynamics, as well as environmental factors influencing mite populations, can be exploited in mite control. Most studies on house dust mites within dwellings have traditionally sampled beds, carpets and upholstered furniture as the 3 main types of the indoor microhabitats of these mites. House-dust-mite species have been recovered from animal and human carcasses and only recently they are being studied for their potential as forensic indicators (Baker, 2009; Braig and Perotti, 2009; OConnor, 2009; Solarz, 2009). The usability of domestic mites in forensic investigations is dependent on a thorough knowledge of their diversity and abundance in a variety of indoor environments. The ubiquity of mites means that there are many situations in which human beings and different objects associated with crime are exposed to these arachnids (Perotti et al., 2009). This chapter gives a faunistic review of the pyroglyphid mites that have actually been recorded in Southern Poland, in dwellings (beds, carpeted and non-carpeted floors, upholstery furniture, desks, walls), hospitals, libraries, and other workplaces and/or public places, in heaps of litter soiled with communal wastes near fences, houses and public buildings. There are no detailed differential diagnoses and identification keys to the pyroglyphid dust mites and other domestic mites, especially for the juvenile stages. Therefore, an acarological diagnostics in forensic studies may be difficult. The taxonomic relationships and number of valid species within the family Pyroglyphidae are not established to date. The measurements and analysis of variation between individuals, populations, species and genera is fundamental to the study of systematic, ecology and evolution, and has numerous applications in the medical, veterinary and agricultural sciences, including the forensic medicine. Therefore, this chapter presents also results of

morphological studies, including most medically important taxa of mites, especially genera from the families Pyroglyphidae (*Dermatophagoides*, *Euroglyphus*, *Gymnoglyphus*, *Sturnophagoides*), Acaridae (*Acarus*, *Tyrophagus*), Glycyphagidae (*Glycyphagus*, *Lepidoglyphus*, *Gohieria*) and Chortoglyphidae (*Chortoglyphus*). I obtained most mite specimens from house dust samples, bird nests, farming environments, and from research collections in the United States, UK and Belgium. Own detailed descriptions of all species examined, differential diagnoses and identification keys are presented. Results suggest that the current division of the subfamilies of the family Pyroglyphidae should be revised. These results are compared with published studies with the aim of outlining and examining the weaknesses of the approach. It is commonly known, that more detailed descriptions of mites in different indoor situations are very important for forensic investigations (Perotti et al., 2009).

2. Recent studies on the house-dust-mite acarofauna in Poland

The study was carried out from July 2007 to December 2009. During this period 1875 house dust samples were collected from flats and one-family homes at different localities in Poland (Silesian Province, Malopolskie Province, Swietokrzyskie Province); 1053 (56.16%) samples were positive for mites. A total of 15,698 mites were isolated and 18 species were identified, including 5 species from the family Pyroglyphidae (house dust mites). Among them *Dermatophagoides pteronyssinus* was predominant (6,870 specimens; 43.8% of the total count), followed by *D. farinae* (6,553 ones; 41.7%). The second species was predominant in Czestochowa (88.3%), Katowice (91.9%), Sosnowiec (89.4%), Chorzow (94.8%), Tychy (59.4-92.8%), Bytom (50.9%) and generally in Upper Silesia (55.8-87.61%), whereas *D. pteronyssinus* dominated in old buildings in Chorzow and Sosnowiec (60.31%), Bytom (52.7%) and vicinity (68.4%), in old buildings in Upper Silesia (49.6%), in Upper Silesian dwellings of allergic patients (70.8%), in Cracow (centre of the city; 50.83%), one-family homes in Zywiec and vicinity (90.3%), Miechow and vicinity (43.8%), Swietokrzyskie Province (mainly Staszow, Sedziszow and vicinity, Skarzysko-Kamienna; 41.9%) and Bielsko-Biala vicinity (76.51%). Another pyroglyphid mites, *E. maynei*, *G. longior* and *H. chelidonis*, occurred in very small numbers (190, 1 and 6 specimens, respectively). Highest mite densities per gram of dust were noted in one-family homes. *D. pteronyssinus* was more abundant per gram of dust mainly in the one-family houses on agricultural or subagricultural settlements, especially in bed mattresses, whereas *D. farinae* in samples from the remaining indoor places examined, and especially from dwellings in urban regions. Generally, the highest dust mite concentrations were usually found in dust from beds, upholstery furniture and carpeted floors. An influence of some abiotic indoor factors on the mite prevalence in the examined dwellings were analysed separately in relation to samples of bed dust, floor dust and dust from upholstery furniture. The density of mites was influenced mainly by the type of heating, temperature, relative humidity, type of sleeping accommodation, type of floor or furniture, age of building, type of building, number of inhabitants and weight of samples. Mean relative humidities were 59.7%, 60.4% and 72.0% for samplings of dust from the Upper Silesian dwellings, from other urban localities and from agricultural or subagricultural settlements, alternatively. In hospitals a total of 80 samples were examined, always from two sites – floor and patient's mattresses. Mites (209 specimens) were isolated from 44 samples (55%). The most abundant mites were members of the family Pyroglyphidae, which formed 99.01%of the total count. *D. farinae* was predominant (66.5% of all mites collected), followed by *D. pteronyssinus* (32.1%). The former species was more frequent in samples from floors than from patients' beds, whereas *D. pteronyssinus* was

collected more frequently from beds than from floors. *D. farinae* was distinctly more abundant per 1 gram of dust (arithmetic mean 19.8) than *D. pteronyssinus* (7.7), whereas alive mites were slightly more numerous in populations of the second species (5.4 vs. 5.3). Populations of both species were dominated by adult mites. The density of mites was influenced mainly by the type of mattress, number of patients and relative humidity. The research has revealed differences in the occurrence and abundance of both species of house dust mites between hospitals examined and between particular places within the same hospital. Moreover, the study suggests that the house dust mites and other mites, including also some allergenic taxa, should be considered as occupational risk factors contributing to the occurrence of respiratory and dermal diseases among patients and different workers of hospitals. Most probably, these mites are introduced into hospitals by humans from their houses and/or flats. House dust mite prevalence was also studied in the rooms of a tertiary care hospital in Knurow (Upper Silesia). A total of 60 samples were examined, always from two sites - from floors and patient's beds. Only 10 samples were positive for mites (16,67%) and only 19 mites were isolated; among them the most abundant ones were pyroglyphids (16 specimens; 84.21% of the total count), two species of the family – *D. farinae* (12 specimens) and *D. pteronyssinus* (4 ones). The first species was more abundant per gram of dust (mean number 34.9) than *D. pteronyssinus* (27.0). Main sources of mites in libraries and drug-stores are shelves, upholstery chairs and carpeted floors, whereas in offices carpeted floors and upholstery furniture. Although beds are commonly known as the main indoor places of mite occurrence, they were however – besides the dwellings – more abundant in libraries than in hospitals. The highest numbers of *D. farinae* per gram of dust were found in samples of dust from book-shelves and carpets. *D. farinae* was the dominant constituting approximately 575 of mites collected. It is possible that older books, and also book-shelves and carpets contain significant quantities of skin scales or dander from the readers or library workers (librarians) which skin scales serve as suitable food for pyroglyphid mites. These data confirm the results of several acarologists of small numbers of mites in hospitals, offices, hotel rooms and other social buildings or public places, suggesting that the environment in these places is unsuitable for the mite growth. Repeated routine cleaning practices as well as maintenance of low relative humidity could in part explain the small abundance of mites in public places/buildings. This research, as well as some other studies, has revealed differences in the occurrence and prevalence of different species of domestic mites between geographical areas and between dwellings within the same geographical area, between particular places within the same dwelling, and between the seasons of the year. This knowledge may be very useful in the forensic medicine. Moreover, the study suggests that the house dust mites and other domestic mites, including also some allergenic or parasitic taxa, should be considered as occupational risk factors contributing to the occurrence of respiratory and dermal diseases among librarians, barkers, cleaners, different workers of hospitals, drug-stores, airports, offices, and many other occupational categories. Exposure to indoor allergens, especially dust mites has been recognized as a risk factor for sensitization and allergy symptoms that in extreme conditions could develop into asthma (Spiewak et al., 1995).

3. Species composition of the house-dust-mite acarofauna

Pyroglyphid mites usually make up 60-90% of the house dust acarofauna in temperate climate regions throughout the world (Van Bronwijk 1981; Fain et al., 1990; Colloff, 2009), also in Poland (Solarz, 2010). In the case of mite density, the number of mites per gram of

dust may range from a few to 16,000 or more, although the results of the surveys are difficult to compare and evaluate because of the lack of standardization of both dust collecting methods and reporting procedures. It has been shown, however, that occurrence and abundance of house dust mites may vary in particular topographical regions and are associated to a large degree with the climate of a region, and especially with outdoor and indoor humidity (Korsgaard, 1998; Mumcuoglu, 1976; Mumcuoglu et al., 1999; Colloff, 2009). Ratios of numbers of the particular pyroglyphid dust mite species, especially between *D. pteronyssinus* and *D. farinae*, are different in separate regions of the world (Fain et al., 1990; Mumcuoglu, et al. 1999). Decisive factors influencing their occurrence and abundance are mainly relative humidity and temperature of both outdoor and indoor air (Solarz, 2001 a, b). It is commonly known that the optimal temperature is higher (25-30 ^{o}C) and optimal humidity lower (50-75 %RH) for *D. farinae* than for *D. pteronyssinus*. The former species appear to survive better in dryer habitats than the latter, whereas lower temperature (15-20 ^{o}C) and higher humidity (75-80 %RH) favours *D. pteronyssinus* in mixed laboratory cultures (Arlian et al., 1998). Within the wide zone of temperate climate *D. pteronyssinus* is the most common and dominant species in more damp areas, at the seaside or in lowlands, which have a more humid climate. *D. farinae*, however, is more common and abundant in areas with a dry continental climate (intercontinental and alpine regions) (Voorhorst et al., 1969; Fain et al., 1990; Colloff, 2009; Solarz, 2001a, b, 2010). In Europe, most abundant mite populations were usually collected from bed mattresses (Van Bronswijk, 1981; Fain et al., 1990; Hallas & Korsgaard, 1997; Horak et al., 1996; Solarz, 2006). In previous surveys (Solarz, 1998) of house-dust-mite fauna in dust samples from dwellings and hospitals located in Sosnowiec and Katowice (Upper Silesia), the dominance of the Pyroglyphidae was demonstrated (Solarz, 2001 a, b). Approximately 63.5% of the total mite population belonged to this family. Most abundant were the following members of Pyroglyphidae – *D. pteronyssinus* (29% of the total mite population), *D. farinae* (25.5%) and *E. maynei* (6.0%). Unidentified *Dermatophagoides* spp. formed 3% of mites isolated from the samples examined. As indicated by the results of other previous surveys in Poland, *D. pteronyssinus* was found to be the dominant species in Warsaw, Poznan, and two Upper Silesian cities-towns Katowice and Sosnowiec (Horak et al., 1996; Solarz, 1998). As demonstrated by the more direct investigations of the house dust samples from dwellings (in Katowice, Sosnowiec, Myslowice, Chorzow, Tarnowskie Gory, Bytom, Zabrze, Gliwice, Dabrowa Gornicza and Ogrodzieniec), libraries (in Sosnowiec), institutes (in Katowice) and hospitals (in Katowice and Sosnowiec), the dominance of Pyroglyphidae was more significant than previously (Solarz, 1998, 2001a, b). About 89.2% of the total mite population from dwellings constituted the following members of this family – *D. pteronyssinus* (45.1%), *D. farinae* (40.2%), *E. maynei* (2.6%), *G. longior* (0.05%) and unidentified *Dermatophagoides* (1.24%). A total of 31 species of mites from 15 families were identified, of which 18 species belonged to Astigmatina, 3 to Prostigmata, 3 to Oribatida sensu lato and 7 to Mesostigmata. The fauna of house dust mites was therefore rather differentiated in this region. This was particularly apparent in dwellings, where 49 combinations of species composition in collected mite populations were observed. This study has clearly established that mite species in beds and other sleeping accommodations are different from the mite species on bedroom floors. The pyroglyphid mites were most abundant in samples from beds and upholstery furniture whereas floors were dominated with the non-pyroglyphid mites. A total of 402 samples were analysed: 238

samples from dwellings, 122 samples from hospitals, 14 from libraries and 28 from institutes. Mites were present in 51.3%, 50.0%, 21.3% and 17.9% of dust samples from dwellings, libraries, hospitals and institutes, respectively. Generally, they were found in 160 samples (39.8% of the total count). The majority of mites (96.0 %) were found in samples from the dwellings, especially in dust from upholstery furniture, couches, sofas and beds. Altogether, the pyroglyphid mites constituted 89.2%, 78.9% and 57.5% of a total population of mites collected from dwellings, libraries and hospitals, respectively, but were not found in institutes. In total, *D. pteronyssinus* was the most dominant, especially in libraries and hospitals, however in dwellings *D. farinae* was more abundant per 1 gram of dust than the former species. Another pyroglyphid mite, *E. maynei*, occurred in very small numbers (Solarz, 1998, 2001a, b). Mites of families Glycyphagidae, Chortoglyphidae and Acaridae are considered to be much more sensitive to desiccation than pyroglyphids (Van Bronswijk, 1981; Fain et al., 1990; Hallas & Korsgaard, 1997). It has also been suggested that some domestic mite species thrive in very damp conditions; this group include domestic acarids, glycyphagids (*L. destructor*, *G. domesticus*) and cheyletids *(Cheyletus* spp). Therefore, the presence and abundance of these mite species can be used as an indicator of humid environments (Fain et al., 1990; Solarz, 1998, 2003). The relatively low frequency of mites in a total of samples from dwellings examined and relatively lower abundance of glycyphagids, acarids, cheyletids and *E. maynei* mites is clear, taking into account the aforementioned values of indoor relative humidity observed in these dwellings (Fain et al., 1990; Solarz, 1998, 2003). In general, these mites are not as abundant or frequent in Europe as in the Tropics (Fain et al., 1990; Puerta et al., 1993; Mehl, 1998; Mumcuoglu et al., 1999; da Silva et al., 2001; Colloff, 2009). The mean concentration of mites in examined samples and mite frequency was at the lower end of the published range for more humid regions (Van Bronswijk, 1981; Fain et al., 1990; Mumcuoglu, et al. 1999; Colloff, 2009) and was comparable with some European results from France, Denmark and Holland (Van Bronswijk, 1981; Fain et al., 1990; Harving et al., 1993) and with other results from Poland (Horak et al., 1996; Racewicz, 2001).

4. Acarofauna of the synanthropic outdoor sites

The occurrence of allergenic mites (pyroglyphid house-dust mites, acarid and glycyphagid storage mites and others) in synanthropic outdoor sites in a densely populated urban area was investigated. Litter soiled with communal wastes was sampled. 80.5% of the total population was formed by allergenic mites. These mites (11 species) belong to Acaridae and Winterschmidtiidae. Among the astigmatic mites two acarids were dominant: *Tyrophagus silvester* and *T. longior* (28.7% and 25.1% of all mites respectively), with the latter being the most frequent (44.2% of all samples). The age structures of the two species versus relative humidity were investigated. The correlations between the age structures of *T. silvester*, *T. longior*, *T. molitor* and *T. similis* were statistically analysed. The most important allergenic mites from Pyroglyphidae (house dust mites) or Glycyphagidae (stored food mites) were not found. However, allergenic mites from Tarsonemidae – important for house dust, and Acaridae – reported from food stores, were presented numerously in the samples, which bring us to the conclusion that litter can be an important source of invasion of the mites into dwellings or food stores.

5. Allergenic mites as the occupational and/or environmental risk factors

Many species of mites that humans come in contact with, besides the house dust mites or storage mites, induce allergic reactions. These include some species of spider mites (e.g., the 2-spotted spider mite *Tetranychus urticae* and *Panonychus ulmi*), which are common pests in orchards, greenhouses, and gardens. These mites were recently proved to induce IgE-mediated reactions (Arlian, 2001, 2002; Solarz, 2004a, 2006). It should come as no surprise to learn that chigger mites (larvae of Trombiculidae), ticks (Ixodida) and other species of ectoparasitic mites (Mesostigmata) of fowl, pigeons, other birds, mice, guinea pigs, and other mammals and some predaceous mites sensitize and induce allergic reactions in human (Arlian and Platts-Mills, 2001). Many species of stored-product mites occur in both residential and occupational environments and in processed foods and can cause allergic disease. In addition, humans may contact or be exposed to predaceous mites and parasitic mites of plants and animals that are also the sources of allergens that induce allergic disease.

5.1 Storage mites

The stored-product mites, especially several species from the families Acaridae, Glycyphagidae and Chortoglyphidae (Acari: Astigmatina), are commonly found in different stored food products, hay, straw, granaries, barns and other farming and occupational environments, as well as in samples of house dust. The most abundant and most often reported are *Acarus siro*, *A. farris* and *Tyrophagus putrescentiae* from Acaridae, *Lepidoglyphus destructor*, *Glycyphagus domesticus* and *Gohieria fusca* from Glycyphagidae and *Chortoglyphus arcuatus* from Chortoglyphidae (Hughes, 1976; Franz et al., 1997; Mehl, 1998; Baker, 1999; Müsken et al., 2000; Solarz, 2011; Solarz et al., 1997, 2004b). These mites are also the source of clinically important allergens and the cause of occupational allergies (known as an allergy to storage mites) among farmers, grain-storage workers and other agricultural workers (van Hage-Hamsten & Johansson, 1998; Morgan & Arlian, 2006; Fernández-Caldas et al., 2007). The greates exposure to storage mites usually occurs in an occupational and/or rural setting where allergies to these mites are of major importance (van Hage-Hamsten et al., 1992; van Hage-Hamsten & Johansson, 1998; Arlian, 2001, 2002; Stejskal & Hubert, 2008). Many species of storage mites are found in processed foods (flour, boxed baking mixes such as cakes, pancakes, and beignets); in stored hay, grain and straw; in dust in grain and hay storage and livestock feeding facilities. Exposure to storage mite allergens can be by ingestion or by inhalation. Several studies report anaphylactic reactions after patients consumed beignets, cakes, pancakes, pizza, pasta, cornmeal cakes, and bread made from ingredients contaminated with mites. The importance of storage mites as ingested or aeroallergens in the urban population has not been studied extensively. The greatest exposure to storage mites usually occurs in an occupational setting where allergies to storage mites are of major importance. Kronqvist et al. (2000) reported that 12% of 440 farmers tested were sensitive to the storage mites *Acarus siro*, *L. destructor*, *T. putrescentiae*, and *Glycyphagus domesticus*. Similar sensitivities to storage mites have been reported for farmers in Scotland and USA (Arlian et al., 1997; Arlian, 2002). Important storage mite species in occupational settings are *L. destructor*, *G. domesticus*, *A. siro*, *T. putrescentiae*, *Tyrophagus longior*, *Aleuroglyphus ovatus*, *Suidasia medanensis*, *Chortoglyphus arcuatus*, and *Carpoglyphus* sp. Sensitization to the storage mite *T. putrescentiae* is present in the urban population of Upper Silesia in similar proportions as to pyroglyphid house-dust mites (*Dermatophagoides* spp.) (Szilman et al., 2004). Testing with storage mites should be considered routine allergological diagnostic

procedure. In other words it is necessary to establish methods for identification and quantification of mites in the Upper Silesia (Szilman et al., 2004).

5.2 Other mites inducing allergic reactions

Many species of mites that humans come in contact with, besides those found in house dust, induce allergic reactions. These include the citrus red mite (*Panonychus citri*) and the two-spotted spider mite (*Tetranychus urticae*), which are common pests of apple orchards. Mites are ubiquitous and thrive in many diverse environments. Thus humans contact many species of mites and their products in their daily lives. The role of these less-known mites in causing allergic disease is not yet known. Phytophagous mites of fruit trees, vegetable crops, and yard, greenhouse, and house plants can cause allergic disease in at-risk populations. A study of 725 Korean farmers working in apple orchards found that 23.2% and 21.2% were sensitive based on skin tests to the two-spotted spider mite (*T. urticae*) and the European red mite (*Panonychus ulmi*), respectively. In this study population, the prevalence of sensitivity to these mites was greater than it was to the house dust mites, *D. farinae* and *D. pteronyssinus* (Kim et al., 1999; Arlian, 2002; Solarz 2003, 2004a, 2006). Another study by this group found that skin tests of 14.2% of 1055 children living around citrus orchards were positive to *P. citri* (Lee et al., 2000). Multiple erythematous papules accompanied by severe pruritus were observed in humans bitten by the mites *Pyemotes tritici* (Pyemotidae), *Dermanyssus gallinae* (Dermanysidae), *Ornithonyssus bacoti* (Macronyssidae) and *Andrlaelaps casalis* (Laelapidae) in Israel (Rosen et al., 2002). The mite *Hemisarcoptes cooremani*, a parasite of scale insects that is commonly found in orchards, yards, and gardens, was recently discovered to induce IgE-mediated reactions (Arlian et al., 1999). *Hemisarcoptes cooremani* that feeds on scale insects that parasitize trees and shrubs in orchards, yards, and gardens can induce allergic diseases. Immunoblotting of extracts of this mite showed that they contain 16- and 19-kDa proteins that bound IgE in the serum of an exposed and symptomatic individual (Arlian et al., 1999). It should come as no surprise to learn that chigger mites (Trombiculidae), ticks (Ixodida) and other species of ectoparasitic mites (Mesostigmata) of fowl, pigeons, other birds, mice, guinea pigs, and other mammals and some predaceous mites either sensitize or induce allergic reactions in human as well (Arlian & Platts-Mills, 2001). The saliva of ticks (Ixodida) contains immunogenic proteins that can induce IgE-mediated reactions while they feed; cases of anaphylactic reactions from a tick bite have been reported (Arlian, 2002). Predaceous mites such as *Phytoseiulus persimilis* and *Amblyseius cucumeris*, that feed on spider mites and larvae of thrips, respectively, can sensitize greenhouse workers (Kronqvist et al., 2000). This raises the possibility that predaceous mites, used for biological control of pest species in fields and orchards, may be important sources of allergens for gardeners, farmers, and people living around fields and orchards (Arlian, 2002). Molecules of from the human itch mite (*Sarcoptes scabiei var. hominis*), which burrow in the stratum corneum of the skin, induce IgE production and an IgE-mediated reaction in some parasitized human hosts (Arlian, 2002; Arlian & Platts-Mills, 2001). Many of these immunogens are cross-reactive with antigens of the house dust mites *D. farinae* and *D. pteronyssinus*. Capability of other parasitic mites, such as follicle mites (*Demodex folliculorum*, *Demodex brevis*), red chicken mites (*Dermanyssus gallinae*), rat mites (*Ornithonyssus bacoti*) and sheep scab mites (*Psoroptes ovis*), inducing IgE reactions in humans needs to be investigated (Arlian, 2002).

6. Identification diagnoses to mites of the families Acaridae, Glycyphagidae, Chortoglyphidae and Pyroglyphidae in taxonomic order

The measurements and analysis of variation between individuals, populations, species and genera (or subfamilies), is fundamental to the study of systematics, ecology and evolution, and has numerous applications in the agricultural, veterinary and medical sciences (Klimov & OConnor, 2009; Dabert et al., 2010), including the forensic medicine (Perotti, 2009a). In forensic acarology it is necessary to produce the data that clearly demonstrate how mites can contribute to investigations (Perotti et al., 2009). Therefore, a following priority is to to provide more user and friendly identification aids, such as differential diagnoses and/or keys for different groups of synanthropic or semisynanthropic mites, including the domestic and storage mites (Baker, 1999; Colloff, 1998; 2009; Desch, 2009; Perotti et al., 2009; Solarz, 2011).

6.1 Family: Acaridae

6.1.1 Genus: *Acarus* L.

Differential diagnosis: In both sexes: solenidion sigma 1 on genu I at least 3 times as long as sigma 2 (Fig. 1A); setae *v e* less than half the length of setae *v i* ; setae *v e* arising near the anterior angles of the dorsal propodosomal or slightly posterior; ventral apex of tarsus I with proral (*p*, *q*) and unguinal (*u*, *v*) setae as thin, not short, stout spines; setae *c 1* and *d 2* short; setae *sc e* about equal in length to *sc i* (Fig. 1B); seta *sc x* generally expanded basally and thickly pectinate (Figs 1B, 2). In males: legs I enlarged; femur I with a stout ventral apophysis or process (seta *vF*) (Fig. 1); ventral side of genu I with small thickenings of cuticle; lateral arms of the penis support diverge posteriorly. In females: characteristic structure of reproductive system, with chitinised depression in body wall, external opening of expansible tube of bursa copulatrix, chitinised bell-shaped structure leading into receptaculum seminis and two armed flame-like chitinised opening to thin-walled oviduct; claws of female never bifid.

6.1.1.1 *Acarus siro* L.

Differential diagnosis: In both sexes: setae *sc e* slightly shorter than *sc i*; setae *d 1* intermediate in length between *c 1* and *e 1*, never more than 3 times longer than *c 1*; seta *sc x* expanded basally and thickly pectinate; solenidion omega 1 on tarsi I and II long, recumbent and the angle between the dorsal surface of the tarsus and the anterior face of the solenidion rarely exceeds 45 degrees (generally about 30). In males: tarsus II of male with seta *s* large, about equal in length to length of empodial claw; ventro-posterior margin of this seta concave, claw tip directed backwards; seta *sc x* expanded basally and thickly pectinate (Fig. 2); lateral arms of the penis support diverge posteriorly; penis (aedeagus) as an arc-shaped tube with a blunt end. In females: tarsi I-II with seta *s* large, about equal in length to length of empodial claw (Fig. 3); ventro-posterior margin of the seta concave, claw tip directed backwards; setae more sparsely pectinate as that of the male; bursa copulatrix opens into a narrow expansible tube which joins a sclerotized bell-shaped structure; setae *ps 3* are twice and *ps 2* almost four times the lengths of *ad 3*, *ad 2* and *ad 1*; vulva characteristic, positioned between *coxae* III and IV. Hypopi: mobile form; gnathosomal remnant with well developed solenidia; posterior ventral attachment organ (sucker plate) well developed, with 8 distinct suckers; legs well developed, with normally formed setae and solenidia; scapular setae relatively long; length of *sc i* greater than distance between alveoli; hysterosomal setae *c 1*, *d 1*, *d 2* and *e 1* long, extending beyond base of next most posterior seta; *sc i* about 1.5 times length of *c 1* and 1.2 times length of *d 1*; setae *c 1* and *d 1* about 3 times longer than *h 1*; bases

of genital setae and flanking pair of coxal suckers almost in line, distance between base of sucker and base of seta is less than width of setal base.

6.1.1.2 *Acarus farris* (Oudemans)

Differential diagnosis: In both sexes: setae *sc e* about equal in length to *sc i*; setae *d 1* intermediate in length between *c 1* and *e 1*, never more than 3 times longer than *c 1*; most dorsal setae short, setae *d 1* and *e 1* not extending to base of next posterior seta; solenidion omega 1 of tarsus II short, compact, with sides expanding gradually from the base, then narrowing to an indistinct neck before expanding into a terminal head, width of widest part of head equal to width of widest part of shaft; the angle between anterior margin of the solenidion and the dorsal surface of the tarsus II is nearer to 90 degrees than 45 degrees. In males: tarsus II of male with seta *s* slender, about 1/2-2/3 the length of empodial claw and points anteriorly; ventro-posterior margin of the seta convex, seta tip directed forward. In females: tarsi I-II with seta *s* slender, about half to two-thirds the length of empodial claw; ventro-posterior margin of seta convex, seta tip directed forward; setae *ad 3*, *ad 2* and *ad 1* almost equal in length, *ps 3* about 1/3 and *ps 2* about twice as long; vulva as in *A. siro*. Hypopi: hysterosomal setae *c 1*, *d 1*, *d 2* and *e 1* appreciably shorter than scapulars, and not extending to bases of next most posterior setae; setae *sc i* at least 2 times length of *c 1* and *d 1*; setae *c 1* and *d 1* about equal in length to *h 1*; bases of genital setae just forward of coxal sucker bases; distance between base of sucker and base of seta about equal to width of setal base.

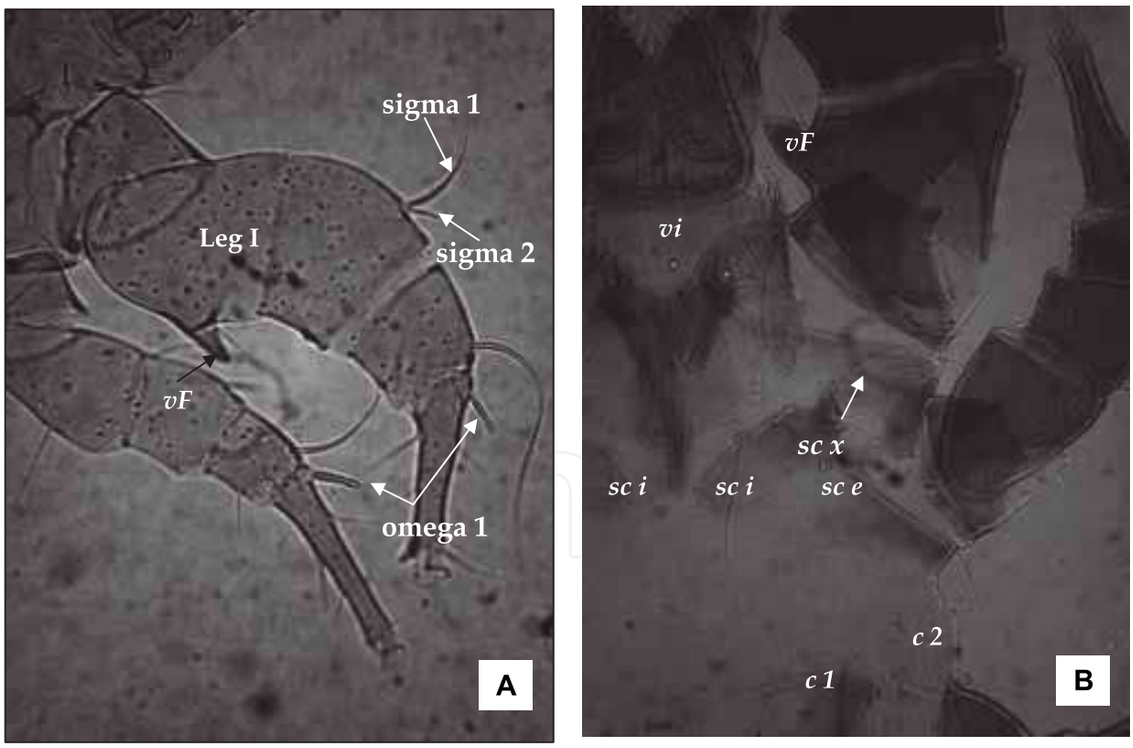

Fig. 1. *Acarus* sp. – A. *Acarus immobilis*, male: legs I and II; B. *Acarus nidicolous*, male in dorsal aspect: seta *vF* on femur I, shape of supracoxal seta (*sc x*) and propodosomal chaetotaxy; key: solenidia omega 1 on tarsi I and II; solenidia sigma 1 and 2 on genu I; *vF* = seta *vF* on femur I; *sc x* = supracoxal seta; external (*sc e*) and internal (*sc i*) scapular setae; dorsal setae *c 1* and *c 2*.

6.1.1.3 *Acarus immobilis* Griffiths

Differential diagnosis: In both sexes: setae *sc e* about equal in length to *sc i*; setae *d 1* intermediate in length between *c 1* and *e 1*, never more than three times longer than *c 1*; most dorsal setae short, setae *d 1* and *e 1* not extending to base of next posterior seta; tarsus II with solenidion omega1 with sides almost parallel, expanding into a distinct egg-shaped terminal head which is wider than widest part of shaft (Fig. 1A); the angle between the dorsal surface of the tarsus and the anterior face of the solenidion generally about 45-50 degrees. In males: tarsus II with seta *s* slender, about half the length of empodial claw; ventro-posterior margin of the seta convex, seta tip directed forward. In females: tarsi I-II with seta *s* slender; ventro-posterior margin of the seta convex, seta tip directed forward. Hypopi: inert forms; legs short (in dorso-ventral mounts tarsi of legs I and II are the only segments completely visible); setae very reduced or absent; gnathosoma rudimentary, flagelliform bristles (solenidia) not present; posterior ventral attachment organ rudimentary, with at most one pair of well-developed suckers on sucker plate, the central pair of suckers vestigial, anterior peripheral pair moderately well developed; all setae on tarsus III and IV shorter than length of tarsus, spine-like, never leaf-shaped; solenidion omega 1 on tarsus I long, at least twice the length of empodial claw.

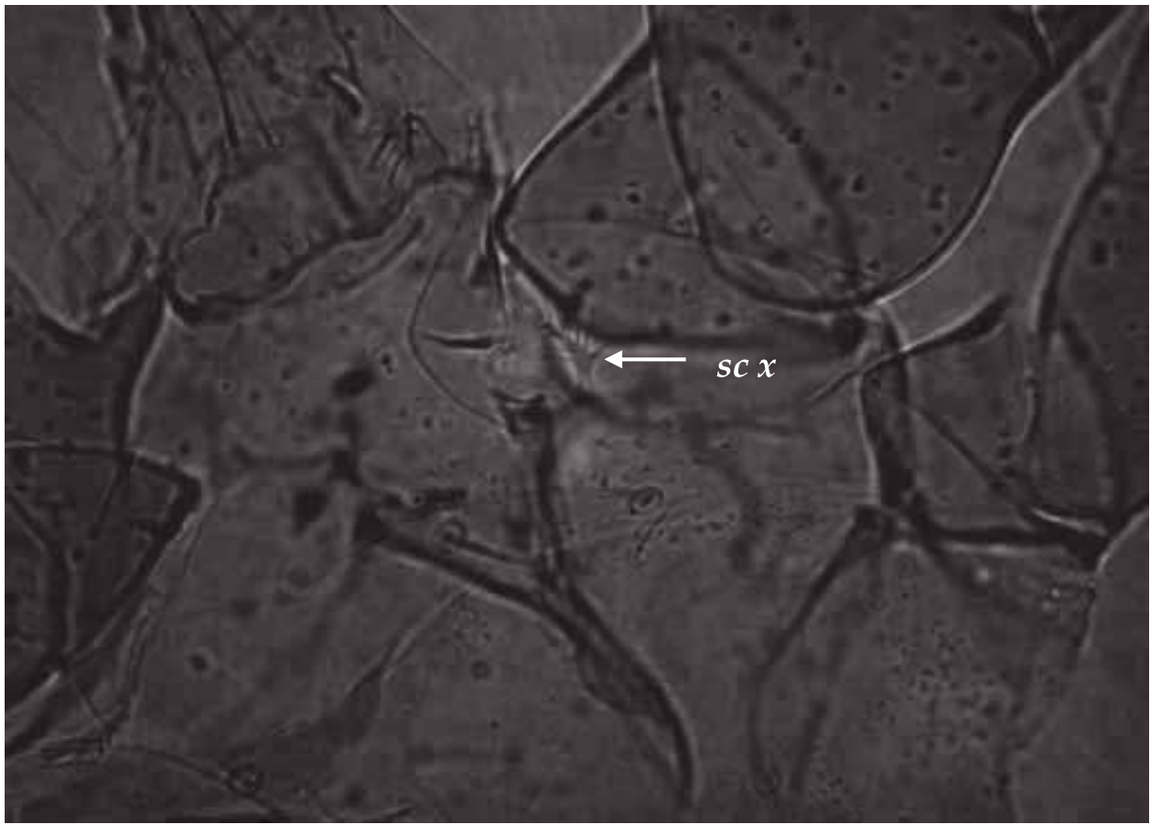

Fig. 2. *Acarus siro* – male, dorsal aspect: supracoxal seta; key: *sc x* = supracoxal seta.

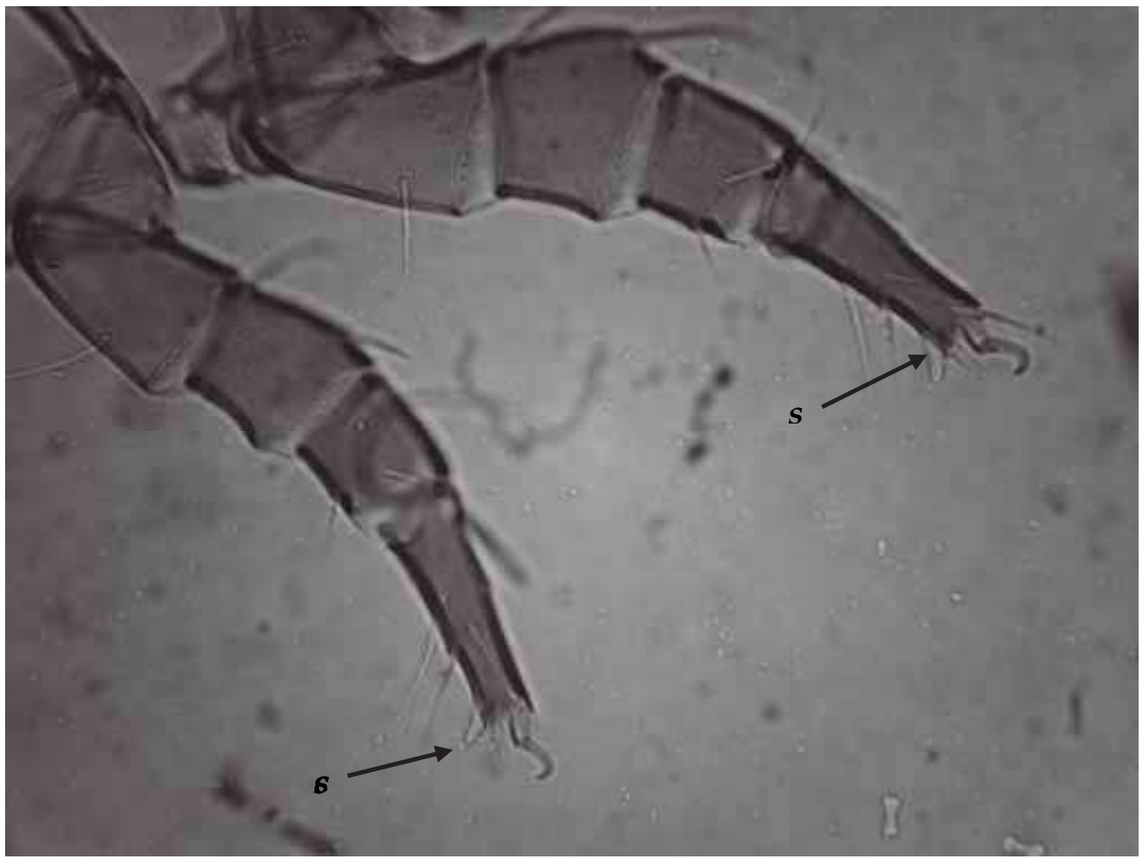

Fig. 3. *Acarus siro* – female, legs I and II; key: s = seta (spine) *s*.

6.1.2 Genus: *Tyrophagus* Oudemans

Differential diagnosis: In both sexes: setae *v e* distinctly barbed, relatively long, longer than the length of the genu I and usually positioned near anterior lateral corners of propodosomal shield; setae *v e* at almost the same level as *v i* and curve downwards; setae *sc i* longer than *sc e*; setae *c 1* and *d 2* usually almost equal in length, and shorter than *e 1* and *h 1*; the dorsal terminal seta *e* on tarsi I needle-shaped; presence of 5 ventral setae on tarsi I, of which the three central ones are thickened; solenidion sigma 1 on tibia I always less than three times as long as sigma 2; ventral apex of tarsi with proral and unguinal setae usually in the form of short, stout spines, occasionally one or both pairs strongly reduced or absent; tarsi I-II more than twice as long as basal width; proral setae thinner than unguinal setae but similar in length; Grandjean's organ finger-like. In males: without modifications of leg I; legs I not enlarged and the femur does not bear a ventral apophysis.

6.1.2.1 *Tyrophagus putrescentiae* (Schrank) (Fig. 4)

Differential diagnosis: In both sexes: anterior margins of propodosomal shield with pigmented spots (corneae); coxal plate II with a sinuous posterior margin so that the plate narrows sharply along the distal 1/3; tarsi I and II with solenidion omega 1 terminating in a distinctly expanded tip; distal 2/3 of solenidion omega 1 on tarsi I widened. In females: genital seta *g* longer than vulva; paraproctal setae *ad 1* much shorter than *ad 2*; setae *ad 2* distinctly longer than anal slit; internal spermathecal apparatus large, base of spermatheca

expanded, flat, spermathecal duct with distinct constriction about halfway along length; proximal part of spermathecal duct gradually widened. In males: aedeagus shorter (<20μm), S-shaped with two deep curves, one at base, the other in apical third; distal 1/3 of aedeagus curved at an angle of about 75-100° to its median part; tarsal copulatory suckers on tarsus IV equidistant from the base and apex of the segment; setae *ps 2* more than 1.8-2 times longer than the anal slit.

6.1.2.2 *Tyrophagus longior* (Gervais)

Differential diagnosis: In both sexes: anterior margins of propodosomal sclerite without pigmented spots *(corneae)*; supracoxal seta (*sc x*) thin, not expanded basally, pectination variable; setae *d 2* short, at most only slightly longer than *c 1*; setae *d 1* about 1.3-2 times as long as *c 1* and *d 2*; tarsi I-II with solenidion omega 1 long, slender, tapering toward tip; tip pointed and not expanded apically. In males: supracoxal seta (*sc x*) thin, with short lateral barbs of about equal lengt; the lateral sclerites supporting the penis (*aedeagus*) turned inwards; aedeagus straight only slightly curved distally and shaped like the spout of a teapot; aedeagus long, slender and tapering towards its free end; tarsus IV longer than the combined length of the genu and tibia; both tarsal copulatory suckers positioned nearer to the base of tarsus than the apex. In females: anterior margins of propodosomal sclerite without pigmented spots (*corneae*); internal spermathecal apparatus large, spermathecal duct moderate or large, base of spermatheca moderately long or very wide, distinctly wider than spermathecal duct; setae *ad 2* considerably longer than *ad 3*, *ps 3*, *ps 2* and *ad 1*.

6.2 Family: Glycyphagidae

6.2.1 Genus: *Lepidoglyphus* Zachvatkin

Differential diagnosis: In both sexes: setae *v e* absent; setae *v i* long and barbed, extend well beyond the tips of chelicerae; scapular setae arranged in a trapezoid or rectangle; gnathosoma at anterior apex of the body; prodorsal aclerite crista metopica absent; seta *sc x* slender, much branched; trochanteres I-II not surrounded basally by large, thickened apodemes (as in the genus *Xenocaster*); with pectinate subtarsal scales on all tarsi; on genu I solenidion sigma 2 more than 3 times longer than solenidion sigma 1; setae *la*, *ra*, *ba* on tarsus I arise in the distal third of the tarsus. In males: penis (*aedeagus*) posterior to coxal epimera I and positioned between coxae II and III and with anterior end marked by a triangular plate. In females: epigynium not fused to coxal apodemes I; vulva positioned between coxae II and III.

6.2.1.1 *Lepidoglyphus destructor* (Schrank)

Differential diagnosis: In both sexes: ventral seta *nG* of genua III not widened to form a pectinate scale; solenidion sigma on genu II not thickened. In males: without modifications of leg I; on genu I sigma 2 more than 4 times longer than sigma 1; ventral setae *kT* on tibiae III and IV does not arise from the edge of the arthrodial membrane as in *L. michaeli*. In females: setae *4 a* arises behind the posterior edge of the genital opening; anus terminal; 2 pairs of setae (*ad 3*, *ps 3*) inserted on either side of its anterior end. Hypopi: inactive, oval colourless, with reduced legs, rudiment of the genital slit and apodemes I and II feebly sclerotized; enclosed within the protonymphal cuticle.

6.2.2 Genus: *Glycyphagus* Hering

Differential diagnosis: In both sexes: without a subtarsal pectinate scale on all tarsi; usually with a prodorsal sclerite crista metopica; seta *sc x* more robust, forked and branched;

solenidion sigma 2 on genu I is more than twice as long as solenidia sigma 1 and omega 1; 2 ventral setae present on tibiae I and II; genital opening lies between coxae II and III.

6.2.2.1 *Glycyphagus domesticus* (De Geer)

Differential diagnosis: In both sexes: crista metopica extends from the base of the chelicerae to level of the anterior scapular setae (= *sc i*) (Fig. 5A); setae *v i* inserted almost in the middle of the crista metopica; setae *d 1* arising almost at the same

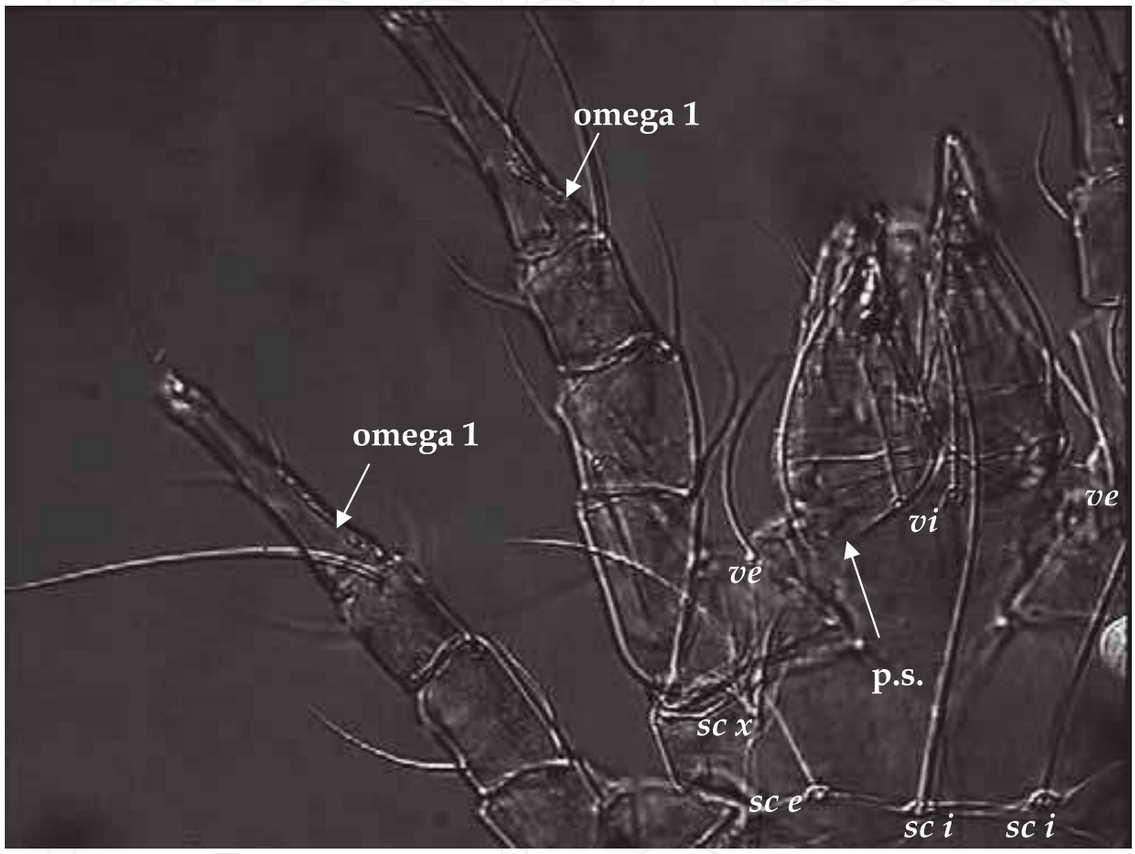

Fig. 4. *Tyrophagus putrescentiae* – legs I and II and dorsal propodosomal chaetotaxy; key: solenidia omega 1 on tarsi I and II; *sc x* = supracoxal seta; external (*v e*) and internal (*v i*) vertical setae; external (*sc e*) and internal (*sc i*) scapular setae.

level as *e 1*; the subtarsal seta is replaced on all the legs by a pectinate seta *wa* arising from the middle of the tarsus; setae *la, ba* and *ra* arise between the base of *wa* and the apex of the tarsus; solenidion omega 1 on tarsus I as a slender rod longer than omega 1 on tarsus II; solenidion omega 2 is relatively long and about half the length of solenidion omega 1 and much longer than the famulus epsilon; on genu I solenidion sigma 1 is less than half the length of sigma 2 and about the same length as omega 1. In males: with normal setae on tibiae I and II; on tibiae III and IV seta *kT* is well removed from the distal edge of the segment. In females: genital opening extends to the posterior edge of of acetabula III and it is shorter than the distance separating it from the anterior end of the anus; setae *4a* inserted just behind the hind end of the genital opening; 2 pairs of setae (*ad 3*, *ps 3*) lie on either side of the anterior end of the anal slit; a tubular bursa copulatrix projects from the hind margin

of the opisthosoma; setae *d 1* arising almost at the same level as *e 1*; distal setae (*la*, *ra*, *ba*, *wa*) on tarsus I more widely spaced. Hypopi: oval body, white in colour, with small bud-like gnathosoma, enclosed in protonymphal cuticle without reticulations.

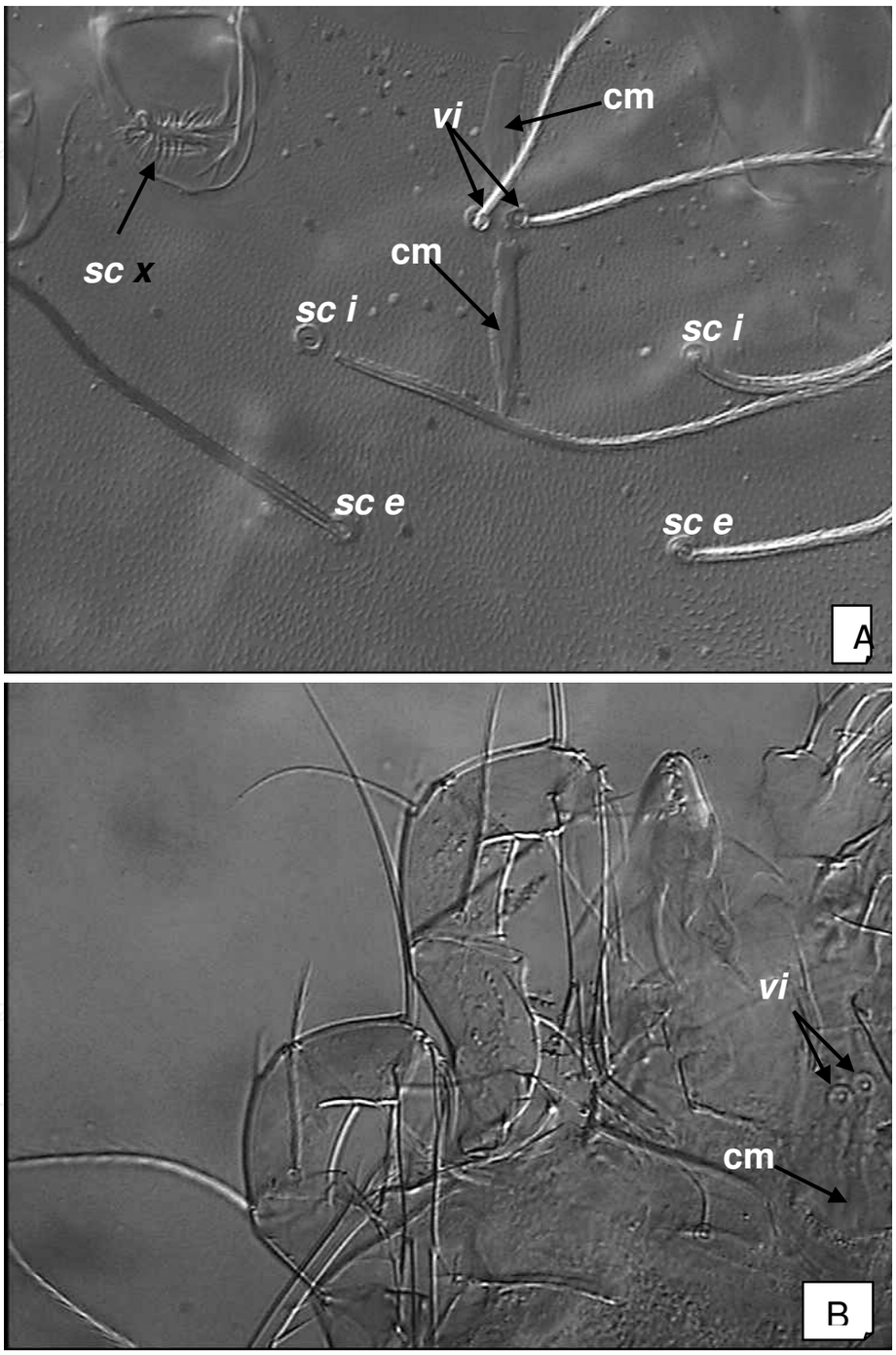

Fig. 5. *Glycyphagus* spp., females, dorsal aspects – shape of *crista metopica*: A. *G. domesticus*; B. *G. privatus*; key: cm = *crista metopica*; *v i* = internal vertical setae *sc i* = internal scapular setae; *sc e* = external scapular setae; *sc x* = supracoxal seta.

6.2.2.2 *Glycyphagus privatus* Oudemans (Syn.: *G. cadaverum* Schrank)

Differential diagnosis: In both sexes: setae *v i* inserted almost at the anterior end of the crista metopica (Fig. 5B); setae *d 1* arising anterior to *e 1* and on the same level as *c 1*; solenidion omega 2 on tarsus I very short, the same length as the famulus; solenidion sigma 1 on genu I shorter than in *G. domesticus*, much shorter than omega 1; seta *sc x* forked and branched. In females: genital opening (*vulva*) longer than in *G. domesticus*, extending as far back as the posterior edge of acetabula IV and longer than the distance between it and the anus. In males: with normal setae on tibiae I and II.

6.2.3 Genus: *Gohieria* Oudemans; *Gohieria fusca* (Oudemans)

Differential diagnosis: In both sexes: propodosoma without a division into 2 planes and extended forward and overhangs the gnathosoma; chelicerae with 1 seta; cuticle evenly sclerotized, pitted deeply tanned, pinkish-brown and ornamented with fine setae; ornamentation not in the form of small triangular microtrichae; no distinct propodonotal sclerite (or crista metopica) present; lateral body setae of both sexes not arising from tubercles; lamellae absent; setae *v i* and *sc x* pectinate, the remaining setae of the idiosoma only slightly serrated; setae *v i* situated almost on the apex of the propodosoma (only slightly more posterior); setae *v e* much more posterior, positioned almost in the same transverse line as setae *sc x*; seate *sc i*, *sc e* and *c 2* on a level with one another; legs short and massive, distinctly ridged; apodemes of all legs slender and unite to surround the genital opening; empodial claws present; tibiae and genua distinctly ridged especially in females; genua and femora freely articulated on all legs, distal edges of genua and femora expanded, femora without large ventral keel; tibiae I-II with 2 ventral setae; genu III with solenidion sigma present; solenidion phi on tibia I unusually long. In males: pretarsi expanded basally and arising ventrally on tarsal apex; legs III and IV with long pretarsi and noticeably bent; genitalia relatively simple, aedeagus anteriorly directed, positioned between coxal fields IV; body form of males similar to females, sexual dimorphism slight. In females: legs more slender than in males, the longitudinal ridges better developed; setae on tarsus I spaced out along the segment instead of being concentrated at the distal end; genital papillae everting in posterior region of oviporus (vulva); female oviporus region elongate, parallel sided; coxal apodemes I fusing separately with epigynium; ventral seta of femur I nude, without barbs.

6.3 Family: Chortoglyphidae

6.3.1 Genus: *Chortoglyphus* Berlese; *Chortoglyphus arcuatus* (Troupeau)

Differential diagnosis: In both sexes: chelicerae chelate, conspicuous; idiosoma oval and not divided into propodosoma and hysterosoma; body cuticle smooth and shining, without striations and microtrichae; discrete propodosomal sclerite absent; body setae short and nearly all smooth; genital papillae normal in form, strongly enlarged and reduced; solenidion omega 1 on tarsus I formed as a long curved rod arising close to a small solenidion omega 2; tarsus I with seta *wa* enlarged to form a stout spine and *ba* as a thin seta; only 1 solenidion sigma on genu I; tibiae I-II with dorsal solenidion and 0-2 ventral setae; legs ventrally positioned; praetarsi fleshy with inserted claws; empodial claws simple; anus positioned near posterior margin of body; both sexes with empodial claws simple or absent; ventral subcapitulum without external ridges; discrete coxal apodemes III and sometimes IV absent. In females: vulva (*oviporus*) longitudinal with genital valves fused to body anteriorly,

free posteriorly, and situated between coxae III and IV; genital papillae always associated with genital opening; 5 pairs of setae in anal region. In males: aedeagus long, situated between coxae I and II; adanal suckers conspicuous; 2 pairs of setae in anal region; tarsal suckers present on tarsi IV; legs III similar to legs IV.

6.4 Family: Pyroglyphidae

6.4.1 Subfamily Pyroglyphinae

Differential diagnosis: In both sexes: setae *v i* absent; tegmen well developed; cuticle from slightly to strongly sclerotized; striations either relatively thick, irregular and well spaced, or completely lacking the median area separating the epimera I punctate; idiosomal setae variable, either all very thin and very short, or with some setae (*sc e*, *h 2* and *h 3*) very long and strong. In females: cuticle lacking projections as in the genus *Glycyphagus;* setae *sc i* never very strong and long; ventral surface of tarsi I and II without projections; cuticle variable; epigynium distinctly separated from epimera I; tarsi III and IV lacking apical spines (except in *Weelawadjia* which presents these spines); posterior lip of the vulva always punctate; posterior vulvar lip generally fairly long and in some species incised in its anterior angle. In males: cuticle variable - slightly or strongly sclerotized; striations either present but irregular, thick and well spaced, or absent; setae *sc i* never very strong and very long; tarsi IV normal (not very short); legs III variable; femora III lacking a spur; tarsi IV always without a bifid or trifid subapicoventral spine; tarsi III with or without the subapicoventral spine; adanal copulatory suckers either present or lacking; tarsal copulatory suckers (on tarsi IV) either present or (generally) replaced by thin and short setae; setae *sc e* either long and strong (genera *Weelawadjia* and *Campephilocoptes*) or short and thin (other genera); tarsi III lacking an apical forked spine.

6.4.1.1 Genus: *Euroglyphus* Fain; *Euroglyphus maynei* (Cooreman)

Differential diagnosis: In both sexes: tegmen well developed, triangular with rounded apex (not bifid in the male as figured in the typical description); cuticle slightly sclerotized with rather well formed striations or folds; hysteronotum with in a median shield with poorly distinct margins; anterior legs lacking chitinous membranes; chaetotaxy reduced: trochanterals I-III, tibials IV, genital anterior setae (*3 b*) and anal external (*ps 2*) setae are lacking; tarsi III with 5 setae; tarsi IV with 3 setae; dorsal setae very thin and short; setae *h 3* very thin and short (maximum length 50 μm); setae *h 2* short (not exceeding 30 μm) and very thin; genu I with one solenidion. In males: tegmen with rounded, unforked apex; dorsal setae variable; opisthosoma slightly but regularly narrowed backwards; anus more posterior (anal suckers situated at 25 μm from the posterior margin of the body); posterior margin of the body straight and wide with 2 very small paramedian lobes; adanal suckers well developed; tarsi IV lacking suckers. In females: setae *sc e* thin and short (maximum 50 μm); no chitinous pouches at the bases of legs II; tegmen either triangular and prominent but with apex rounded and not forked or poorly developed, rounded with a small median notch; posterior lip of vulva punctate and short, not covering the vulvar slit; anterior angle of posterior vulvar lip not incised; tegmen triangular with rounded, not incised apex; hysteronotum striated with a median shield; copulatory vestibule ovoid, strongly sclerotized and opaque; tarsi I-IV without apical processes nor spines.

6.4.1.2 Genus: *Gymnoglyphus* Fain

Differential diagnosis: In both sexes: tegmen is triangular with bifid apex and the chaetotaxy is not reduced: the setae trochanterals I-III, tibials IV, setae *ps 2* and *3 b* are present; the tarsi

III and IV bear 6 and 5 setae, respectively. In males: adanal suckers well developed; dorsal setae short and thin; setae *h 3* and *h 2* very thin and short (maximum length 50 µm); tegmen deeply incised at apex; opisthosoma strongly narrowed backwards; anus more anterior (adanal suckers at 40 µm from posterior margin of body); posterior margin of body (idiosoma, opisthosoma) narrower, concave in the middle and with 2 small but well distinct paramedian lobes; chaetotaxy normal (trochanteral setae I-III, tibial IV setae, *ps 2* and *3 b* setae present). In females: setae *sc e* thin and short (maximum 50 µm); setae *h 2* and *h 3* short or very short (less than 50 µm) and thin; no chitinous pouches at bases of legs II; tegmen triangular, prominent with apex forked; posterior vulvar lip very long; anteriorly and completely covering the vulvar slit, its anterior angle not incised; opening of bursa copulatrix situated near the posterior extremity of anus and followed by a small ovoid strongly sclerotized pouch (vestibule); dorsum with thick striations and a small median opisthosomal (opisthonotal) shield; epimera I free.

6.4.1.2.1 *Gymnoglyphus longior* (Trouessart)

Differential diagnosis: posterior region of opisthonotum not punctate; setae *ps 3* situated at the junction of the anterior third and the posterior two thirds of the anus; setae *h 2* 20-25 µm long; idiosoma 280-290 µm long.

6.4.1.2.2 *Gymnoglyphus osu* Fain et Johnston

Differential diagnosis: only the female of this species is known; posterior region of dorsum (opisthonotum) punctate; setae *a i* situated close to the anterior angle of the anus; setae *h 2* 40-50 µm long; larger species; idiosoma 328-345 µm long; smaller length of the solenidia of tibiae I and II.

6.4.2 Subfamily: Dermatophagoidinae

Differential diagnosis: In both sexes: setae *v i* absent; tegmen absent; cuticle lacking projections as in the genus *Glycyphagus;* cuticle soft, with well-developed striations; striations generally very thin and set close together, only rarely of the striated-punctate type (*Sturnophagoides*); the area separating epimera I exceptionally punctate; setae *sc e* strong and long (except in the genus *Malayoglyphus* where they are short or very short); setae *h 2* and *h 3* long. In females: setae *sc i* never very strong and long; ventral surface of tarsi I and II without projections; epigynium distinctly separated from epimera I; tarsi III and IV lacking apical spines; cuticle soft and finely striated; hysteronotal shield present only in *Sturnophagoides*; posterior lip of vulva (vulvar lip) soft and striated, not punctate and not incised anteriorly (except in *Sturnophagoides* where this lip is punctate, either partly or completely, and incised anteriorly. In males: cuticle soft and striated; setae *sc i* never very strong and very long; tarsi IV normal (not very short); legs III variable; femora III lacking a spur; tarsi IV always without a bifid or trifid subapicoventral spine; tarsi III with or without the subapicoventral spine; adanal copulatory suckers present; tarsal copulatory suckers (on tarsi IV) present (except in *Malayoglyphus*); tarsi III with an apico-ventral forkate spine (except in *Malayoglyphus* and *Sturnophagoides*, where this spine is lacking).

6.4.2.1 Genus: *Sturnophagoides* Fain

Differential diagnosis: In both sexes: striations of the cuticle punctate and more or less sclerotized over a part or all of the body; the region between epimera I completely punctate; setae *sc e*, *h 2* and *h 3* long or very long; setae *c p* very short.

In females: dorsum with a median hysteronotal shield (absent in the other genera of *Dermatophagoidinae*); cuticle striated-punctate over a large part or all of the body; posterior lip of vulva long, punctate (either partially or completely) and incised in its anterior angle (as in some Pyroglyphinae). In males: perianal chitinous frame not denticulate; legs III and IV less unequal; the legs III a maximum of 1.6 times as long as IV; tarsi III either with a subapical conical unforked spine and 5 thin setae or with all setae simple; tarsi IV with 2 small tarsal copulatory suckers; adanal copulatory suckers well developed; legs III distinctly stronger and longer than legs IV; at least tarsus I with an apical process; setae *sc e* strong and long (minimum 110 μm).

6.4.2.1.1 *Sturnophagoides brasiliensis* Fain

In females: small species; idiosoma 246-262 μm long; posterior lip of vulva punctate only in its lateral parts; hysteronotal shield situated inside setae *e 1;* striations behind the hysteronotal shield distinctly thickened, more punctate and more spaced than on other parts of the body; solenidia of genua I very short (10 and 4 μm). In males: idiosoma 175-185 μm long; perianal chitinous frame narrow, oval in shape; tarsi III with an apical curved process, but lacking a subapical spine.

6.4.2.1.2 Sturnophagoides bakeri Fain

Differential diagnosis*:* In females: larger species (idiosoma 390-420 μm long); posterior lip of vulva completely punctate; striations behind the hysteronotal shield not modified; setae *d 1* and *e 1* situated outside the hysteronotal shield; solenidia of genua I 30-35 and 6 μm long, respectively. In males: idiosoma 270-290 μm long; perianal chitinous frame wide, piriform (pear-shaped); tarsi III ending in a conical spine and a curved apical process; hysteronotal shield piriform passing hardly beyond setae *d 1* (heteromorphic males).

6.4.2.1.3 *Sturnophagoides petrochelidonis* Cuervo et Dusbabe**k**

Differential diagnosis*:* In females: idiosoma 310-379 μm long; posterior lip of vulva completely punctate; striations behind the hysteronotal shield not modified; setae *d 2* and *d 3* situated on the margins of the hysteronotal shield. In males: idiosoma 245-272 μm long; perianal chitinous frame wide, piriform (pear-shaped); tarsi III ending in a conical spine and a curved apical process; hysteronotal shield rectangular, reaching setae *c 1* (heteromorphic males).

6.4.2.2 Genus: *Hirstia* Hull

Differential diagnosis: In both sexes: striations of the cuticle are finer and set closer together; striations are separated by less than 1 μm (at the level of setae *c 1*); more distinct reduction of legs IV compared to legs III. In females: hysteronotum striated, lacking a median shield; cuticle with non-punctate striations; cuticle between epimera I not punctate; posterior lip of vulva smaller and shorter and with anterior angle not incised; legs III distinctly longer (length of the four apical segments - tarsus-femur) and thicker than legs IV; the ratio of the lengths of legs IV / lengths of legs III = 1 : 1.4 (to 1.56); cuticle with very thin striations separated by less than 1 μm (at the level of setae *d 1*). In males: perianal chitinous frame finely denticulate inside; legs III much thicker than legs IV and from 1.8 to 1.9 times longer than the latter (length of the 4 apical segments); tarsi III bearing in their middle 2 strong conical spines (setae *w* and *r*).

6.4.2.2.1. *Hirstia chelidonis* Hull

Differential diagnosis*:* In both sexes: larger species. In females: idiosoma 395-426 μm long; posterior region of dorsum not punctate and not sclerotized; length of legs III 174 μm, legs

IV 118 μm (= length of 4 apical segments); length of tarsi I-IV = 40-43-66-48 μm. In males: idiosoma 321 to 345 μm long; tarsi I-IV = 33-39-51-24 μm long.

6.4.2.2.2. *Hirstia domicola* Fain, Oshima et van Bronswijk

Differential diagnosis: In females: idiosoma 298-310 μm long; posterior region of dorsum sclerotized and punctate mainly around the bases of setae *d 5* and *l 5;* legs III and IV – 123-129μm and 85-90 μm long, respectively (= length of 4 apical segments); tarsi I-IV = 40-43-66-48 μm long, respectively. In males: idiosoma 240 to 248 μm long; tarsi I-IV shorter, 22-27-32-18 μm long, respectively.

6.4.2.3 Genus: *Malayoglyphus* Fain, Cunnington et Spieksma

Differential diagnosis: In both sexes: short, thin shape of setae of the setae *sc e* ; the normal development of legs IV which are as long as legs III; the presence of only one solenidion on genu I. In females: hysteronotum striated, lacking a median shield; cuticle with non-punctate striations; cuticle between epimera I not punctate; posterior lip of vulva smaller and shorter and with anterior angle not incised; legs III and IV equal or subequal in length and in width; cuticle with dorsal striations more spaced (separated by 1.2 to 2.3 μm at level of setae *d 2*); setae *sc i* and *sc e* thin and short, either equal or suequal, or slightly unequal (*sc e* less than 35 μm long); epigynium poorly developed and slightly sclerotized; genu I with only one very short solenidion (5-6 μm). In males: perianal chitinous frame not denticulate; legs III and legs IV less unequal; the legs III a maximum of 1.6 times as long as legs IV; tarsi III with only thin setae (there is no forked spine on the apex of tarsus III as in *Dermatophagoides*) setae *sc e* thin and short (maximum 30 μm long); adanal copulatory suckers poorly developed (reduced); tarsi I and II without apical processes; legs III and IV subequal; tarsi IV without suckers; tarsus IV bears 3 thin setae and one rounded papilla which is a remnant of a sucker.

6.4.2.3.1 *Malayoglyphus intermedius* Fain, Cunnington et Spieksma

Differential diagnosis: In both sexes: smaller species. In females: idiosoma 218-243 μm long; setae *sc i* and *sc e* equal or subequal (about 12-15 μm long); posterior half of opisthonotum distinctly punctate and with thicker and more spaced striations than on other parts of the dorsum. In males: idiosoma 168 to 175 μm long; setae *sc e* and *sc i* equal or subequal (12-15 μm long); striations of the posterior half of hysteronotum thick, punctate and sclerotized.

6.4.2.3.2. *Malayoglyphus carmelitus* Spieksma

Differential diagnosis: In both sexes: larger species. In females: idiosoma 320-348 μm long; setae *sc e* distinctly longer (30-35 μm) than *sc i* (15 μm); punctation of posterior half of opisthonotum indistinct. In males: idiosoma 240 to 283 μm long; setae *sc e* distinctly longer (30 μm long) than setae *sc i* (15 μm); posterior half of hysteronotum with a large punctate and not striated shield.

6.4.2.4 Genus: *Dermatophagoides* Bogdanov

Differential diagnosis: In both sexes: cuticle with dorsal striations more spaced (separated by 1.2 to 2.3 μm at level of setae *d 1*); setae *sc i* and *sc e* very unequal; the *sc e* long and strong; genu I with 2 very unequal solenidia. In females: hysteronotum striated, lacking a median shield; cuticle with non-punctate striations; cuticle between epimera I not punctate; posterior lip of vulva smaller and shorter and with anterior angle not incised; legs III and IV equal or subequal in length and in width; setae *sc i* and *sc e* very unequal; the *sc e* long and strong; epigynium well developed and sclerotized. In males: perianal chitinous frame not denticulate; legs III distinctly stronger and longer than legs IV; but the legs III a maximum of

1.6 times as long as legs IV; tarsi III with a strong subapical forked (bifid) spine (seta *f*); setae *sc e* minimum 110 μm long; tarsi IV with two small copulatory tarsal suckers; adanal suckers well developed; at least tarsus I with an apical process.

6.4.2.4.1 The *Dermatophagoides pteronyssinus* group

Differential diagnosis: In females: median area comprized between setae *d 1* and *e 1* [= M area] completely striated longitudinally; opening of the bursa copulatrix situated on posterior margin of the body. In males: hysteronotal shield long, reaching forwards to setae *d 1* and/or further in front (anteriorly).

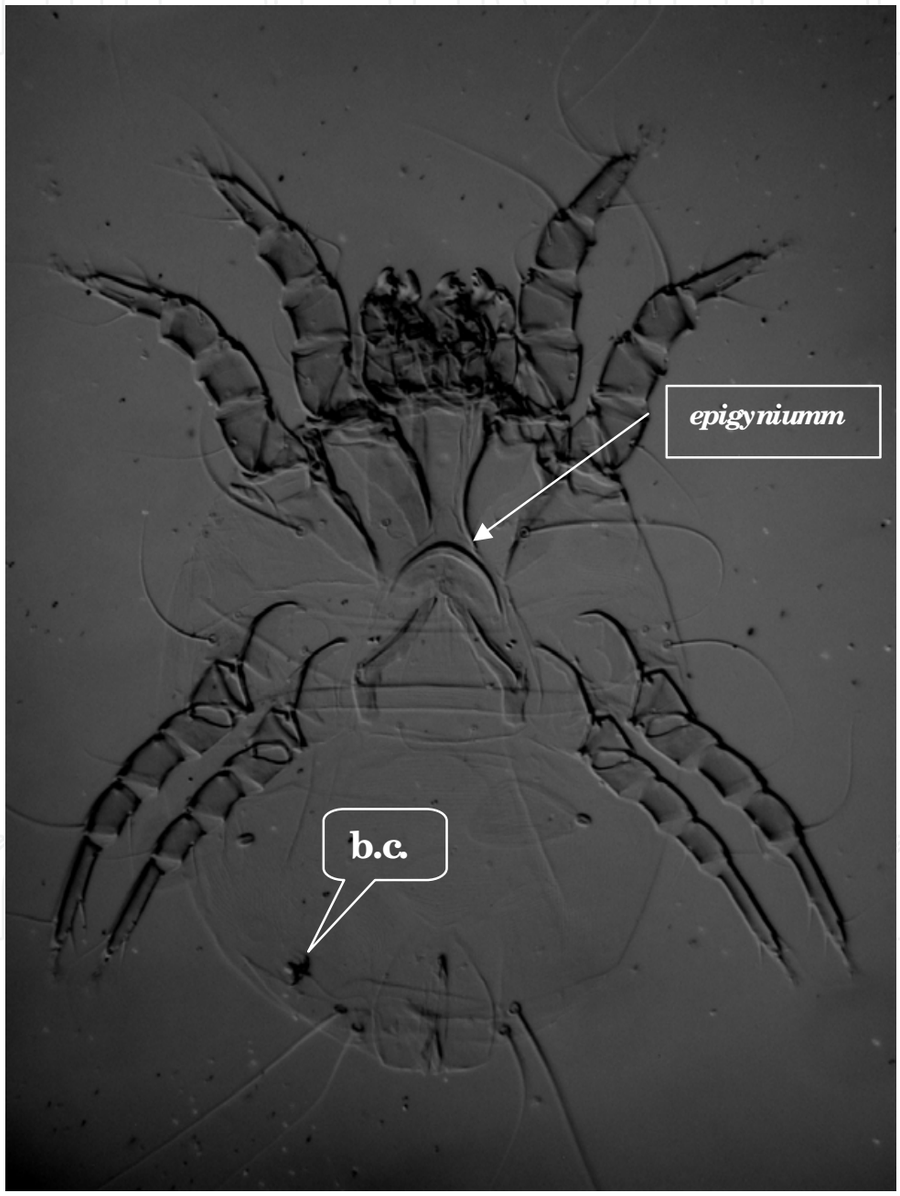

Fig. 6. *Dermatophagoides pteronyssinus,* female – ventral aspect; key: b.c. = sclerite surrounding an internal opening of *bursa copulatrix*; *epigynium* = anterior genital apodeme, pregenital sclerite.

6.4.2.4.1.1. *Dermatophagoides pteronyssinus* (Trouessart)

Differential diagnosis: In females (Fig. 6): bursa copulatrix very narrow, of uniform calibre and ending inside (proximally) in a daisy-like sclerite. In males: hysteronotal shield distinctly extending forward to beyond the bases of setae *d 1;* coxae II closed; adanal suckers 12 μm in diameter; males homeomorphic: epimera I free; tarsi I with 2 unequal apical processes (ongles); tarsus II with a small apical process; legs III 1.3 times thicker (at level of femur) and 1.46 times longer (length of 4 distal segments) tthan legs IV; setae *h 2* and *h 3* with bases poorly sclerotized; setae *cp* 80-90 μm long; setae *d 2* situated at 40 μm from the opening of the fat gland; the male differs from that of *D. evansi* mainly by: the dorsal shield is shorter and broader than in *D. evansi;* ratio width (at level of *d 1*) : length = 1 : 1.8-1.9 [whilst in *D. evansi* this ratio is 1 : 2.5]; legs III and IV are much less unequal than in *D. evansi.*

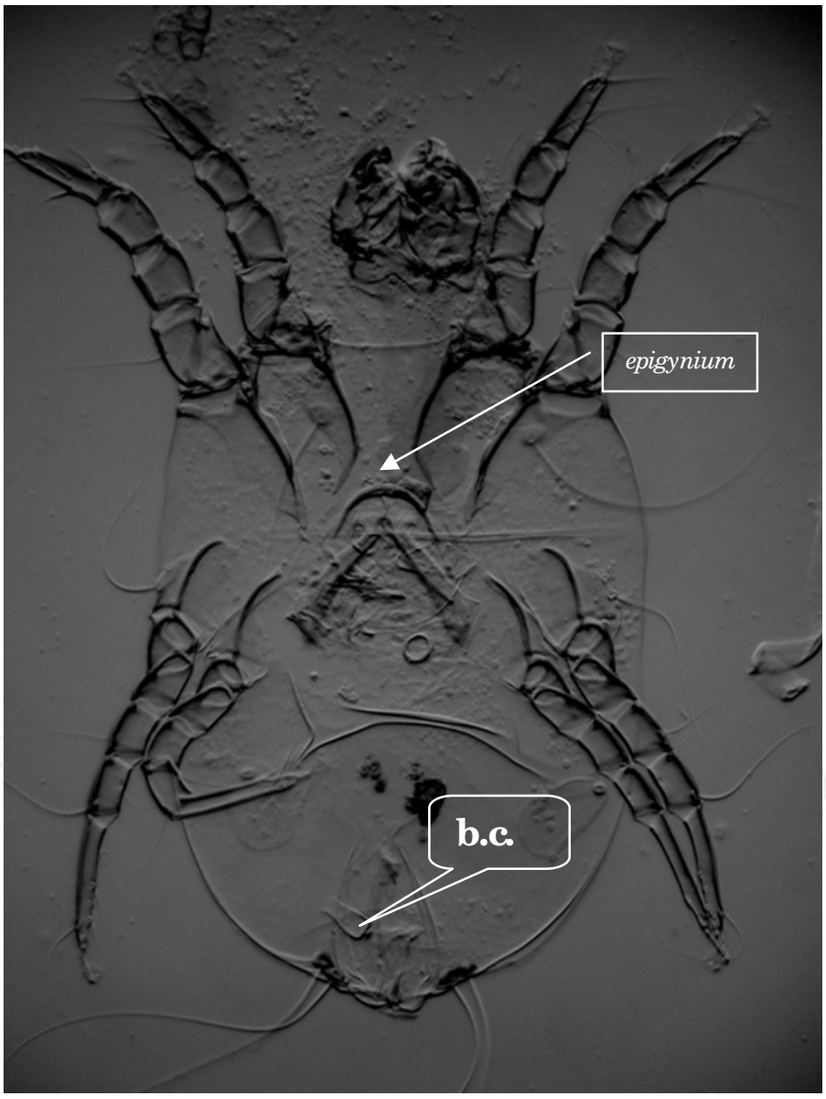

Fig. 7. *Dermatophagoides evansi,* female – ventral aspect; key: b.c. = sclerite surrounding an internal opening of *bursa copulatrix*; *epigynium* = anterior genital apodeme, pregenital sclerite.

6.4.2.4.1.2 *Dermatophagoides evansi* Fain, Hughes et Johnston

Differential diagnosis: In females (Fig. 7*):* bursa copulatrix strongly enlarged in its distal third and very narrow in its proximal two thirds (internal); spermatheca sclerotized and tulip-like. In males: hysteronotal shield distinctly extending forward to beyond the bases of setae *d 1;* coxae II closed; adanal suckers 12 µm in diameter; males homeomorphic, epimera I free; tarsi I with 2 unequal apical processes (ongles); tarsus II with a small

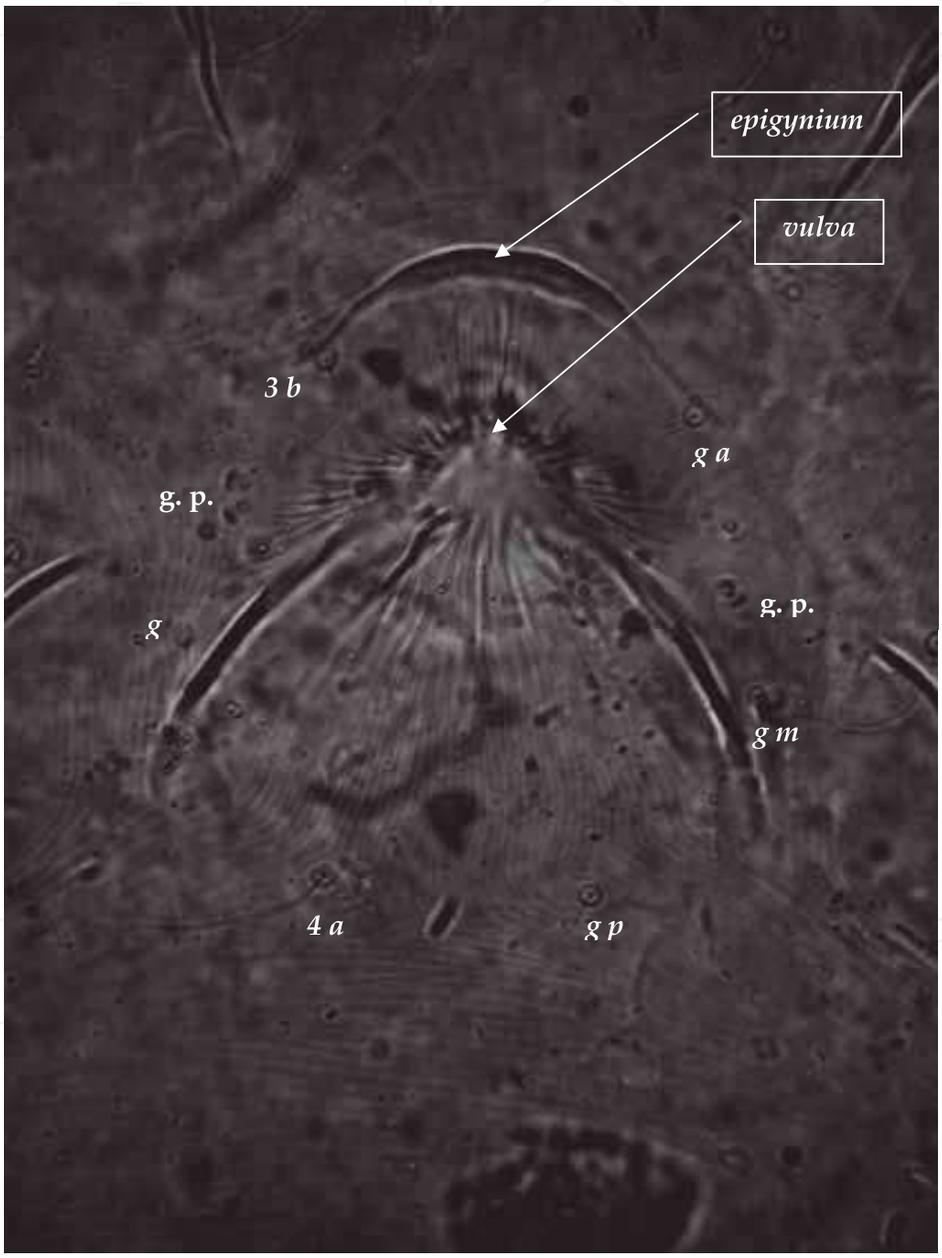

Fig. 8. *Dermatophagoides farinae,* female – ventral aspect, *vulva* and *epigynium* (anterior genital apodeme, pregenital sclerite); genital chaetotaxy: setae *3 b* (or genital anterior setae *g a*), genital setae *g* (or genital median setae *g m*), setae *4 a* (or genital posterior setae *g p*); g. p. = genital papillae.

apical process; legs III 1.8 times thicker (at level of femur) and 1.6 times longer (length of 4 distal segments) than legs IV; setae *h 2* and *h 3* with bases strongly sclerotized; setae *cp* 110 µm long; setae *d 2* situated at 55-65 µm from the opening of the fat gland; the male differs from that of *D. pteronyssinus* mainly by: the dorsal hysterosomal shield is longer and narrower; ratio width (at level of setae *d 1*) : length = 1 : 2.5 [whereas in *D. pteronyssinus* this ratio is 1.8 to 1.9]; legs III and IV are much more unequal than in *D. pteronyssinus*.

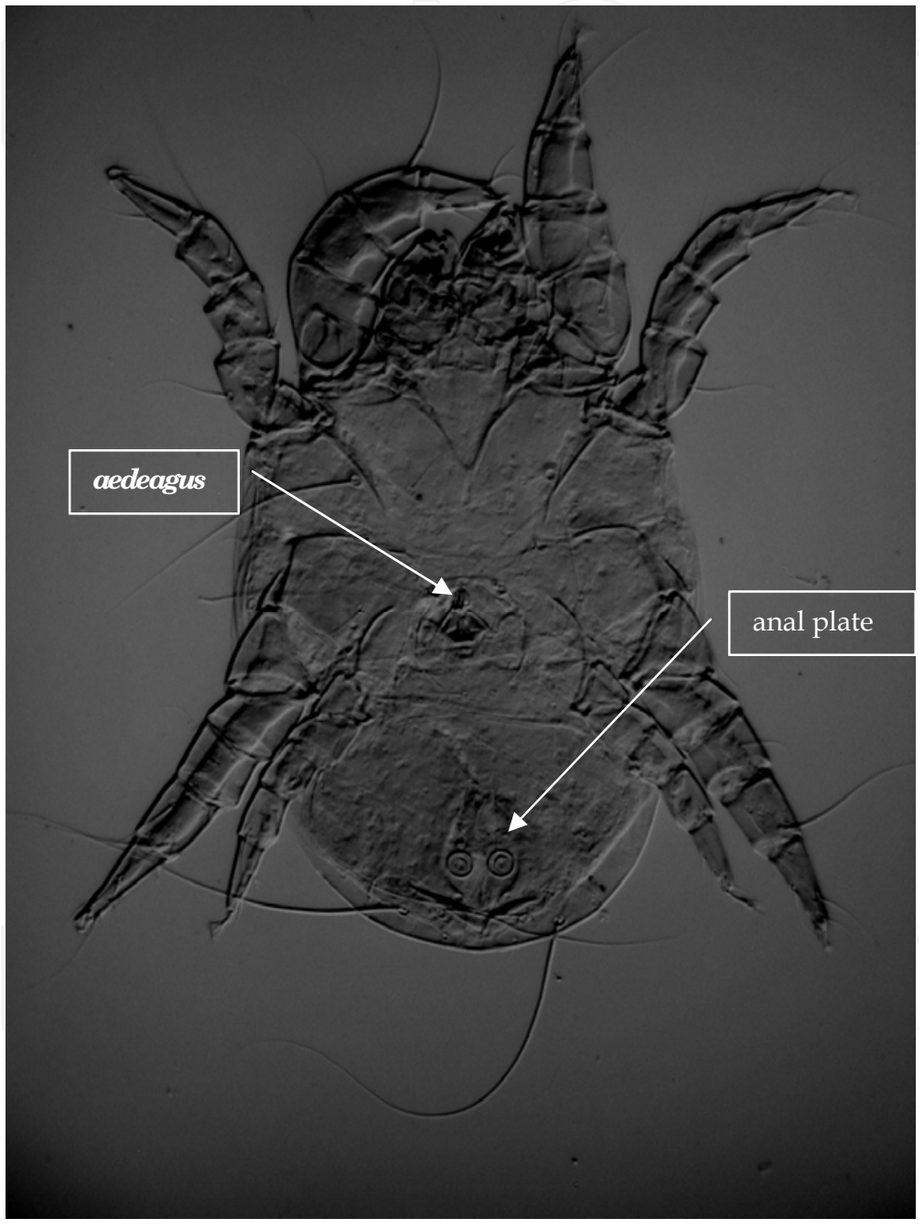

Fig. 9. *Dermatophagoides farinae*, heteromorphic male – ventral aspect.

6.4.2.4.2 The *Dermatophagoides farinae* group

Differential diagnosis: In females: striations of the posterior half of the area M only slightly convex; opening of the bursa situated ventrally on the side of the posterior third of the anus;

first part of the bursa forming (sometimes not) a sclerotized pocket (vestibule). In males: hysteronotal shield short, extending forwards to a point situated at equal distance from setae *d 1* and *e 1*; hysteronotal shield wider than long (in its middle); seta r on tarsus III is thin and situated basally epimera I free in the homeomorphic male.

6.4.2.4.2.1 *Dermatophagoides siboney* **Dusbabek, Cuervo et Cruz**

Differential diagnosis: In both sexes: small species. In females: idiosoma 258-311 μm long; propodonotal shield approximately twice as long as wide. In males: small species; idiosoma 199-245 μm long; all known males are homeomorphic.

6.4.2.4.2.2 *Dermatophagoides farinae* Hughes

Differential diagnosis: In both sexes: larger species. In females: idiosoma 395 to 435 μm long; propodonotal shield approximately 1.4 times as long as wide; vestibule of bursa well sclerotized and shaped like a calabash pipe; beyond this vestibule the bursa is not expanded; tarsus I generally with well developed curved process (ongle); epigynium crescent-shaped (Fig. 8). In males: idiosoma 285-345 μm long; males either homeomorphic with epimera I free (and normal first legs) or heteromorphic with epimera I fused to form a V or Y (and enlarged I legs) (Fig. 9).

6.4.2.4.2.3. *Dermatophagoides microceras* Griffiths et Cunnington

Differential diagnosis: In females: idiosoma 395 to 435 μm long; propodonotal shield approximately 1.4 times as long as wide; vestibule of bursa lacking, the bursa opens at the bottom of a non-sclerotized depression of the tegumen; the first part of the bursa proper is slightly dilated and distinctly sclerotized; apical process of tarsus I generally very small or lacking. In males: idiosoma 285-345 μm long; males either homeomorphic with epimera I free (and normal first legs) or heteromorphic with epimera I fused to form a V or Y (and enlarged I legs).

7. Phylogenetic reconstructions of the Pyroglyphidae

The family Pyroglyphidae presently consists of 47 species and 20 genera, whose species are associated with birds, mammals or house dust and stored products (Mumcuoglu et al., 1976; Fain et al., 1990; Evans, 1992; Colloff, 2009; Krantz and Walter, 2009; Solarz, 2004b, 2011). The majority of these species are nidicolous, with bird associates outnumbering mammal associates. They are associated with many avian groups, but most of them are nidicoles of Passeriformes. These mites feed on animal detritus and/or dander in the nests and have given rise to several more typically parasitic taxa (Fain et al., 1990). The Pyroglyphidae are small mites, whitish in colour; the length of idiosoma of adults ranges from 168 μm (*Malayoglyphus intermedius*) to 585 μm (*Onychalges longitarsus*). The idiosoma is generally oval in shape with parallel sides, and broadly rounded anterior and posterior margins. The degree of the cuticle sclerotization is variable; in some subfamilies or genera it is almost completely sclerotized, without true striations, whereas in others the cuticle is soft and striated, in which case the dorsal shields are more poorly developed. Morphology and biology of the pyroglyphids seems to indicate that the free-living forms have evolved from obligate parasitic ancestors (OConnor, 1982; Woolley, 1988). These mites morphologically show some characters of parasitic Psoroptidia, particularly a regression of legs IV (especially in males), dorsal shields (mainly the hysterosomal), copulatory suckers (vestigial or

reduced, in the shape of small sclerotized rings), tarsal claws (only in the form of a small median axis). On the other hand, it has been suggested by Fain (Fain et al. 1990) that in the Pyroglyphidae the regression of the organs has preceeded the invasion of the host as if there were a preadaptation. This regression involves also an idiosomal and leg chetotaxy. Pyroglyphids have 8 setae on tarsi I and on II, and 1 seta on each of tibiae I and II, whereas in the Acaridae there are 13 and 12 tarsal setae on tarsi I and II, respectively, and 2 tibial setae on tibiae I and II. Vertical setae are generally absent; thus, the scapular setae (*sc e* and *sc i*) are the first pair, most anteriorly located. The absence of setae *v e* is the typical feature of the Pyroglyphidae; whereas setae *v i* occur only in the members of the genus *Paralgopsis* (subfamily Paralgopsinae). The external scapulars (*sc e*) are longer, more or less, as the internal setae (*sc i*). Female have only 2 pairs of adanal setae (*ps 2* and *ps 3*), whereas females of the family Acaridae have 5-6 pairs of anal/adanal setae. Phylogeny basically means, the history of the tribe. Reconstructing a phylogeny is similar to compiling a genealogic tree in that both indicate the degree of relatedness between the members of the tribe, or other taxon. However, the family tree is based on known fact and documentary evidence, whereas a phylogeny is only ever, at best, an hypothesis of the most likely evolutionary history of the taxon (Colloff, 1998). There has been no detailed phylogenetic revision of the family Pyroglyphidae to date. In opinion of Colloff (1998), the host relationships of pyroglyphid mites with birds indicate that the two subfamilies which contain species found in house dust, the Pyroglyphinae and Dermatophagoidinae, are the most widespread geographically and the most species-rich. They are associated with a higher diversity of avian taxa than the other subfamilies, that do not contain the house-dust-mite species (Colloff, 1998). Indeed, the Pyroglyphidae probably form a link between the free living and parasitic Astigmatina. It was also shown that some pyroglyphids are able to adopt a parasitic mode of life and feeding (Fain et al., 1990; Proctor, 2003; Dabert et al., 2010). But mites of this family are perhaps best known as the house dust mites, because of their occurrence in human dwellings. Main sources of the mite allergens in dwellings usually are beds, couches or sofas in bedrooms and couches or sofas in living-rooms (family rooms). New dwellings might be colonized via mite-infested furniture, by humans, on skin, clothing, or by their pets (Hewitt et al., 1973; Hoeven et al., 1992; Perotti et al., 2009) The natural sources of allergenic mites in stores are still not quiet known (Hallas & Iversen, 1996; Solarz et al., 2007; Hallas, 2010). Possible sources of these mites in farming environments are also the nests of synanthropic birds (Hughes, 1976; Wharton, 1976; van Bronswijk, 1981; Fain et al., 1990; Solarz et al., 1999). On the other hand, it has been suggested that the majority of the mite population is brought from the cultivated field into the stores, and that the open field is the main source of storage-mite populations (Hallas & Iversen, 1996), whereas the bird nests are less important (Solarz, 2003).

Indoor acarofauna depends on the people living and working in these buildings. Different indoor environments are very important places for forensic investigations, but the richness of mite biodiversity, phylogenetic relationships between different groups of domestic mites and their associations with potential hosts has not been exploited by forensic investigators. Summarizing it should be stressed that knowledge about occurrence of particular species of parasitic and/or synanthropic on man or in human environment as well as the correct identification of mites colonising dead body are very important factors in forensic investigations of past human activity (Perotti, 2009b; Braig & Perotti, 2009; Perotti & Braig, 2009; OConnor, 2009; Turner, 2009; Solarz, 2009; Desch, 2009; Baker, 2009, Proctor, 2009).

8. Domestic mites and forensic medicine. Final remarks

More than 100 species of mites from over 60 families were collected from animal carcases, and apprioximately 75 mite species from over 20 families from human corpses (Braig & Perotti, 2009), including also the astigmatid mite taxa. Within the Astigmatina were involved some domestic mite species such as *Acarus siro*, *A. farris*, *A. immobilis*, *Tyrophagus longior*, *T. putrescentiae*, *Tyrolichus casei*, *Caloglyphus berlesei*, *Rhizoglyphus echinopus*, *Lardoglyphus* spp. and *Lepidoglyphus destructor*. Among them from human carcases were noted *Myianoetus diadematus* (mass population), *C. berlesei* (many), *A. siro* (common), *A. immobilis* (common), *T. longior* (abundant), *T. putrescentiae* (common and abundant) and *L. destructor* (very rare) (Braig & Perotti, 2009). *Tyrophagus longior* is particularly active at lower temperatures. This mite is almost always associated with dry cheese and/or meat. It was known to feed on the fatty acids and soapy substances containing ammonia that form on carcasses during dry decomposition (Perotti et al., 2009). In 1878 these mites were found in the mummified body of a newborn baby girl in Paris and they were studied by Mégnin. He estimated and identified approximately 2.4 million specimens of *T. longior* in this material (Perotti, 2009). In a more recent case reported from Germany a child corpse found in a basement was also associated with a mass populations of *Myianoetus diadematus*, *A. immobilis* and *T. putrescentiae* (OConnor, 2009; Braig & Perotti, 2009). Mites originating from outdoor environments can also be useful trace evidence and give accurate evidence about movements or transportation of a body (Perotti et al., 2009). Many mite species arrive at a carcase via phoresy on insects. The phoresy is often taxon specific (Braig and Perotti, 2009). Phoretic hypopi (heteromorphic deutonymphs) are known in *Acarus farris*, *A. siro*, *Caloglyphus berlesei*, *Rhizoglyphus echinopus* and *Myianoetus diadematus*. Summarizing, it should be stressed that the astigmatid mites have played little role in the field of forensic medicine to date (OConnor, 2009). Domestic mites have not yet been explored in forensic investigations, but there is every reason for doing this. Dust mites and other domestic mites are globally present, yet species composition may vary between seasons, between dwellings and even places within a single indoor environments (e.g., beds vs. floors, floors vs. upholstery furniture, or dust from a book shelve vs. a librarian's desk) (Solarz, 2009). Subtle differences in the house-dust-mite acarofauna between sites may yield valuable information, for instance as indicator of time and circumtances of death (Solarz 2009; Perotti, 2009).

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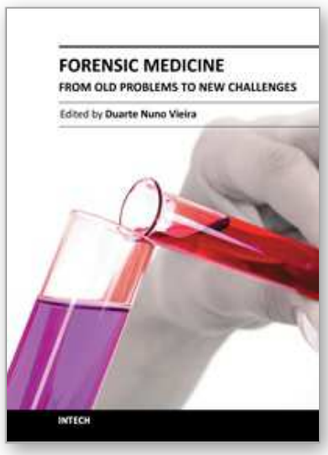

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Forensic medicine is a continuously evolving science that is constantly being updated and improved, not only as a result of technological and scientific advances (which bring almost immediate repercussions) but also because of developments in the social and legal spheres. This book contains innovative perspectives and approaches to classic topics and problems in forensic medicine, offering reflections about the potential and limits of emerging areas in forensic expert research; it transmits the experience of some countries in the domain of cutting-edge expert intervention, and shows how research in other fields of knowledge may have very relevant implications for this practice.

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