

ALLERGIES IN THE WORKPLACE

A PILOT STUDY OF EXPOSURE TO FLOUR DUST AND ALLERGENS IN CAPE TOWN BAKERIES

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ABSTRACT

Background: A pilot study was performed as part of a large exposure assessment study, with the aim of documenting variability in environmental exposure and high-risk work processes/job types in bakeries of varying sizes in a large supermarket chain store in the Western Cape province of South Africa. The results of this pilot study have been used to design the measurement strategy for the main exposure study.

Methods: Personal inhalable flour dust samples were collected on randomly selected individuals within each job category (bread baker, baker controller, confectioner, counterhand, cleaner). The samples were analysed for particulate mass and specific flour dust allergens (wheat and α -amylase allergens). Exposure metrics were developed on the basis of individually measured exposures and average levels of these personal samples within each job category. Surface samples collected were analysed for presence of other biocontaminants such as house-dust mite and mould.

Results: A total of 42 full-shift personal samples were collected and analysed. Personal sampling revealed moderate variation across job titles in flour-dust concentration. Bread bakers had the highest average (geometric mean (GM)) flour-dust concentration (0.904 mg/m³), followed by confectioners

(0.539 mg/m³) and bakery controllers (0.289 mg/m³), with counterhands having the lowest average exposures (0.125 mg/m³). Similarly, in respect of the distribution of wheat allergen levels, bakers had the highest average (GM) allergen concentration (16.504 μ g/m³), followed by confectioners (7.307 μ g/m³), with counterhands the lowest (0.84 μ g/m³). There was a significant degree of correlation between general dust levels and wheat allergen concentrations (Spearman $r = 0.91$). Surface samples demonstrated the presence of house-dust mite and mould species *Aspergillus* and *Penicillium* sp.

Conclusion: This study demonstrates that bread bakers have the highest and counterhands the lowest flour-dust and wheat-allergen exposures. The findings also suggest that flour-dust particulate exposure could be used as a proxy for wheat-allergen concentrations. The results of this study have been used to optimise the study design for the larger exposure assessment study to flour dust-allergens (wheat, rye and fungal α -amylase) among supermarket bakery workers in the Western Cape.

INTRODUCTION

Baker's asthma due to airborne allergens present in flour dust in the work environment, is one of the most commonly reported manifestations of occupational asthma worldwide.^{1,2} Baker's asthma, like other forms of occupational asthma is probably the most serious manifestation of occupational allergy among bakery workers, hence the need for preventative strategies to reduce exposure.³ Occupational exposure to flour occurs mainly in occupations in bakeries, flour mills, other food-producing and processing industries, as well as related industries such as enzyme-producing and baking-ingredient industries. Many of these bakeries are increasingly located in small-scale enterprises and supermarkets in South Africa.

Numerous studies have evaluated exposure to flour dust among bakery workers.⁴ Most of these studies have been conducted in industrial bakeries, where the differences in exposure between job titles and tasks are more distinct. In relation to bakers, results of these studies demonstrate that workers at the front end of the baking process (dough makers, bread formers) have the highest 8-hour average dust exposures (average inhalable dust exposures of 3-9 mg/m³).⁵ Among bread- and cake-baking groups, sieving gives rise to the greatest dust exposures, followed by weighing and mixing.⁶ Furthermore cleaning operations, bread and roll production also give rise to high exposures.⁷ Most peak exposures are caused by dusting during dough forming (to prevent dough adhesion to surfaces) or by adding ingredients into the dough mixer.

A recent study among bakery workers employed in supermarkets in the UK, however, demonstrated much lower dust concentrations, with a geometric mean (GM) dust exposure for bakers of 1.2 mg/m³, followed by managers (0.5 mg/m³) and confectioners (0.3 mg/m³).⁸ It has also been demonstrated that the relationship between dust and wheat antigen exposure

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varies considerably, depending on the specific bakery occupation, the size of the bakery, and the type of product produced by the bakery.⁹

Although exposure to inhalable flour dust and allergens among bakery workers has been very well documented, there are no exposure assessment studies reported of workers in bakeries within the South African context in general and supermarkets in particular.

This pilot study was conducted as part of a wide-scale exposure assessment study looking at exposure to flour dust, wheat allergens and several other occupational allergens in South African supermarkets. The main objectives of this study were to quantify exposure to flour-dust particulate levels and wheat allergens among bakery workers employed in supermarkets of variable size and production output. The results of this study were used to optimise the design of the main exposure study for the larger baseline exposure assessment study to flour dust and allergens (wheat, rye and fungal α -amylase) in bakeries of a supermarket chain store.

METHODS

Bakeries of a supermarket chain store were stratified into small, medium and large size bakeries by virtue of the number of workers employed, floor size and the production output of the bakery. The categories for these bakery size indices were derived using tertile values of the following variables as cut-off points – number of employees: ≤ 14 , 15-21 and > 21 ; floor size (m^2): ≤ 80 , 81-175 and > 175 ; production output in bakery units per week: $\leq 7\ 504$, 7 505-10 868 and $> 10\ 868$. Bakeries were classified into these categories on the basis of meeting two or more of these criteria. For purposes of the preliminary pilot study, one each of the small, medium and large bakeries were randomly selected for environmental sampling.

Within the bakeries, six main job titles could be distinguished: baker, bakery controller, bakery manager, confectioner, counterhand and cleaner. Bakers, were mainly involved in tasks such as *dough making*; *bread and roll production* that involves emptying bags of flour and other ingredients such as enzymes into a mixer; *dusting* of tables and bread/rolls with flour (Fig. 1). Bakery controllers and managers performed several tasks, *placing orders*, and *supervising production*, but commonly also perform some tasks of bakers. Confectioners were mainly involved with *production of cakes and pastries* (Fig. 2). Counterhands were involved with *serving of customers*, *stocking the counter* and *wrapping of products*. Cleaners are mainly



Fig. 1. Example of activities resulting in 'increased' exposure to flour dust.



Fig. 2. Example of activities with low flour-dust exposure.

involved with *sweeping/cleaning* floors, cleaning tables and washing dishes. In each bakery a random sample of workers from each job category was selected for sampling.

Sampling equipment

Personal sampling was performed on all selected subjects on 2 consecutive days. Full-shift time-weighted-average samples were obtained on each participating worker using a PAS6 sampling head connected to a Gillian GilAir pump with constant-flow calibrated to 2 litres per minute (Fig. 3). Teflon filters (Millipore; pore size 1.0 μm , 25 mm diameter) were used. Field blanks were included for each sampling day. Filters were stabilised for 24 hours in an acclimatised room with controlled humidity and temperature (40%, 22°C) to ensure standard weighing conditions before weighing. Filters were weighed before and after sampling using a microbalance (Mettler Toledo AG245).



Fig. 3. Example of worker wearing a PAS6 sampling head, during exposure assessment.

Personal sample analysis

After weighing, the samples were prepared for immunological quantification by delaminating the filters, extraction in 2.5 ml phosphate buffered saline (0.15 M), centrifugation and storing the supernatant at -20 degrees Celsius. Wheat flour allergens were measured using enzyme-linked immunosorbent assay (ELISA) inhibition and an antiwheat IgG4 serum pool.¹⁰ Alpha-amylase allergens were measured using a sandwich enzyme immunoassay with affinity-purified polyclonal rabbit IgG antibodies. Both methods are described in detail by Bogdanovic *et al.*¹¹

Analysis of surface samples

Dust samples collected from surfaces in the bakery were analysed for dust allergens from house-dust mites (*Dermatophagoides pteronyssinus* and *Dermatophagoides farinae*) using the ELISA-20 kit from Indoor Biotechnologies (UK). Furthermore samples were analysed for the presence of moulds (*Aspergillus* and *Penicillium*) using malt extract agar (MEA) as medium.

Statistical analyses

All statistical analyses were performed using STATA version 8. Descriptive univariate statistics were generated for the total sample distribution. Linear regression models were developed to describe the determinants of variability of the various exposure metrics. The data followed a log-normal distribution, thus the natural logarithm of the measured exposure was used as the dependent variable. Exposure metrics were developed on the basis of individually measured exposures and average levels of these personal samples within each job category.

RESULTS

A total of 42 full-shift personal samples were collected during this survey. Tables I and II present the results for the flour-dust and wheat-allergen concentrations in the personal samples respectively. For inhalable flour-dust and wheat-allergen exposure, the exposure data followed a log-normal distribution.

Inhalable dust and wheat allergen exposures

Bread bakers had the highest average (GM) flour-dust concentration (0.904 mg/m^3), followed by confectioners and bakery controllers, with counterhands having the lowest average exposures (0.125 mg/m^3) (Table I). A similar pattern was observed in respect of the distribution of wheat-allergen levels, as bakers had the highest average (GM) allergen concentration and counterhands the lowest exposures ($0.84 \text{ } \mu\text{g/m}^3$) (Table II). For α -amylase allergen exposure concentrations the results were remarkably different. For most job titles, except for one baker (α -amylase: 1.083 ng/m^3) from a large bakery, all samples were below the limit of detection. All the bulk samples of various raw products were tested for the presence of enzymes and while some tested positive for α -amylase, no xylanase was detectable in any sample (limit of detection: 0.5 ng/mg).

A gradient of exposure was observed for inhalable dust levels when categorised by bakery size, with small bakeries having the lowest average concentration, followed by medium size bakeries and large bakeries having the highest exposure (small GM = 0.281 mg/m^3 ; medium GM = 0.436 mg/m^3 ; large GM = 0.569 mg/m^3). The differences in exposure levels for wheat allergens did not follow a similar trend (small GM = $3.111 \text{ } \mu\text{g/m}^3$; medium GM = $2.941 \text{ } \mu\text{g/m}^3$; large GM = $7.574 \text{ } \mu\text{g/m}^3$). While the differences between the bakery sizes appeared to be quite noticeable between the large and small bakeries, there was no significant trend in this gradient.

Correlation between airborne flour-dust and wheat-allergen concentrations

Scatter plots and correlation analysis indicated that there was a statistically significant linear correlation between the inhalable flour-dust concentrations and the wheat-allergen concentrations (Spearman $r = 0.91$, $p < 0.001$, $N = 40$) (Fig. 4).

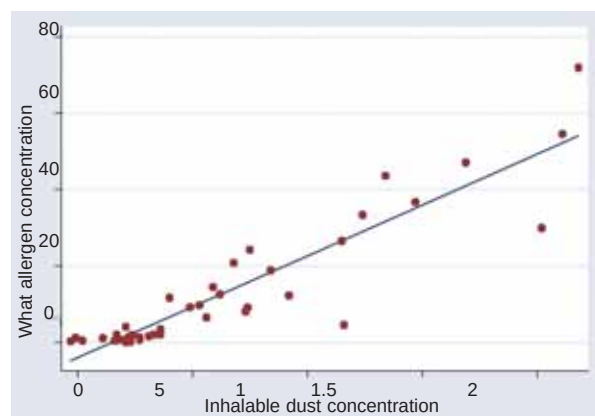


Fig. 4. Relationship between inhalable flour-dust and wheat-allergen concentration of personal samples among bakery workers

Microbial analysis of bakery surface samples

Among the four samples randomly analysed for the presence of house-dust mite allergens, all samples contained elevated levels of Der p1 and Der f1 allergen concentrations. These concentrations ranged from 171.8 to $472 \text{ } \mu\text{g/g}$ of surface sample dust. Furthermore, these four samples were also analysed

Table I. Personal ambient particulate concentration levels of bakery workers classified by job title (mg/m^3)

Job title	k	n	AM	GM	GSD	Range
Baker	9	18	1.067	0.904	1.831	0.360 - 2.180
Baker controller	2	3	0.330	0.289	1.876	0.160 - 0.560
Bakery manager	1	1	0.170	0.170	–	0.170 - 0.170
Confectioner	3	6	0.622	0.539	1.814	0.240 - 1.240
Counterhand	5	10	0.159	0.125	2.950	LOD - 0.330
Cleaner	1	2	0.105	0.210	–	LOD - 0.210
Overall	22	42	0.626	0.424	2.923	LOD - 2.180

k – number of workers sampled in an exposure group; n – number of measurements in a group; AM – arithmetic mean; GM – geometric mean; GSD – geometric standard deviation; LOD – limit of detection.

Table II. Personal ambient wheat-allergen concentration levels of bakery workers classified by job title ($\mu\text{g}/\text{m}^3$)

Job title	k	n	AM	GM	GSD	Range
Baker	9	18	24.220	16.504	2.694	2.092 - 71.89
Baker controller	2	3	2.508	1.204	4.408	0.379 - 6.429
Bakery manager	1	1	1.952	1.952	–	1.952 - 1.952
Confectioner	3	6	12.007	7.307	3.305	1.627 - 33.34
Counterhand	5	10	0.996	0.840	1.911	0.284 - 2.023
Cleaner	1	2	2.591	2.153	2.427	1.150 - 4.032
Overall	22	42	12.688	4.096	5.758	0.084 - 71.89

k – number of workers sampled in an exposure group; n – number of measurements in a group; AM – arithmetic mean; GM – geometric mean; GSD – geometric standard deviation.

for different mould species and the presence of *Aspergillus* and *Penicillium* spp. was established.

DISCUSSION

This study demonstrates that bakers have the highest 8-hour average dust exposures, compared with confectioners and counterhands. The average inhalable flour-dust exposures for the bakery workers in this study were lower ($0.125\text{--}0.904\text{ mg}/\text{m}^3$) than the levels reported by Elms *et al.*¹² ($2.2\text{--}4.7\text{ mg}/\text{m}^3$), Bulat *et al.*¹³ ($0.56\text{--}2.10\text{ mg}/\text{m}^3$), and Houba *et al.*¹⁴ ($0.7\text{--}4.5\text{ mg}/\text{m}^3$) among workers in industrial and traditional bakeries. Our results are however comparable to the exposure levels of Brant *et al.*⁸ (2005) among bakery workers in British supermarkets, which ranged from 0.3 to $1.2\text{ mg}/\text{m}^3$. More importantly, job titles associated with high dust-particulate levels in our study are consistent with almost all other studies reported in the literature.

Looking specifically at allergen exposures, the wheat-allergen exposure for bakers ($16.50\text{ }\mu\text{g}/\text{m}^3$) was similar to the results obtained by Houba *et al.* among dough-makers in large industrialised bread bakeries (GM = $16.51\text{ }\mu\text{g}/\text{m}^3$), but higher than the results in relation to bread bakers in small traditional bakeries (GM = $5.98\text{ }\mu\text{g}/\text{m}^3$).¹⁴ However, the wheat-allergen levels observed in our pilot study were much higher for bakers when compared with results of a recent study by Bulat *et al.* among bakers in industrial bakeries (GM = $6.15\text{ }\mu\text{g}/\text{m}^3$), but slightly lower in comparison with workers involved in bread production in traditional bakeries (GM = $22.33\text{ }\mu\text{g}/\text{m}^3$) in the same study.¹³ The α -amylase exposures obtained in this pilot study were significantly lower than those in British and Dutch studies.^{15,16} Recent studies have demonstrated exposure to α -amylase ranging from 0.33 to $0.61\text{ ng}/\text{m}^3$ among workers involved in dough making and bread production.¹³ Possible reasons for the lower concentrations observed in South African bakeries could be that different preparation and production processes are followed or there may be less reliance on enzymes in this setting.

The importance of measuring allergen concentrations instead of 'general' flour dust levels is reflected in the observation that only small differences in flour-dust levels may be found between occupational titles, more especially between occupational titles with exposure levels below $1\text{ mg}/\text{m}^3$, thereby providing a poor exposure estimate.⁹ A study conducted by Houba *et al.*¹⁴ found that the average dust exposure levels in occupational titles such as all-round staff, oven staff, slicers and packers varied from 0.4 to $0.9\text{ mg}/\text{m}^3$. However, antigen exposure levels in these occupational titles var-

ied 13-fold ($77\text{--}992\text{ ng}/\text{m}^3$), as opposed to the 2-fold variation in dust exposure. A similar observation has been demonstrated by this current study in which important differences were observed in the mean exposures when comparing the lowest (counterhand) and the highest exposed jobs, varying about 7-fold for the inhalable dust-particulate concentrations and 20-fold for the wheat-allergen concentrations.

The findings of this current study suggest however that the measurement of inhalable flour dust in personal samples may be a good surrogate of exposure to wheat allergens because of the high correlation observed between these two parameters of exposure ($r = 0.91$). Furthermore, the findings also suggest that wheat and to a lesser extent α -amylase, but not xylanase, appear to be important occupational allergens in supermarket bakeries. This is an important factor to bear in mind, especially in resource-poor settings with no access to advanced immunological assays or when evaluating the impact of specific interventions to comply with legislative requirements.

Of interest is the finding that the exposure to inhalable flour dust obtained in our study is well below the general occupational exposure limit of $10\text{ mg}/\text{m}^3$ erroneously used for 'general' dust by the industry in South Africa to assess compliance with exposure standards.^{17,18} When using this cut-off, none of the samples exceeded these occupational exposure limits. However, it is widely accepted that the exposure standards for 'general' dust, or for that matter grain dust, are not appropriate for assessing the relevance of elevated exposures to flour dust because of its highly allergenic nature. On the other hand, 45% of the samples were 3–4 times higher than the time-weighted average threshold limit values (TLV-TWA) for flour dust of the American Conference of Governmental Industrial Hygienists ($0.5\text{ mg}/\text{m}^3$).¹⁹ There are currently no specific exposure limits for wheat in South Africa, while internationally an occupational exposure limit of $0.2\text{ }\mu\text{g}/\text{m}^3$ has been suggested. When using this as a benchmark, the majority of the flour dust sample concentrations (95%) exceeded this limit, suggesting that bakery workers are not adequately protected against the allergic health risk associated with flour dust if the current legal standards are applied. This points to an urgent need to have these legal exposure standards revised.

In conclusion, this pilot study of exposure characterisation among bakery workers in South Africa is one of few studies done in supermarkets worldwide. It confirms the increasing trend observed in many countries that the high-risk activities associated with flour

dust/allergen exposure in the production of bread and other products has shifted from large industrial bakeries to smaller bakeries in supermarket chains. The results of this pilot study will be used to optimise the sampling strategy for the larger and more detailed baseline exposure assessment study to flour dust allergens (wheat, rye and fungal α -amylase) in bakeries of this supermarket chain in the Western Cape.

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Declaration of conflict of interest

The authors declare no conflict of interest.

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