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Mites occurring in farm buildings as allergic agents and indicators in forensic analyses

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Original research

ABSTRACT


Storage mites, especially several species in the families Acaridae, Glycyphagidae, and Chortoglyphidae are commonly found in farming and occupational environments. They are a source of clinically important allergens, and may also have a significant impact on forensic analyses. They may be of use in forensic situations, particularly as allergenic taxa, in relation to workers who are occupationally exposed to mites. Additionally, because many of them are present through all stages of vertebrate decomposition, they may provide valuable information as indicators of time and circumstances of death. This study aimed to investigate the possible occurrence and abundance of allergenic mites in farm buildings, as well as to examine and analyse collected material samples in relation to forensic medicine. A total of 58 samples from 15 farms in the Żywiecki district (Silesian Province, Poland) were examined as potential sources of allergenic mites in farm buildings with a special reference to forensic acarology. Mites were found in all the examined samples. A total of 4,473 specimens were isolated and 22 mite species were identified. Most of them were found in barns and pigsties. The species composition of the acarofauna was varied across the particular types of farm buildings examined. Generally, the dominant species were representatives of families Acaridae and Glycyphagidae (Astigmatina). This knowledge may be useful in a variety of cases or situations in the field of forensic medicine.

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Keywords allergenic mites; storage mites; Acaridae; Glycyphagidae; Chortoglyphidae; agricultural areas; forensic acarology; Poland

Introduction

It is impossible to draw a line between allochthonic and autochthonic fauna of mites inhabiting farm buildings (van Bronswijk 1981; Solarz 2009). Storage mites (Acari: Sarcoptiformes: Astigmatina), especially several species in the families Acaridae (*Acarus siro*, *A. farris*, *Tyrophagus longior*, and *T. putrescentiae*), Glycyphagidae (*Glycyphagus domesticus* and *Lepidoglyphus destructor*), and Chortoglyphidae (*Chortoglyphus arcuatus*), are commonly found in hay, straw, stored products, barns and other farming and occupational environments, as well as in dust from freight wagons and house dust (Boström *et al.* 1997; Franz *et al.* 1997; Mehl 1998; Sánchez-Ramos *et al.* 2004; Pike and Wickens 2008; Henszel *et al.* 2011; Solarz 2009; Solarz and Pająk 2019). The listed mite species were identified as a source of clinically important allergens, causing occupational allergies, commonly known as storage mite allergies.

Asthma, rhinitis, and conjunctivitis commonly occur among farmers, grain storage workers, and other agricultural workers (Dutkiewicz *et al.* 1988; Revsbech and Dueholm 1990; Fain *et al.* 1990; van Hage-Hamsten and Johansson 1998). These mites cause IgE-mediated sensitisation in workers from these occupational categories who are exposed to organic dust containing these mites' allergens (Sánchez-Ramos *et al.* 2004; Arlian 2002; Berger *et al.* 2005; Cichecka *et al.* 2006; Solarz 2012).

Storage mites have not yet been explored widely in connection with forensic examinations, but there are good reasons for further investigations (Perotti *et al.* 2009). Indoor mites occur globally in farm buildings, however, the species' composition may vary between places, seasons, and even between sites within the indoor environment of a single farm. Subtle differences in the composition of the storage mite acarofauna between particular sites and types of farm buildings may provide valuable information, such as an indicator of time and circumstances of death (Solarz 2009).

This study aimed to investigate the possible occurrence and abundance of allergenic mites in farms. Moreover, the mite species compositions in material samples collected from farming environments were analysed in relation to forensic medicine.

Material and methods

The study was carried out from July to September 2015. A total of 58 samples of materials collected from 15 farms in 2 localities (Kamesznica and Tresna) in the Żywiecki district (Silesian Province, south-western Poland) were examined as potential sources of allergenic mites in farm buildings with a special reference to forensic acarology (Table 1). All samples were collected in one-litre plastic bags. These samples were sweepings containing organic dust, litter, debris, residues, and other materials from certain farming environments such as barns (n=15), pigsties (n=11), cowsheds (n=6), chaff-cutters (n=9), poultry houses (n=13), and pigeon-houses (n=4) (Table 1). The mites were extracted using the Berlese–Tullgren funnel method described by Berlese (1905) and Tullgren (1918), with some modifications. This method creates a desiccation gradient over the examined samples, so that mobile arthropods will move away from the dry environment and fall into a vessel with 75% ethanol. Faure's medium was used to mount the mites on microscope slides and they were identified with the aid of a stereomicroscope Olympus Europe Highlight 2100. All mite specimens collected were examined using differential interference contrast (Nomarski DIC) (under a light microscope Zeiss Axioskop 2 plus) and phase contrast optics (under a light microscope Olympus CH 40). The mites were identified using descriptions of taxa and the following keys or publications: Hughes (1976), Zhang and Fan (2005), Fan and Zhang (2007a, b), Krantz and Walter (2009), and Solarz (2011a, 2012). The results were expressed as the number of mites per one sample.

The relative abundance and occurrence of the species of mite collected, as well as their categories of dominance and frequency, were calculated according to publications: Rajski (1961), Solarz and Senczuk (2003). The following levels of dominance (D) and frequency (F) were adopted:

- **D**
 - Eudominant – species forming more than 10% of the total mite population.
 - Dominant – species forming between 5.1–10% of the total mite population.
 - Subdominant – species forming between 2.1–5% of the total mite population.
 - Recedent – species forming between 1.1–2% of the total mite population.
 - Subrecedent – species forming less than 1.1% of the total mite population.

• F

- Euconstant – species occurring in more than 25% of samples.
- Constant – species occurring in 11–25% of samples.
- Accessory – species occurring in 1–10% of samples.
- Accidental – species occurring in less than 1% of samples examined.

The average dominance [%] of collected mite species/taxa in the particular types of farm buildings examined was performed using CSS-Statistica for Windows version 12.

Results

Overall results

Mites were found in all the samples examined. In total 4,473 mites were isolated (Tables 1 and 2) and 20 species were identified from the different farm buildings (Table 3). Most of them were found in barns (n=1007, approx. 22.5% of the total count) and pigsties (n=989, 22.1%). The remaining mites were found in cowsheds (17.2%), chaff-cutters (16.9%), poultry houses (16.6%), and pigeon houses (4.7%) (Tables 1 and 2). The material was collected from 15 farms, situated in two localities – Kamesznica (11 farms) and Tresna (4 farms) (Table 2). The highest number of mites was collected in farm no. 12 from Tresna (n=511) and no. 6 from Kamesznica (n=472) (Table 2). The samples were dominated by Acaridae, Glycyphagoidea, and Cheyletidae. The species composition of the acarofauna varied between different types of examined farm buildings (Table 4; Figures 1-2). Generally, eudominant species belonged to the family Acaridae (Astigmatina) – *Acarus siro* (25.6% of all mites) and *A. farris* (17.75%), as well as *Glycyphagus domesticus* (10.3%) of the family Glycyphagidae (Astigmatina). Moreover, among the relatively numerous occurring mites (dominant species) were *Tyrophagus putrescentiae* (9.84%), *Lepidoglyphus destructor* (9.3%), cheyletids (Prostigmata: Cheyletidae) (6.55%), and *Chortoglyphus arcuatus* (Glycyphagoidea: Chortoglyphidae) (5.9%). *Acarus immobilis* (Acaridae) was a subdominant species and accounted for 2.91% of all mites. Other species of storage mites were generally less abundant. *Gohieria fusca*, *Lepidoglyphus michaeli*, and *Ctenoglyphus plumiger* belong to the recedent species group, while, *L. fustifer*, *Tyrophagus longior*, *Gymnoglyphus longior*, *Hirstia chalidonis*, as well as, other members of Oribatida sensu lato and other Prostigmata (Table 3; Figures 1-2) to the subrecedent group. The most frequent species found in samples from the examined farm buildings were *A. siro*, *A. farris*, *T. putrescentiae*, *G. domesticus*, and *L. destructor* with relative frequency 87.9%, 81.03%, 74.14%, 62.1% and 60.34%, respectively (Table 3). Moreover, Cheyletidae (65.5%) and some other potentially allergenic mites in the cohort Astigmatina, such as *Ch. arcuatus* (41.4%), *Ct. plumiger* (37.9%), *L. michaeli* (29.3%), *A. immobilis* (27.6%), and *G. fusca* (25.9%) also belong to the euconstant group (Table 3).

Table 1 Number of mites recovered from the particular farm buildings examined.

Type of farm building examined and number of mites isolated					
Barns	Pigsties	Cowsheds	Chaff–cutter buildings	Poultry houses	Pigeon houses
(n = 15)	(n = 11)	(n = 6)	(n = 9)	(n = 13)	(n = 4)
1007	989	771	756	741	209

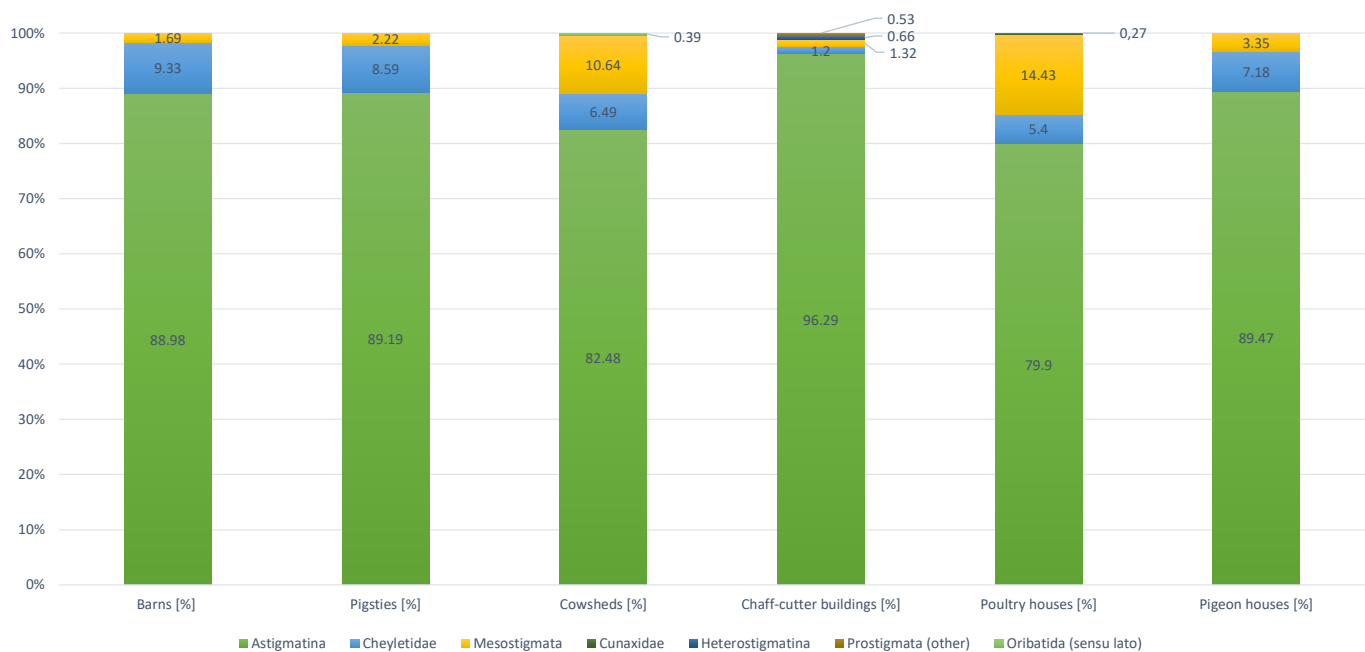


Figure 1 Dominance [%] of the high taxonomic levels of mites recorded from all examined farm buildings.

Mites from barns

A total of 1,007 mites were collected from barns, including 13 species from the cohort Astigmatina (Figure 2). Mite fauna was dominated by *A. siro* (48.2% of mites collected from barns) and *A. farris* (22.8%), both of which were eudominant species. Moreover, allergenic predatory mites of the family Cheyletidae (9.3%) and *T. putrescentiae* (7.8%) were dominants, while *L. destructor* (2.9%) and *G. domesticus* (2.8%) were subdominants. The remaining astigmatic mites belonged to recedent and subrecedent species. Mesostigmata constituted only 1.7% of the collected mites (Figures 1 and 2).

Acarus siro was also the most frequent species (86.7%), followed by *A. farris* (73.3%) and *T. putrescentiae* (46.7%). Among the euconstant species were also cheyletids (60.0%), other astigmatic mites – *L. destructor* and *G. domesticus* (33.33% in both cases), *G. fusca* and *Ch. arcuatus* (26.7% in both cases), as well as representatives of Mesostigmata (53.33%) (Table 4).

Mites from pigsties

Acarofauna from pigsties included 989 specimens of mites. Among them, there were eudominant species, like *L. destructor* (17.5% of the total count), followed by *A. siro* (16.6%), *A. farris* (14.1%), *Ch. arcuatus* (12.5%) and *T. putrescentiae* (11.5%) (Figure 2). In general, 14 species of astigmatic mites were found, including dominant species (*G. domesticus*), subdominant species (*G. fusca*, *A. immobilis*), recedents (*L. fustifer*) and subrecedents (*T. longior*, *Ct. plumiger*, *Rhizoglyphus echinopus*, *L. michaeli*, and *G. ornatus*). Among the remaining mite taxa were cheyletids, which constituted 8.6% of the total mite population of pigsties (dominants), and Mesostigmata (subdominants, 2.2%) (Figures 1 and 2).

Acarus siro was the most frequent species collected from pigsties, and was found in all examined samples (Table 4). Moreover, other allergenic mite species, like *T. putrescentiae* and *L. destructor* (81.8% in both cases), *A. farris* and *G. domesticus* (72.7% in both cases), *G. fusca* (63.6%), *Ch. arcuatus* (54.5%), and taxa, such as cheyletids (63.6%) and Mesostigmata (54.5%) also belong to the euconstant group (Table 4).

Mites from cowsheds

Acarofauna from cowsheds was also dominated by the astigmatic mites. Out of 14 identified Astigmatina species, *A. siro* was an eudominant (22.04%), followed by *G. domesticus* (18.8%), *A. farris* (16.2%), and *L. destructor* (11.02%). Moreover, among the numerous occurring astigmatic mites there were also the subdominant species – *T. putrescentiae* (4.5%), *L. michaeli* (2.2%), *L. fustifer* (2.2%), and one recedent – *Ch. arcuatus* (1.2%). Cheyletid mites were dominants, and constituted 6.5% of the total count from cowsheds (Figures 1 and 2).

It should be stressed, that the most frequently occurring mites (euconstants) once again were allergenic species *A. siro*, *A. farris*, *T. putrescentiae*, and *G. domesticus* (83.3% in all cases), followed by *L. destructor* (66.7%) (Table 4).

Mites from chaff-cutter buildings

A total of 756 mites were isolated from samples collected from chaff-cutter buildings. Acarofauna of chaff-cutters was also dominated by the mites of the families Acaridae and Glycyphagidae, especially *A. farris* (21.8%), *A. siro* (19.8%), *G. domesticus* (17.1%), *T. putrescentiae* (12.2%), *A. immobilis* (11.2%) and *L. destructor* (7.3%) (Figure 2).

Acarus farris was the most frequent species, and other euconstant taxa were *T. putrescentiae* (88.9% of all samples), *A. siro*, *A. immobilis* (77.8% in both cases), *G. domesticus* (66.7%), *L. destructor*, and *L. michaeli* (55.5% for both species), Cheyletidae and Mesostigmata (55.5% in both cases) (Table 4).

Table 2 Number of mites collected from the particular farms in two locations in the Żywiecki district.

Locality	Number and type of farm building	Number of mites	Total	Locality	Number and type of farm building	Number of mites	Total		
Kamesznica	Farm 1	barn	125	391	Kamesznica	Farm 8	barn	53	
		pigsty	149				pigsty	44	
		poultry house	117				poultry house	49	
	Farm 2	barn	58	260		Farm 9	pigeon house	54	298
		pigsty	31				barn	29	
		poultry house	39				pigsty	42	
		chaff-cutter building	93				poultry house	21	
	Farm 3	pigeon house	39	169		Farm 10	chaff-cutter building	45	286
		barn	66				cowshed	161	
		pigsty	53				barn	10	
	Farm 4	pigeon house	50	394		Farm 11	pigsty	161	29
		barn	57				poultry house	66	
		pigsty	137				chaff-cutter building	49	
		poultry house	35				Farm 12	barn	
	Farm 5	chaff-cutter building	165	343		Tresna	Farm 12	barn	274
barn		15	poultry house		83				
pigsty		76	cowshed		154				
poultry house		36	Farm 13		barn			29	
Farm 6	chaff-cutter building	87	472	Farm 14	poultry house	78	309		
	cowshed	129			cowshed	160			
	barn	100			Farm 15	barn		86	
	pigsty	107				pigsty		50	
	poultry house	82				poultry house		61	
Farm 7	chaff-cutter building	117	367	Farm 15	chaff-cutter building	41	177		
	pigeon house	66			cowshed	71			
	barn	36			barn	40			
	pigsty	139			poultry house	12			
	poultry house	62	130			chaff-cutter building	29	96	
	chaff-cutter building	130				cowshed	96		

Mites from poultry houses

Of the 741 mites collected, 11 mite species of the cohort Astigmatina were found in poultry houses. *A. siro* was the eudominant (14.2% of the total count), followed by other species, such as *Ch. arcuatus* and *G. domesticus* (13.5%, in both cases), *T. putrescentiae* (11.5%), and *A. farris* (10.8%). Moreover, *Ct. plumiger*, *G. fusca*, *Lepidoglyphus fustifer*, *L. michaeli*, and *Sancassania berlesei* were reported, while Mesostigmata and Cheyletidae constituted 14.4% and 5.4% respectively of all mites collected from poultry houses (Figures 1 and 2).

The most frequent species in poultry houses were *A. siro* and *G. domesticus* (84.6% of all samples examined in both cases). Among the most frequent species were also some other species of allergenic or potentially allergenic mites – *T. putrescentiae*, *A. farris*, and *L. destructor* (76.9%), *Ch. arcuatus* (61.5%), *Ct. plumiger* (53.8%), *L. fustifer* and *L. michaeli* (30.8%), and *G. fusca* (23.1%). Among relatively frequent taxa were also cheyletids (69.2%) and Mesostigmata (53.8%) (Table 4).

Table 3 Percentage of dominance and frequency of the particular mite taxa identified in samples from the examined farm buildings.

Mite taxa	Dominance		Frequency	
	N	D (%)	n	F (%)
<i>Acarus siro</i>	1147	25.64	51	87.93
<i>A. farris</i>	794	17.75	47	81.03
<i>A. immobilis</i>	130	2.91	16	27.59
<i>Tyrophagus putrescentiae</i>	440	9.84	43	74.14
<i>T. longior</i>	18	0.4	8	13.79
<i>Sancassania berlesei</i>	2	0.04	1	1.72
<i>Rhizoglyphus echinopus</i>	4	0.09	2	3.45
<i>R. robini</i>	1	0.02	1	1.72
<i>Lepidoglyphus destructor</i>	418	9.35	35	60.34
<i>L. michaeli</i>	62	1.39	17	29.31
<i>L. fustifer</i>	37	0.83	12	20.69
<i>Glycyphagus domesticus</i>	459	10.26	36	62.07
<i>G. privatus</i>	2	0.04	2	3.45
<i>G. ornatus</i>	3	0.07	3	5.17
<i>Gohieria fusca</i>	72	1.61	15	25.86
<i>Ctenoglyphus plumiger</i>	60	1.34	22	37.93
<i>C. canestrinii</i>	2	0.04	2	3.45
<i>Chortoglyphus arcuatus</i>	264	5.9	24	41.83
<i>Gymnoglyphus longior</i>	5	0.11	5	8.62
<i>Hirstia chelidonis</i>	1	0.02	1	1.72
Oribatida (sensu lato)	3	0.07	2	3.45
Cheyletidae	293	6.56	38	65.52
Cunaxidae	2	0.04	2	3.45
Heterostigmatina	5	0.11	2	3.45
Prostigmata (other)	4	0.09	4	6.89
Mesostigmata	245	5.48	35	60.34
ACARI (total)	4473	100	58	100

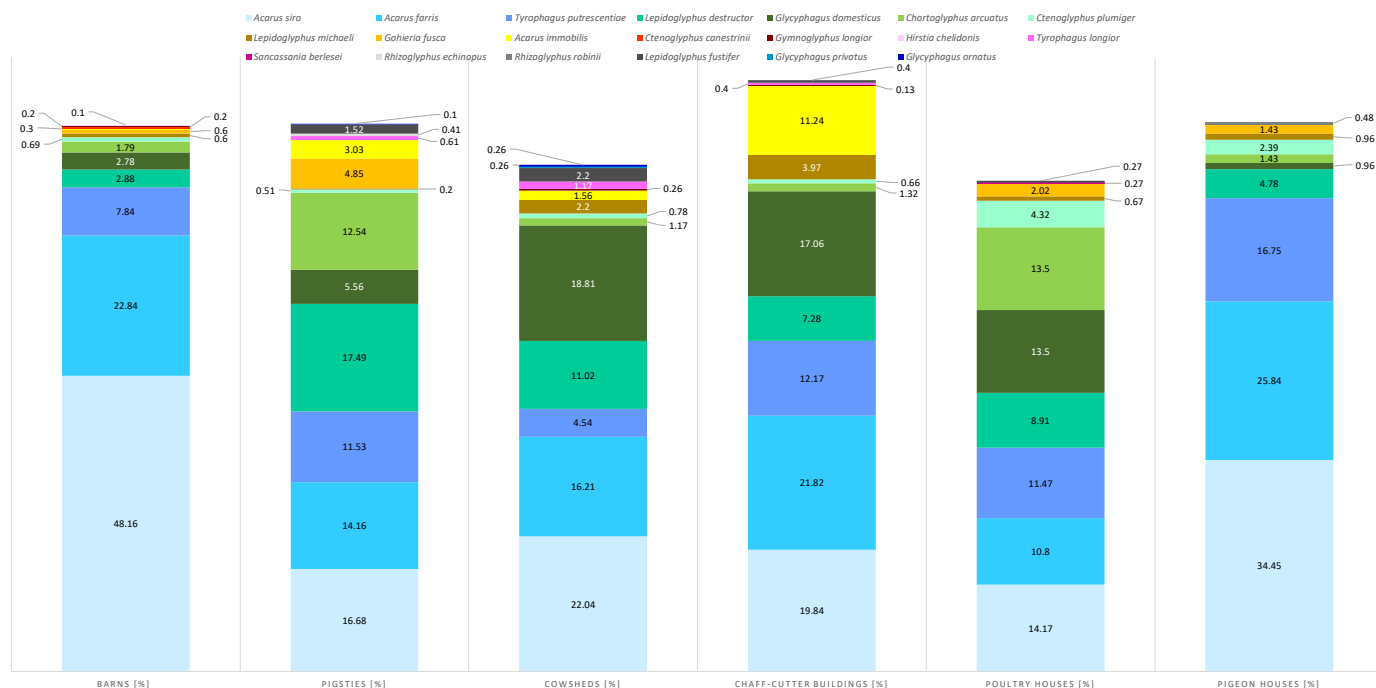


Figure 2 Dominance [%] of the Astigmatina mite species in all examined farm buildings.

Mites from pigeon houses

A total of 209 mites were collected from pigeon houses, including 10 species in the cohort Astigmatina. Mite fauna was dominated by two species (eudominant) of the genus *Acarus* – *A. siro* (34.45% of mites collected from pigeon houses) and *A. farris* (25.8%). A significant part of collected material constituted *T. putrescentiae* (7.8%), *L. destructor* (4.8%), as well as, nonastigmatic mites of the Cheyletidae family (7.18%). The remaining astigmatic mites were less numerous and belonged to the subdominant group – *Ct. plumiger* (2.4%), the recedent group – *Ch. arcuatus*, and *G. fusca* (1.4% in both cases), and the subrecedent group – *G. domesticus* and *L. michaeli* (approx. 1.0%, in both cases). Mesostigmata constituted only about 1.0% of all mites collected (Figures 1 and 2).

The allergenic mite species, like *A. siro*, *A. farris*, and *T. putrescentiae* were euconstants and they occurred in all examined samples from pigeon houses. Other frequently occurring taxa were *L. destructor*, *Ct. plumiger* (50.0% in both samples), as well as, Cheyletidae and Mesostigmata (75.0% in both cases), while *G. domesticus*, *L. michaeli*, *G. fusca*, *Ch. arcuatus*, and *R. echinopus* were constant species (25.0% in these cases) (Table 4).

Exposure of farmers and citizens to allergenic or potentially allergenic mites

The risk of exposure of farmers and other citizens to allergenic mites seems to be highest in barns and pigsties, and lowest in pigeon houses (Tables 3-5). However, it should be stressed that in all examined farm buildings a high number of allergenic mites were found, including the most medically important taxa such as *Acarus siro* complex, *T. putrescentiae*, *G. domesticus*, *L. destructor*, and *Ch. arcuatus*. In barns, the risk of exposure concerned was mainly connected with *A. siro*, *A. farris*, and then *T. putrescentiae*, *L. destructor*, and *G. domesticus* (Figure 2). In pigsties, farmers are exposed mainly to *L. destructor*, *A. siro*, *A. farris*, *Ch. arcuatus*, and *T. putrescentiae*, whereas in cowsheds the main exposure is to *A. siro*, *G. domesticus*,

A. farris, and *L. destructor* (Figure 2). In chaff-cutter buildings apart from members of the *Acarus siro* complex, farmers are exposed to high numbers of *G. domesticus*, and in poultry houses to *G. domesticus*, *Ch. arcuatus*, *T. putrescentiae*, and mites of the genus *Lepidoglyphus* (Figure 2). Among species of the *Acarus siro* complex, *A. siro* was the most numerous in poultry houses, whereas *A. farris* was the most numerous in chaff-cutters. Pigeon houses were dominated by mites of the family Acaridae – *A. siro*, *A. farris*, and *T. putrescentiae*, respectively (Figure 2). It should be stressed that two species of the pyroglyphid mites were also found. *H. chelidonis* was found only in barns, whereas *G. longior* was found in barns, cowsheds, and chaff-cutter buildings (Table 4). Farmers and citizens living in the Żywiecki district (Silesian Province, Poland) are also exposed to high numbers of allergenic predatory mites of the family Cheyletidae, especially in barns and pigsties (Figure 1; Table 4).

Occurrence and frequency of particular astigmatic mite species in different farm buildings in relation to forensic analyses

Acarus siro was the most frequently occurring mite in almost all the types of examined farm buildings except for chaff-cutters, where it was preceded only by *A. farris* and *T. putrescentiae*. In cowsheds, these three species occurred with the same frequency (Table 4). The frequency of *A. siro* was the highest in pigsties and pigeon houses (100%), followed by barns (87%), poultry houses (85%), cowsheds (83%), and chaff-cutters (78%). *G. domesticus* occurred most frequently in poultry houses (85% positive samples) and cowsheds (83% samples) (Table 4).

Table 4 Percentage of frequency of the particular mite taxa identified in samples from the examined farm buildings.

Mite taxa	Type of farm building											
	Barns		Pigsties		Cowsheds		Chaff-cutter buildings		Poultry houses		Pigeon houses	
	n	F [%]	n	F [%]	N	F [%]	n	F [%]	n	F [%]	n	F [%]
<i>Acarus siro</i>	13	86.66	11	100.00	5	83.33	7	77.77	11	84.61	4	100.00
<i>A. farris</i>	11	73.33	8	72.72	5	83.33	9	100.00	10	76.92	4	100.00
<i>A. immobilis</i>	2	13.33	5	45.45	2	33.33	7	77.77	0	0.00	0	0.00
<i>Tyrophagus putrescentiae</i>	7	46.66	9	81.81	5	83.33	8	88.88	10	76.92	4	100.00
<i>T. longior</i>	0	0.00	3	27.27	3	50.00	2	22.22	0	0.00	0	0.00
<i>Sancassania berlesei</i>	0	0.00	0	0.00	0	0.00	0	0.00	1	7.69	0	0.00
<i>Rhizoglyphus echinopus</i>	0	0.00	2	18.18	0	0.00	0	0.00	0	0.00	0	0.00
<i>R. robini</i>	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	25.00
<i>Lepidoglyphus destructor</i>	5	33.33	9	81.81	4	66.66	5	55.55	10	76.92	2	50.00
<i>L. michaeli</i>	3	20.00	1	9.09	3	50.00	5	55.55	4	30.77	1	25.00
<i>L. fustifer</i>	0	0.00	3	27.27	3	50.00	2	22.22	4	30.77	0	0.00
<i>Glycyphagus domesticus</i>	5	33.33	8	72.72	5	83.33	6	66.66	11	84.61	1	25.00
<i>G. privatus</i>	0	0.00	0	0.00	2	33.33	0	0.00	0	0.00	0	0.00
<i>G. ornatus</i>	0	0.00	1	9.09	2	33.33	0	0.00	0	0.00	0	0.00
<i>Gohieria fusca</i>	4	26.66	7	63.63	0	0.00	0	0.00	3	23.08	1	25.00
<i>Ctenoglyphus plumiger</i>	4	26.66	3	27.27	3	50.00	3	33.33	7	53.84	2	50.00
<i>C. canestrinii</i>	2	13.33	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
<i>Chortoglyphus arcuatus</i>	4	26.66	6	54.54	3	50.00	2	22.22	8	61.54	1	25.00
<i>Gymnoglyphus longior</i>	2	13.33	0	0.00	2	33.33	1	11.11	0	0.00	0	0.00
<i>Hirstia chelidonis</i>	1	6.66	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Oribatida (sensu lato)	0	0.00	0	0.00	2	33.33	0	0.00	0	0.00	0	0.00
Cheyletidae	9	60.00	7	63.63	5	83.33	5	55.55	9	69.23	3	75.00
Cunaxidae	0	0.00	0	0.00	0	0.00	0	0.00	2	15.38	0	0.00
Heterostigmatina	0	0.00	0	0.00	0	0.00	2	22.22	0	0.00	0	0.00
Prostigmata (other)	0	0.00	0	0.00	0	0.00	4	44.44	0	0.00	0	0.00
Mesostigmata	8	53.33	7	63.63	0	0.00	5	55.55	7	53.84	3	75.00
ACARI (total)	15	100.00	11	100.00	6	100.00	9	100.00	13	100.00	4	100.00

In summary, it should be stressed that *A. siro* was the most abundant species per sample in barns, cowsheds, and pigeon houses, whereas *Ch. arcuatus* was the most abundant in pigsties and poultry houses. In chaff-cutter buildings, the most abundant species were *G. domesticus* and *A. siro* (Table 5).

Discussion

Up until now many groups of mites have been reported as occupational biohazards for humans (Arlian 2002). This study describes the composition of storage mite communities collected from farm buildings in the southwestern Poland. The greatest exposure to storage mites usually occurs in agricultural settings, and therefore agricultural work is considered a major risk factor for occupational diseases (van Hage-Hamsten and Johansson 1998; Arlian 2002; Berger *et al.* 2005; Cichecka *et al.* 2006). Our previous studies suggest that allergenic mites belonging to Acaridae, Glycyphagidae, and Chortoglyphidae should be described as occupational risk factors contributing to respiratory and dermal diseases among farmers in Poland (Solarz and Pająk 2019; Cichecka *et al.* 2006; Solarz *et al.* 1997). In this study, we confirmed the presence of allergenic mite species in the examined material. The predominant species in all the examined farm buildings were *Acarus siro* and *A. farris*. Additionally, such species as *G. domesticus*, *Ch. arcuatus*, *L. destructor*, as well as *T. putrescentiae* were also frequently reported. These results confirm the presence of allergenic mites in cowsheds, barns, chaff-cutter buildings, pigsties, pigeon, and poultry houses (Solarz and Pająk 2019; Solarz *et al.* 1997; Terho *et al.*

Table 5 Abundance levels of the most abundant mite species/taxa in the different kinds of examined farming buildings.

Type of farming buildings	Most abundant species/taxa	Abundance (number of mites per 1 sample)
Barns	<i>Acarus siro</i>	37.31
	<i>A. farris</i>	20.91
	<i>Tyrophagus putrescentiae</i>	11.28
	Cheyletidae (total)	10.44
Pigsties	<i>Chortoglyphus arcuatus</i>	20.66
	<i>Lepidoglyphus destructor</i>	19.22
	<i>A. farris</i>	17.5
Cowsheds	<i>A. siro</i>	15
	<i>A. siro</i>	34
	<i>Glycyphagus domesticus</i>	29
	<i>A. farris</i>	25
Chaff-cutter buildings	<i>L. destructor</i>	21.25
	<i>G. domesticus</i>	21.5
	<i>A. siro</i>	21.43
	<i>A. farris</i>	18.33
	<i>A. immobilis</i>	12.14
	<i>T. putrescentiae</i>	11.5
Poultry houses	<i>L. destructor</i>	11
	<i>Ch. arcuatus</i>	12.5
	<i>A. siro</i>	9.54
	<i>G. domesticus</i>	9.09
	<i>T. putrescentiae</i>	8.5
Mesostigmata (total)		15.28
	<i>A. siro</i>	18
	<i>A. farris</i>	13.5
Pigeon houses	<i>T. putrescentiae</i>	8.75

1982; Mumcuoglu and Lutsky 1990; Stejskal and Hubert 2008). Thus, all the mentioned farm buildings should be regarded as potential sources of storage mites in rural environments. The stated prevalence of acarids, glycyphagids, and cheyletids in the investigated buildings are not in accordance with earlier data published by Hallas (1981), Terho *et al.* (1982), and Solarz *et al.* (1997).

Beyond their negative role as allergic agents, mites may also be used as professional markers in forensic analyses (Perotti *et al.* 2009; Solarz 2011b). Several genera of the family Acaridae can be encountered in forensic situations, particularly as allergenic taxa, in relation to workers, who are occupationally exposed to mites. However, many mites are also involved in the decomposition of animal carcasses and human corpses at every stage. Some of these species will be represented by just a few specimens, whereas others, such as *Tyrophagus putrescentiae*, *Acarus farris*, *A. immobilis*, and *Sancassania berlesei*, identified in this study, may increase in number to millions (Szelecz *et al.* 2018; Solarz 2011; OConnor 2009; Perotti 2009a; Braig and Perotti 2009; Perotti and Braig 2009; Russell *et al.* 2004). It is widely accepted that the first arthropod scavengers who colonised a dead body were flies with phoretic mite species. The flies complete their life cycle in and around the corpse, while the mites may feed on their immature stages. Since mites reproduce much faster than their carriers, they may offer themselves as valuable timeline markers. Among the mites, which were identified in this study, were species such as *A. siro*, *A. farris*, *A. immobilis*, *T. putrescentiae*, *T. longior*, *S. berlesei*, *R. echinopus*, *L. destructor*, *G. domesticus*, and other *Glycyphagus* spp, that are often found at every stage of decomposition on animal carcasses and human corpses. Many of them are known from forensic investigation cases (Russell *et al.* 2004). Members of the Astigmata are more frequently found during the dry decay stage of decomposition. Some of them belong to the phoretic mites of scavengers, while the majority travel on late-arriving carrion insects, such as moths, hide, and skin beetles (Perotti and Braig, 2009). Even though insects are larger, and hence more easily identifiable, in particular situations, an informative diversity of phoretic mites may be found on a decaying carcass at any given time and their composition may provide valuable information in forensic investigations (OConnor 2009). The genus *Tyrophagus* was one of the first mite taxa found on human corpses. It has been used to estimate a post-mortem interval (PMI). The question of how this genus arrives on a carcass is still unresolved (OConnor 2009; Perotti 2009a). Mites of the genus *Tyrophagus* are not considered to be phoretic, but their long setae might allow them to be lifted and carried by mammals (Marzouk *et al.* 2006; Serpa *et al.* 2004; Perotti and Braig, 2009). It should be stressed that except for *T. formicetorum*, the remaining species of this genus do not go through the hypopial stage (heteromorphic deutonymph) in their life cycle. *Tyrophagus* species can be easily confused with other Acaridae species, such as *T. longior*. This species normally occurs together with another acarid mite – *A. farris*, which presents the deutonymphal phoretic stage (or hypopus). *A. farris* hypopi is even attached to the adults of *T. longior* (Hughes 1976; OConnor 2009). *Sancassania berlesei*, another reported mite species, may produce the hypopial stage, which could attach to chaffers (*Scarabaeidae*) and stored product beetles (*Tenebrioniidae*), e.g. the flour beetle (*Tenebrio molitor*) (Szelecz *et al.* 2018). Moreover, mites of the genus *Rhizoglyphus* also have the ability to develop heteromorphic deutonymphs, which are morphologically similar to those of *Sancassania*. They are phoretically associated with several species of *Scarabaeidae* (Coleoptera), such as *Osmoderma eremicola*, *Bothynus gibbosus*, and *Phyllophaga* spp. – insects, which belong to the group of opportunistic colonisers of human and animal remains (Rai *et al.* 2020). Many of mites described above belong to the most numerous species in the analysed farm buildings. Further studies are needed to clarify the relationship between indoor conditions in farm buildings and the species composition of the storage mite acarofauna. Our study may increase awareness of the occurrence of many allergenic mite species in the locations investigated in the Żywiecki district, as well as being of use in forensic medicine cases.

In conclusion, the acarofauna from the analysed farm buildings seems to be dominated by the allergenic mites of the families Acaridae (*Acarus siro*, *A. farris*) and Glycyphagoidae (*G. domesticus*, *L. destructor*). Moreover, all examined farms were sources of storage mites and

therefore posed a potential risk of exposure to the mite allergens for farmers. The study suggests that the mites found in farm buildings, particularly the allergenic taxa should be considered occupational risk factors contributing to the occurrence of occupational respiratory and dermal diseases among farmers. This knowledge may be very useful in forensic and occupational medicine as well as in criminal investigations.

Conflict of interests

No conflict of interest

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