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Arthropods as sources of contaminants of stored products: an overview

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Abstract

Current IPM theory does not reflect that the quality of marketable yield may be damaged via bio-contamination of the crop even without a visible crop injury. To turn attention to this problem we have reviewed the main types of biocontamination associated with the food products thought claimed to be an unavoidable consequence of growing, harvesting and processing food products. Critical levels for some classes of contaminants have been determined and indicate what levels of foreign matter are considered safe. Stored product pest (SPP) may be source of indirect contamination of stored commodities, by pesticide residues (> MRLs) of chemical treatment by protectants. Direct contamination includes physical, microbial and chemical (toxins, carcinogens and allergens) arthropod contaminants. Parts of arthropod bodies, exuviae and feces are physical contaminants whose safe levels are regulated by Defect Action Levels (DALs) in USA. All stored product inhabiting arthropods (cca 500 species), pest, non-injurious fungivores and beneficials parasites and predators of pests all can become source of physical contamination. The most frequently reported cause of physical contamination are internally feeding insects (*Rhizopertha sp.*, *Sitophilus* sp.). Many species host and transfer toxinogenic fungi or microbial human/animal pathogens. Mites produce chemicals responsible for bad smell of grain while *Tribolium* spp. are the only storage pests producing carcinogens. Evidence is growing that exposure of alimentary products to arthropods causes of allergenic sensitization. Some species of Acarina, Blattodea, Coleoptera, Lepidoptera, and Psocoptera may cause allergic reactions in humans exposed to remnants of their bodies. No critical levels are available for contamination of food agro-commodities by allergens of arthropods.

Key words: contaminants, pests of stored grain.

Contamination of agri-commodities and food

Food safety and quality is among the important political priorities in most of the countries. Traditional integrated pest management (IPM) considers only decreasing yields. It is based on concept of “Economic Injury Level“ (EIL) (Pedigo et al., 1986) without a particular reference to quality and safety of the food products. However, the latter may not be correlated with crop injury or yield loss. This was demonstrated by Mesterházy et al. (1999) who found that mycotoxin (deoxynivalenol- DON) contamination of *Fusarium* infected grains is frequently not proportional to plant health or yield. Hodges stressed that for store managers the major problem is contamination by storage pest remnants rather than losses of the commodity which is often rather small. This implies that, critical pest

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population size is not a function of crop injury but considers also crop product contamination. Arthropods are among the main contamination sources. For example, Orris and Whitehead (2000) reported on the analysis of 4795 USA-FDA detentions of imported agricultural food-products which showed that the most frequent problem was arthropod filth (32 %), followed by low acid canned food (12 %) and microbial contamination (11 %). The contamination of stored crop products by arthropod contaminants may not only negatively affect the required quality-standards but also human health. The consumption of grain-derived products contaminated by storage-mite allergens resulted in human anaphylaxis.

Contaminants associated with storage pests

Traditionally, contaminants associated with the occurrence of storage pests in agri-commodities are divided into 3 classes that include physical and biological (microbial) and chemical contaminants. Dividing contaminants into particular class is arbitrary since, as stressed by Olsen (1998a), in many cases the distinction between the classes of food contaminants is not clear.

Physical contamination

Arthropod fragments, exuviae and feces as well as hairs and feces of rodents are considered physical contaminants (Gorham, et al., 1977, Zimmermanm and Friedmann, 2000). The total pool (cca 500 species) of stored product and food industry arthropods, including non-injurious fungivores and beneficials (parasites, predators), can become source of physical contamination. Also arthropods accidentally introduced to stores from the field during may contribute to physical contamination of stored commodities. For example, exported cereal-grain or compressed bales of rye straw were quarantined for the folivorous beetle *Oulema melanopus* in USA (Yokoama et al. 2002) . Internally feeding insects such as the rice weevil, *Sitophilus oryzae*, granary weevil, *S. granarius* L., and the lesser grain borer, *Rhyzopertha dominica,* that develop and feed inside grain kernels are the main source of insect fragments in wheat flour (Campbell et al., 1976; Singh et al., 1976; Pedersen, 1992, Perez-Mendoza et al. 2003). Gecan and Atkinson (1983) analyzed for physical animal contaminants 5,081 flour samples collected in 75 flour mils in the USA, from 1969 to 1979. The summary of defects revealed different frequency of various groups of filth contaminants: insect fragments - 83,0 %, rodent hairs - 17,6 %, feather barbules - 2,5 %, insect heads - 1,3 %, mites - 0,6 %, larvae - 0,3 %, psocids - 0,2 %. Several methods are available to detect insect fragments that include filth flotation test (AOAC, 1997**,** Thind, 2000), immunochemical methods (ELISA) (Dunn et al., 2002) molecular methods (PCR) and near-infrared spectroscopy (NIRS**)** (Perez-Mendoza et al., 2003, 2005) .

Biologial (microbial) contamination

Food industry pests such as flies, cockroaches, silverfishes, wasps and rodents are able to host and disseminate more than 100 species of pathogenic viruses, bacteria and fungi (Olsen, 1998b). Although the vector potential of “true” stored product arthropod pests is lower many species were shown to have capacity to host and transfer many pathogenic or toxinogenic microbial agents (Sinha, 1964, Aucamp, 1969**,** Ragunathan 1974, Beti et. al., 1995, Hubert et. al, 2003). Hence the associations of storage pests with fungi may increase the risk of occurrence of mycotoxins. This is a considerable risk to human food and animal feed safety. Beti et al. (1995) showed that stored maize kernels infested with A. flavus-contaminated *S. zeamais* weevils had higher levels of aflatoxin than non-infested maize. Hubert et. al, (2004) isolated 94 fungal species from 4 species of storage mites (*Acarus siro*, *Caloglyphus rhizoglyphoides*, *Lepidoglyphus destructor*, *Tyrophagus putrescentiae* and *Cheyletus malaccensis*) found in Czech seed stores. Fungi are also connected with rodents infesting grain stores. Recently we isolated 11 genera and 35 species of fungi from mice feces collected in grain stores in Czech Republic (Stejskal et al. 2005).

Chemical contamination

Chemical contamination of agri-products associated with the presence of storage pest arthropods includes undesirable odors and smells, carcinogens and allergens.

Odours, smells, carcinogens

Mites are notorious for producing volatile chemicals which are responsible for bad smell of the mite-infested grain (Tuma et al., 1990); tridecane is a major volatile odour compound produced by storage mites. Smith et al. (1971) reported that bread prepared from the flour infested by *Tribolium* spp. and *Oryzaephilus surinamensis* had a bad taste. Seitz and Sauer (1996) analyzed infested samples of grain for volatiles in 4 storage beetles (*R. dominica, T. castaneum, S. oryzae, O. surinamensi, s Cryptolestes ferrugineus)* and found that *R. dominica* caused severe off-odor, *T. castaneum* caused moderate off-odor and the other three beetles caused little or no odor. According to Pedersen (1992) the odor of grain infested by *R. dominica* can be described as "sweetish and musty". Seitz and Sauer (1996) concluded that 2-pentanol, an aggregation pheromone of *R. dominica*, and several other metabolites including unsaturated free acids are responsible for the unpleasant odor of grain infested by *R. dominica*. *Tribolium* spp. are the only storage pests producing carcinogenic and teratogenic contaminants (El-Mofty et al., 1989; 1992). Qinones may cause jaundice, anaemia, haemoglobinuria and cachexia in humans (Omaye et al., 1981). The secretion of *T. castaneum* contains at least 13 different quinones (Howard, 1987). These compounds give an unpleasant smell to stored food and may be responsible for liver and spleen tumours in small vertebrates (El-Mofty et al., 1988; 1989; 1992). The mutagenic effects on mice were still evident after contaminated flour had been cooked and consumed (El-Mofty et al., 1992). Although quinones may endanger animal health Hodges et al. (1996) concluded that the rate of contamination in the stores is rather low and "normal" *Tribolium* infestation are unlikely to result in quinine accumulation resulting in a serious damage to human health. No routine testing for presence of odor contaminants is performed.

Allergens

Eleven percent of the cca 30 insect orders may cause allergenic reaction in man, including species of Zygentoma (silverfishes), Blattodea (cockroaches), Phasmatodea (stick insects), Orthoptera (locusts, crickets), Phthiraptera (lice), Hemiptera (true bugs, cicadas), Coleoptera (beetles), Diptera (flies, mosquitoes), Siphonaptera (fleas), Caddisflies (Trichoptera), Lepidoptera (butterflies, moths) and Hymenoptera (bees, wasps, ants) (Arlian, 2002, Auerswald, Lopata, 2005). Evidence is growing that an exposure to storage and food industry arthropods is a cause of serious allergenic sensitization. Acarina, Blattodea, Coleoptera, Lepidoptera, and Psocoptera include species whose body parts or secretions cause allergic reactions in humans (Arlian, 2002). Known allergens have now been identified in four stored product mite species (Arlian, 2002) and the extracts of four other species showed specific IgE determinations (Musken et al., 2003). Psocids show some allergen potential, but observations on particular species have not been done. Among beetles, extracts from *Tribolium* spp. and *Sitophilus* spp. showed specific human IgE reactivity (Alanko, et. al., 2000, Herling, et. al., 1995). The continual presence of insects and mites in workplaces may lead to the development of occupational allergenic diseases of farmers, millers, bakers and other food industry operators (Revsbech, 1990). The exposure to infested grain dust is associated with a number of allergic difficulties, including conjunctivitis, rhinitis, dermatitis and asthma (Jeebhay, 2001). No routine testing for presence of allergen contaminants in stored product agri-commodities is performed. Immunological kits are available for detection of dust mites and cockroaches.

Population density and contamination thresholds

Arthropod parts, exuviae and feces are considered physical contaminants and the safe levels are regulated by Defect Action Levels (DALs) in USA. The US food and Drug Administration (FDA) has established a defect action level of 75 insect fragments per 50 g of wheat flour (FDA, 1988), but this level is often higher than US mills will tolerate (Flinn and Hagstrum, 2001). Although in Europe is zero tolerance to insects fragments in food, in reality, no regular inspection are performed for insect fragments.

No critical levels are available for contamination of food agro-commodities by allergens and chemical contaminants of storage arthropods. Recently, we have attempted (Stejskal Hubert, 2006 submitted) estimating the relationship between mite density and allergy risk in Czech grain stores. The estimation of mite allergy-risk levels (ARLs) was based on published mite densities that cause human health problems (Lau et. al., 1989, Platts-Mills et. al., 2000). Exposure to more than 100 mites.g-1 dust (1 mites.g-1 grain) is considered to increase the risk of sensitization and symptoms, while exposure to more than 500 mites.g-1 dust (5 mites.g-1 grain) may increase the risk of acute asthma attacks (Lau et al., 1989, Platts-Mills et al., 2000). Based on these data we estimated the following five classes of, Allergy-Risk-Level" (ARL) for occupational allergy in grain stores: (i) safe level (mite-free grain), (ii) low risk level (up to 1 mites. g-1 grain), (iii) high risk level (from 1 to 5 mites.g-1 grain), (iv) danger -acute asthma-level (higher than 5 mites .g-1 grain). Grain samples (N= 514 grain stores) belonged to the established ARL classes as follows: (i) safe-ARL: 37 % (ii) low-ARL: 53 %; (iii) high-ARL: 6 %; (iv) danger-acute asthma-ARL: 4 % (Tabela 1).

Table 1. Allergy threshold levels (ARL) of samples from Czech grain stores, absolute numbers and percentage of samples in ARL levels.

ART level abundance (ind.g -1grain)		i absolutly safe 0	ii posible risk level up to 1	iii danger level 1 - 5	iv acute allergy risk 5 and more
All mite species	total	150	291	39	34
	%	29	57	8	7
Allergenic mites	total	191	273	30	20
	%	37	53	6	4
Acarus farris	total	482	27	1	4
	%	94	5	0	1
Acarus siro	total	377	115	10	12
	%	73	22	2	2
Aleuroglyphus ovatus	total	513	1	0	0
	%	100	0	0	0
Chortoglyphus arcuatus	total	503	6	4	1
	%	98	1	1	0
Glycyphagus domesticus	total	513	1	0	0
	%	100	0	0	0
Cheyletus eruditus	total	389	118	7	0
	%	76	23	1	0
Lepidoglyphus destructor	total	340	166	7	1
	%	66	32	1	0
Tyrophagus putrescentiae	total	439	71	1	3
	%	85	14	0	1

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