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Can environmental dust from silo area allow the development of stored product insects?

D.P. Locatelli, S. Savoldelli, P. Girgenti, G.A. Lucchini, L. Limonta*

Department of Food, Environmental and Nutritional Sciences, University of Milan, via G. Celoria 2, 20133, Milan, Italy

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ABSTRACT

Dust derived from food processing can accumulate in places difficult to reach, where stored-product pests could thrive. The purpose of this work was to verify the development of *Plodia interpunctella*, *Ephestia kuehniella*, and *Tribolium castaneum* in dust collected on pipes and beams (15 m and 7.5 m) in a silo area of a pasta industry. Proximate analyses showed a higher metal content in the dust collected at the two different heights than semolina, including the presence of chrome, cobalt, arsenic, and lead. Particle size distribution analysis showed that in the two samples of dust the highest percentage was constituted by particle sizes smaller than 106 μm. The tests were carried out by using two quantities 4 g or 0.15 g of dust (corresponding to 3 mm and 0.1 mm), at controlled conditions. Fifty larvae, 0–24 h old, of each species, were used for each dust, semolina, and thickness test. The number of emerged adults was assessed daily. *T. castaneum* developed on all the tested substrates, despite the high content of metals and the small particle size in the environmental dust. A significant interaction between diet and thickness of the layer was observed, but thickness had a stronger influence than diet. Moreover, light filth analysis detected a large number of fragments of *Tribolium* sp. in dust collected at a different height. Dust was unsuitable for the development of moths; only two *E. kuehniella* adults emerged from 3-mm-deep dust collected at 15 m, and development lasted more than 90 d.

1. Introduction

Cereals and their byproducts are susceptible to attack of several species of stored product insects (Keskin and Ozkaya, 2013). Food processing industries offer optimal conditions for the development of such pests, including shelter, high temperature and relative humidity, the absence of predators and parasitoids, and plenty of food. Moreover, dust derived from food processing can accumulate in places difficult to reach, inside and under machinery, on electric cables and cabinets, and on windowsills where insects can develop unobserved (Dal Monte, 1984; Trematerra et al., 1984; Rotundo et al., 1995; Trematerra and Süss, 2006; Phillips and Throne, 2010).

Flying insects can thrive on uncollected dust and contaminate food on production lines. The presence of insects or their fragments in processed food can damage company reputations; therefore, taking targeted action to avoid insect contamination is of primary importance. This action includes checking raw materials, modifying the environment to make it less favorable for pest establishment, and applying integrated pest management strategies. Dust that accumulates in the upper areas of the food plants is particularly difficult to reach and remove, and regular monitoring cannot be carried out easily. Consequently, cleaning of high areas such as beams, pipes, and windowsills cannot be included in routine cleaning for several reasons; instead, these operations must be performed by specialized cleaning companies, and they are expensive and, therefore, occur rarely. It must be considered that, in dust derived from food processing, stored-product pests such as darkling beetles and pyralid moths can settle, as they find food and suitable conditions for development, and make them permanent hotbeds of infestation in the plant. On the other hand, dust, deposited as time goes by, can be enriched with particles of various origin that are derived from the surrounding environment. In particular, they may be enriched with metals that could affect the development of stored-product pests (Perron et al., 1966; Baker et al., 1976; Davis and Boczek, 1987).

The purpose of this work was to observe the development of *Plodia interpunctella* (Hübner) (Indian Meal Moth), *Ephestia kuehniella* Zeller (Mediterranean Flour Moth), and *Tribolium castaneum* (Herbst) (Red Flour Beetle) on dust collected at different heights in

* Corresponding author.
E-mail address: lidia.limonta@unimi.it (L. Limonta).

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the silo area of a pasta plant. The aim was, first, to verify whether flour dust, produced during processing and enriched with airborne dust, is suitable for the development of the above-mentioned insects and secondly, to establish the amount of dust that can be tolerated to improve cleaning operations.

2. Materials and methods

2.1. Collection and analysis of flour dust and semolina

Samples of flour dust were collected in the North of Italy, from a silo area of a pasta plant belonging to a company that produces more than 30,000 tons per year of traditional and organic pasta. Pyrethrum (Piretro Safe H, Copyr S.p.A.) was used 2–3 times a year, during spring and summer to control flying adults.

Dust was collected with a flat brush and a dustpan, during a rare comprehensive cleaning operation, by pipelines (7.5 m height) and beams (15 m heights) surfaces and placed in plastic bags. The amount of dust collected from pipelines and beams was respectively 942 g and 791 g. Dust samples were sieved with 20 mesh to separate any larger concrete particles. Samples of semolina, 500 g for each of the four silos, were also collected during charging operation; the samples were mixed before tests. The particle size distribution of dust and semolina was measured by sieve analysis, using six sieves of 20, 45, 70, 100, 125, and 140 US mesh, on a sample of 100 g (Table 1). In dust collected at 7.5 m and at 15 m, the highest percentage of particles was smaller than 106 μm, 62.69% and 79.10%, respectively. In semolina, the highest percentage of particles (49.70%) ranged from 212 to 354 μm. The semolina was ground to obtain a particle size distribution similar to the collected flour dust. Semolina and ground semolina were used as controls. All samples were kept at −18 °C for 15 days before the tests, to eliminate any possible prior infestation.

Proximate analyses were performed on 50 g the dust and semolina samples to determine the nutritional value (2 replicates). Different methods were used, fiber content was analyzed according to Prosky et al. (1988); carbohydrates were determined with Rocklin and Pohl (1983) method; Association Of Analytical Communities and American Association for Clinical Chemistry methods were performed to measure proteins (Anonymous, 1995), fats (Anonymous, 1996), moisture (AACC 44–15.02), ashes (AACC 08–01.01). The results of analysis are summarized in Table 2. Semolina has the highest moisture content (11.4%), followed by dust collected at 7.5 m (8.6%) and dust collected at 15 m (7.8%). Insoluble and soluble fiber content in dust collected at the two different heights was twice the one observed in semolina. Similar amounts of proteins, fats, and sugars were present in all three substrates. Ash content was higher in dust collected at 15 m (2.4%) and lower in dust collected at 7.5 m (1.7%). The lowest ash content was observed in semolina (0.8%). To determine elements of interest (Al, Cr, Fe, Co, Ni, Cu, Zn, As, Sr, Mo, Ag, Cd, Tl, and Pb), 0.25 g of each of the dust and semolina samples were digested by a microwave digestor system (Multiwave-Eco Anton Paar GmbH, Graz, Austria) in Teflon tubes filled with 10 mL of 65% HNO_3 by applying a one-step temperature ramp (at 210 °C in 10 min, kept for 10 min). After being cooled for 20 min, the mineralized samples were transferred to polypropylene test tubes and diluted at a ratio of 1:40 with MILLI-Q water. Then, the concentration of elements was measured by ICP-MS (BRUKER Aurora-M90 ICP-MS). An aliquot of a 2 mgL^{-1} of an internal standard solution (72Ge, 89Y, 159 Tb) was added to both samples and by calibration curve to give a final concentration of 20 mgL^{-1}. Typical polyatomic analysis interferences were removed by using CRI (Collision-Reaction-Interface) with an H_2 flow of 75 mL min^{-1} flow through a skimmer cone. Metal content (Table 3) was higher in dust collected at 15 m, and it gradually decreased in dust collected at 7.5 m, and in semolina. In particular, the amount of aluminum in dust collected at 15 m was twice the one observed in dust collected at 7.5 m, and iron was three times higher. Furthermore, both dust collected at two different height contained chrome, cobalt, arsenic, and lead, and all these metals were absent in semolina.

Table 1
Percentage distribution of particle size (μm) of dust collected at 15 m (A) and 7.5 m (B) and of semolina (C) and ground semolina (C-ground) from silos.

μm	Particle size distribution (%)			
	A	B	C	C-ground
<106	79.10	62.69	16.24	79.00
106–124	3.83	3.08	2.92	4.00
125–149	2.40	4.21	5.74	2.00
150–211	4.66	5.75	7.13	5.00
212–354	7.99	16.32	49.70	8.00
355–850	2.02	7.95	18.27	2.00
>850	0.00	0.00	0.00	0.00

Table 2
Results (%) of proximate analysis of dust collected at 15 m (A) and 7.5 m (B) and of semolina from silos (S.E.: standard error; CV: coefficient of variation).

Substrate	A		B		C	
	Mean ± S.E.	CV%	Mean ± S.E.	CV%	Mean ± S.D.	CV%
Moisture	7.8 ± 0.08b	0.9	8.6 ± 0.02b	0.3	11.4 ± 0.20a	3.8
Ash	2.4 ± 0.02a	1.0	1.7 ± 0.00b	0.1	0.8 ± 0.02c	3.8
Protein[a]	11.0 ± 0.02b	0.3	11.0 ± 0.03b	0.4	11.3 ± 0.10a	1.3
Fat	1.3 ± 0.04	4.6	1.4 ± 0.03	3.5	1.4 ± 0.01	0.6
Insoluble fiber	4.2 ± 0.27a	8.9	4.2 ± 0.06a	2.2	2.0 ± 0.08b	5.8
Soluble fiber	2.2 ± 0.16a	10.5	2.2 ± 0.17a	10.9	1.0 ± 0.08b	11.9
Glucose	0.3 ± 0.01a	3.9	0.2 ± 0.02a	14.8	0.1 ± 0.01b	28.1
Fructose	0.3 ± 0.01a	6.9	0.3 ± 0.01a	6.9	0.1 ± 0.00b	9.3
Saccharose	1.2 ± 0.01a	1.5	1.2 ± 0.01a	1.5	0.8 ± 0.07b	12.2
Maltose	1.6 ± 0.09	7.7	1.6 ± 0.09	7.7	1.2 ± 0.09	10.6
Starch[b]	67.7 ± 0.24b	0.5	67.5 ± 0.23b	0.0	70.0 ± 0.00a	0.0

The means followed by different letters in the same line are significantly different (LSD, $P < 0.05$).
[a] A conversion factor of 5.70 was used for protein.
[b] Estimated by difference.

Table 3
Mean (±SE) metal content (μg g^{-1}) of dust collected at 15 m (A) and 7.5 m (B) and of semolina from silos (C)[a].

	Metal content (μg g^{-1})		
	A	B	C
Na	156.3 ± 1.60a	121.7 ± 2.20b	15.7 ± 1.27c
Mg	1397.0 ± 15.81b	1557.6 ± 19.17a	446.4 ± 5.64c
Al	216.8 ± 3.93a	99.4 ± 4.05b	1.8 ± 0.17c
P	2.4 ± 0.02b	2.6 ± 0.04a	1.8 ± 0.02c
K	3485.4 ± 34.01b	3754.1 ± 43.52a	2646.9 ± 32.60c
Ca	969.9 ± 6.38a	685.7 ± 38.27b	267.7 ± 3.69c
Cr	19.2 ± 0.67a	14.2 ± 0.66b	0.0 ± 0.00c
Mn	24.1 ± 0.25a	17.4 ± 0.27b	9.3 ± 0.14c
Fe	1579.7 ± 96.62a	481.8 ± 28.4b	9.3 ± 0.16c
Co	0.4 ± 0.02a	0.2 ± 0.01b	0.0 ± 0.00c
Ni	10.4 ± 0.79a	7.8 ± 0.15b	0.2 ± 0.01c
Cu	27.0 ± 1.22a	11.4 ± 0.23b	3.4 ± 0.14c
Zn	196.0 ± 13.26a	123.9 ± 5.74b	15.5 ± 0.51c
As	0.2 ± 0.01a	0.1 ± 0.00b	0.0 ± 0.00c
Sr	3.3 ± 0.03a	2.4 ± 0.03b	0.9 ± 0.85c
Mo	1.5 ± 0.03a	1.2 ± 0.02b	0.8 ± 0.04c
Pb	3.4 ± 0.15a	1.9 ± 0.05b	0.0 ± 0.00c

The means followed by different letters in the same line are significantly different (LSD, $P < 0.05$).
[a] Ag, Cd, Tl were absent.