Exposure to inhalable Flour Dust, Wheat-Allergens and Fungal α-Amylase in Flour and Enzyme Processing Industries and Bakeries

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Introduction

Exposure to flour dust and especially to (flour) aeroallergens is associated with an increased asthma and rhinitis risk in bakers. However, hardly any information on exposure levels is available for other companies than bakeries. The objectives of the present study were to measure full-shift exposure to inhalable dust, wheat-allergens and α-amylase in different industries with flour and enzyme exposure, and to investigate relevant exposure determinants which indicate directions for control strategies.

Methods

Personal full-shift (at least 6 hours) exposure to inhalable dust was estimated in four sectors, i.e. small traditional bakeries, large industrialised bakeries, flour mills, and suppliers of bakery ingredients. A PAS6 sampling head equipped with a teflon filter (25 mm PTFE filters, Type FA, pore size 1 µm, Millipore Limited, UK) and connected to a Gilair-5 pump (2 L/min) (Sensidyne, USA) was attached to the worker's torso in the breathing zone. The dust level was determined by pre- and post-weighing the filter. In the dust, wheat-allergens (detection limit 0.02-1.6 µg/ml) and fungal α-amylase (detection limit 100 pg/ml) concentrations were analysed using earlier described immuno-assays [Houba e.a., 1996]. 87 workers were measured on two or three days. For each worker, the following information was recorded: job title, frequency and duration of tasks performed during the day, work practices, type of products manufactured and used, and the presence of potentially effective control measures.
Statistical analysis was done using SAS version 8.2 for Windows (SAS Institute Inc., NC, USA). To identify relevant exposure determinants, mixed effects models were used to account for repeated measurements.
Further details of the study are presented in De Pater *et al.* [2003].

Results

Exposure levels

In total, inhalable dust exposure was measured in 55 traditional bakeries, 16 industrialised bakeries, 6 flour mills and 7 bakery ingredients suppliers.
In Table 1, concentration levels are presented per sector. The number of samples differ for dust and allergens because not all filters have been analysed for allergens so far.

On average, highest dust concentrations were found in flour mills and suppliers of bakery ingredients. Wheat-allergen exposure was highest in flour mills and small bakeries with 14% and 22% of samples being lower than the limit of detection (LOD). Highest exposure levels for fungal α-amylase were found for suppliers of bakery ingredients and flour mills where workers regularly handled the enzymes in a relatively pure formulation. In bakeries were 60 to 70% of the workers exposed to concentrations below the LOD.

Determinants of exposure

Mixed effects models were used to identify significant predictors of exposure.

For inhalable dust and wheat-allergens more variability was explained by the tasks performed than with sector and job title only (dust R^2 43% versus 33%; wheat-allergens 42% versus 32%). Sector and job title explained most of the variability in α-amylase exposure (R^2 47%). Compared to a model with only sector and job-title, including tasks in the model did not seem to explain much more of the variability in exposure (R^2 50%). Not much variability in exposure is further explained by adding ventilation, season, weekday, number of employees or amount of flour handled to the model. The low explained variability suggests that differences in task performance should be investigated more thoroughly to recognize good work practices.

Relatively high exposed job-titles were dough makers in large bakeries; milling operators, cleaners, and operators involved in bagging in flour mills; and weighers and operators involved in dumping or bagging in bakery ingredients supplying companies.
Regression coefficients were highest for tasks such as weighing, dusting, mixing, dumping, cleaning and filling/bagging with differences for type of exposure, indicating that control measures should preferably be focussed on these tasks.

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Table 1 Exposure levels for inhalable dust, wheat-allergens and α-amylase per sector

Sector	Component	N	GM	GSD	%<LOD*
Traditional bakeries	Dust (mg/m³)	162	1.5	3.0	-
	Wheat (µg/m³)	134	5.5	9.3	22
	α-Amylase (ng/m³)	135	1.3	4.3	64
Industrialised bakeries	Dust (mg/m³)	186	1.0	3.8	-
	Wheat (µg/m³)	175	2.2	13.1	40
	α-Amylase (ng/m³)	175	1.0	3.3	71
Flour mills	Dust (mg/m³)	156	3.2	4.7	-
	Wheat (µg/m³)	140	11.7	10.1	14
	α-Amylase (ng/m³)	143	8.0	9.8	26
Bakery ingredients suppliers	Dust (mg/m³)	128	2.0	5.9	-
	Wheat (µg/m³)	114	4.0	12.1	31
	α-Amylase (ng/m³)	114	32.4	22.2	17

** percentage of the samples with a concentration below the limit of detection*

Exceedance of occupational exposure limits

For flour dust, wheat-allergens and α-amylase no (Dutch) occupational exposure limits are available (8 hr-TWA). The Dutch Expert Committee of the Health Council has recommended a health-based occupational exposure limit of 0.5 mg/m³ for flour dust. In Sweden the exposure limit for flour dust is 3 mg/m³ and in the United Kingdom 10 mg/m³. In the literature, No Observed Adverse Effect Levels (NOAELs) for allergens are suggested as follows: 2-6 µg/m³ for wheat-allergens and 1-5 ng/m³ for α-amylase [Houba *et al.*, 1996; Nieuwenhuijsen, 1997; Heederik & Houba, 2001]. A probability approach was followed to test compliance with these limit values as described in EN 689. The probability of non-compliance is given in Table 2. Overall, the probability of exceeding the Dutch recommend exposure limit for flour dust of 0.5 mg/m³ is 81%. Generally, a probability of larger than 5% is considered too high and appropriate actions have to be taken to reduce exposures.

Required reduction factors

The probability approach can also be used to determine required reduction factors assuming a probability of exceeding limit values of 5% or less. For bakeries reductions of a factor 20 are required for inhalable dust, and in flour mills and bakery ingredients suppliers up to a factor 80. For wheat-allergens factors varying from 70 to 300 are required. For α-amylase in flour mills and bakery ingredients suppliers highest reduction factors are required (several hundreds to thousands).

Control measures

Several control measures have been evaluated for their effectiveness for exposure reduction. Overall, only in few companies operational control measures have been implemented. Therefore, possible reductions are based on very limited data and are only indicative.

In traditional bakeries local exhaust ventilation, dust-free flour, divider oil, closed mixers and solid dough improvers were evaluated with reduction factors of 1.3 to 10. In industrial bakeries, liquid dough improvers, local exhaust ventilation and as much as possible replacement of bagged products by silo products reduces exposures with a factor of 1.4 to 2.8. In flour mills and bakery ingredients suppliers only local exhaust ventilation was evaluated (reduction factor 1.5-10). For dust and allergens, relevant measures and accompanying reduction factors differed to some extent. For example, as was to be expected, liquid or solid dough improvers only reduce exposure to α-amylase.

Conclusions and recommendations

In the measured sectors, i.e. small traditional bakeries, large industrialised bakeries, flour mills, and suppliers of bakery ingredients, (very) high inhalable dust, wheat-allergens and fungal α-amylase exposure levels were found according to the latest opinions about exposure limits. High reduction factors are required (factor ten to thousands) to reduce exposure to levels below recommended limit values, especially in flour mills and among bakery ingredients suppliers and for job-

*Table 2 Probability of exceeding (recommended) limit values or NOAELs**

Sector	Inhalable dust 0.5-10 mg/m³	Wheat-allergens 2-6 µg/m³*	α-Amylase 1-5 ng/m³*
Traditional bakeries	4-84%	48-67%	16-57%
Industrialised bakeries	4-70%	35-52%	9-50%
Flour mills	23-89%	61-78%	58-82%
Bakery ingredients suppliers	18-78%	44-61%	73-87%

** No Observed Adverse Effect Levels*

titles such as dough makers, weighers, operators involved in bagging and dumping, and hygiene workers.
Only few (effective) control measures were found operational in practice. Reductions up to a factor 10 seems achievable with correctly installed and now used local exhaust ventilation. However, in most situations this is not sufficient.
It is recommended to develop new exposure control techniques, focused on specific tasks that largely contribute to full-shift exposure, like dusting, mixing, dumping, filling, maintenance and cleaning. Furthermore, more effort is needed to investigate good work practices in more detail.

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