

Respiratory symptoms and sensitization in bread and cake bakers

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This purpose of this study was to examine the relationship between exposure to wheat flour, soya flour and fungal amylase and the development of work-related symptoms and sensitization in bread and cake bakery employees who have regular exposure to these substances. The study populations consisted of 394 bread bakery workers and 77 cake bakery workers whose normal jobs involved the sieving, weighing and mixing of ingredients. The groups were interviewed with the aim of identifying the prevalence, nature and pattern of any work-related respiratory symptoms. They were also skin-prick tested against the common bakery sensitizing agents, i.e., wheat flour, soya flour, rice flour and fungal amylase. The results of personal sampling for sieving, weighing and mixing operations at the bakeries from which the study groups were taken were collated in order to determine typical exposures to total inhalable dust from the ingredients, expressed as 8 hour time-weighted average exposures. Data from the health surveillance and collated dust measurements were compared with the aim of establishing an exposure-response relationship for sensitization. The prevalence of work-related symptoms in bread bakery and cake bakery ingredient handlers was 20.4% and 10.4% respectively. However, in a large proportion of those reporting symptoms in connection with work, the symptoms were intermittent and of short duration. It is considered that the aetiology of such symptoms is likely to be due to a non-specific irritant effect of high total dust levels, rather than allergy. None of the cake bakers and only 3.1% of the bread bakers had symptoms which were thought to be due to allergy to baking ingredients. Using skin-prick testing as a marker of sensitization, the prevalence of positive tests to wheat flour was 6% for the bread bakers and 3% for the cake bakers. Comparable prevalences for soya flour were 7% and 1% respectively. However, the prevalence of positive skin-prick tests to fungal amylase was 16% amongst the bread baking group with only a single employee (1%) in the cake baking group having a positive test. Furthermore, this employee had previously worked in a bread bakery. The difference in rates of sensitization to wheat flour between the bread and cake bakers is not statistically significant, whereas the difference for soya flour is at the borderline of statistical significance ($p = 0.045$). In contrast, the difference in fungal amylase sensitization is significant at the 0.1% level. For both bread and cake bakers, the 8 hour time-weighted average exposures for each of the activities showed a wide variation with mixing having the lowest average exposure and sieving the highest. Out of the allergens studied in this investigation, fungal amylase is the principal sensitizer in large scale bread bakeries, with the main source of exposure being the handling of bread improvers. In contrast, the risk of sensitization to wheat flour is low in both bread and cake bakeries. The absence of positive skin-prick tests in the subgroup of cake bakery employees who regularly handle fungal-amylase-containing flour suggests that their levels of exposure are below the threshold for sensitization to amylase.

Key words: Amylase; asthma; flour.

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INTRODUCTION

Baker's asthma is a term which has gained widespread acceptance in the medical literature over the course of the last 30 years or so, on the basis that there is a link between exposure to dust from the baking ingredients and the development of symptoms. The potential of wheat flour to provoke IgE-mediated immunologic responses has also been documented at some length.¹⁻⁴ These two factors have led to the term 'baker's asthma' becoming generally synonymous with allergy to flour. In consequence, there is often an assumption that bakery employees who develop respiratory symptoms have done so because of an acquired allergy to wheat flour. Furthermore, a diagnosis of baker's asthma, is often made even where there are no supporting immunologic findings relating to wheat flour allergy.

During the same period when baker's asthma has become an accepted phenomenon, relatively little account has been taken of the fact that baking processes have changed significantly. The development of baking technology, particularly in relation to bread making, has brought with it a need for considerably more sophisticated ingredients than those used in traditional baking processes. Certain of the new ingredients, such as enzymes,⁵ are known to be potent respiratory sensitizers in their own right. One of the enzymes, fungal amylase, has been recognized as a sensitizer for some time, although it has only been recognized as a sensitizer in a baking context for 10 years.⁶ However, interest in the role of fungal amylase as an allergen in the baking industry is increasing⁷⁻¹⁰ and it has been suggested that this substance may be the principal allergen in bread bakeries.¹¹ The main source of exposure to fungal amylase is bread improver, whose typical constituents are listed in Table 1. A secondary source of possible exposure comes from certain types of flour to which fungal amylase has been added during milling. However, the concentration of fungal amylase by weight in these flours is some 200 times less than that of bread improvers, *i.e.*, 0.00125% in these flours *vs.* 0.025% in improvers.

It is also widely assumed that the wheat flour used in all baking processes is broadly similar in its allergenic potential. Little cognizance has been paid to the fact that cake bakers frequently use flour which is either chlorinated or heat-treated. The heat treatment process is known to reduce the natural cereal enzyme activity

within the flour through protein denaturation. Since cereal amylase is known to be one of the principal allergenic proteins in flour,¹² the allergic potential of heat-treated flour will be correspondingly reduced.

The purpose of this piece of work is to examine the differences between the prevalence of work-related symptoms and sensitization in bread and cake bakers who have regular exposure to ingredient dust and their link with total inhalable dust exposures. It also sets out to compare the relative sensitizing potential of the ingredients which are currently believed to be sensitizers in the baking environment, and how dose-response information might be useful in determining safe levels of exposure.

METHOD

The health surveillance study groups

The two study groups consisted of bread and cake bakery workers who had regular exposure to ingredient dusts during their normal working shifts. In selecting these groups, the key issue was regular exposure to ingredients in a production context, rather than occasional very high one-off exposures such as those experienced by cleaning or engineering personnel. The jobs which give rise to these exposures are sieving, weighing and mixing, for both bread and cake baking groups.

The bread baking group consisted of 392 employees from 19 plant bakeries within the UK. This represented the whole population in each of the job categories at all of the bakeries in a single food manufacturing company. With the exception of two employees at one bakery who declined to take part in the study, the group of 392 represented the total who were engaged in the activities described above across all the bakeries, at the time of the study.

The cake baking group consisted of 77 employees from three large cake bakeries within the UK. In these bakeries, all ingredient handling and mixing activities are carried out in Mixing Rooms which are physically separate from other production processes. The 77 represented the total who were engaged in the activities described above across the three bakeries, at the time of the study. Of the three bakeries, the type of flour used to produce the cake differed in that two of the

Table 1. Typical composition of bread improvers (from suppliers data sheets)

<i>Substance</i>	<i>Percentage by weight</i>	<i>Role</i>
Soya flour	30%–50%	Lipoxygenase activity
Wheat flour	0%–40%	Carrier/filler
Gypsum (calcium sulphate)	0%–30%	Carrier/filler
Emulsifier E422 (DATEM — monoglyceride esters of diacetyl tartaric acid)	15%–25%	Emulsifier
Creta (calcium carbonate)	0%–15%	Carrier/filler
Ascorbic acid	0.5%–1.5%	Oxidising agent
Fungal amylase	0.025%–0.055%	Starch breakdown

bakeries used substantial quantities of fungal amylase-containing flour, whereas the other used no amylase-containing flour. Furthermore, the bakeries which used amylase-containing flour had done so consistently for several years in both bulk and bagged form and in quantities approximating to half of the total flour usage. The bakery which used no amylase-containing flour had not done so at any time for at least the previous five years.

A prospective study of health surveillance findings was carried out on both of the groups.

Health surveillance procedures

Screening consisted of interview and skin-prick testing by one of three occupational physicians. Where appropriate, serial peak flow readings were also performed. The interview covered occupational history in relation to baking and enquiry regarding work-related or allergic respiratory symptoms. In particular, employees were asked about symptoms relating to possible rhinitis, conjunctivitis and asthma. The interviewing procedure covered the following points:

- Episodes of wheezing or chest tightness.
- Symptoms of shortness of breath or cough.
- Symptoms of sneezing, runny nose or blocked nose.
- Time of onset of symptoms.
- Duration of symptoms.
- Relationship of symptoms to work, *i.e.*, whether worse at work or at home, whether only arose exclusively at work and whether connected with particular task or ingredient.
- If symptoms were associated with a particular tasks or use of a particular ingredient, the temporal relationship with dust exposure and the duration after exposure ceased.
- If symptoms were relatively persistent, if there was an improvement away from work during rest periods or on holiday.
- Whether treatment had been taken for symptoms.

The usual epidemiologic tool for determining the prevalence of asthma or rhinitis symptoms is a standardized questionnaire. We have deliberately chosen not to use this approach for two reasons. Firstly there is some question regarding the accuracy of questionnaires for this purpose.¹³ Secondly we wished to probe the relationship between exposure to dust and the pattern of symptoms in some detail. We believe that a structured interview is the most appropriate method under these circumstances. However, it has to be accepted that this form of data collection, based essentially on clinical acumen, can introduce bias. In order to minimize this, the participating occupational

physicians broadly agreed the criteria for diagnosis prior to the commencement of the study. The diagnosis of occupational asthma or rhinitis was backed up by positive skin-prick tests to at least one work-related allergen in all cases, and by serial peak flow recordings as considered appropriate.

Skin-prick testing was performed against a standard set of solutions, namely: saline and histamine controls; commercially available common environmental allergens, *i.e.*, house dust mite, cat fur and mixed grass pollens (Biodiagnostics Limited); work-related allergens at a concentration of 1 mg/ml⁻¹, *i.e.*, wheat flour, soya flour, rice flour and *Aspergillus*-derived amylase (prepared from base ingredients by the National Heart and Lung Institute). The wheat flour used to make up the skin-prick test solution was a standard bread-making variety with no fungal amylase added during milling. Skin-prick tests were read after 10 minutes and were considered to be positive if there was a weal of at least 3 mm diameter.

Following interview and skin-prick testing, employees were allocated to one of four diagnostic categories: occupational asthma; occupational rhinitis; respiratory irritation or asymptomatic (*i.e.*, no work-related symptoms). The principal determinant of allocation to occupational asthma or occupational rhinitis categories was the presence of persistent relevant work-related symptoms. Where work-related symptoms were intermittent and/or short-lived, a diagnosis of non-specific respiratory irritation was made. For the purpose of this study, atopy was defined by positive skin-prick tests to one or more of the common environmental allergens, *i.e.*, house dust mite, cat fur or mixed grass pollens.

Dust exposure measurements

In choosing relevant exposure data, one of the considerations was the anticipated timescale of the sensitizing process. For high molecular weight sensitizers such as those encountered in a baking environment, sensitization may take a number of months or even years to develop. In order to take account of the latent period between onset of exposure and development of sensitization, all relevant occupational hygiene measurements over the seven years from the beginning of 1990 to the end of 1996 were collated. During this period, local exhaust ventilation had been installed at some of the bakeries. Although the bread baking samples were divided into those where local exhaust ventilation was in operation and those without, it was not considered relevant to the purpose of this study to compare rates of sensitization for these different groups. One reason for this is that those who were working with local exhaust ventilation in place at the time of the dust sampling may have become sensitized before the local exhaust ventilation was installed.

Personal sampling of total respirable dust was carried out at all of the 19 bread bakeries and three cake

bakeries at various times between 1 January 1990 and 31 December 1996, according to the methods described by the Health and Safety Executive.¹⁴ Samples were taken in connection with the activities which give rise to significant exposure to ingredient dusts on a regular production basis, *i.e.*, sieving, weighing and mixing/doughmaking.

For both bread baking and cake baking, personal samples were taken according to the principal activity undertaken at the time of the survey. Working practices vary considerably across both types of baking operation such that an employee who sieves ingredients will often weigh materials also during the same shift. The same is true for weighing and mixing (or doughmaking in the case of bread bakeries). Samples were therefore assigned to a category of either sieving, weighing or mixing/doughmaking according to the principal activity carried out during the working shift when the sampling took place. Nevertheless, part of the exposure may have arisen from one of the other tasks.

At the time of the surveys, some of the bread bakeries had local exhaust ventilation (LEV) applications for sieving and/or weighing operations. The type of LEV varied from simple hood extraction to laminar flow booths. The sampling results from activities where LEV was in place, regardless of type, have been separated from those with no LEV.

Statistical methods

Comparisons between the prevalence of different types of symptoms or positive skin-prick tests in the bread baking and cake baking groups were carried out using tests of statistical significance. Data comparison was made independently either by using a 2×2 χ^2 test or

by calculating Fisher's exact probability where any of the expected cell frequencies were very low (*i.e.*, < 5).

RESULTS

Health surveillance

The results of health surveillance are shown in Tables 2–4. A comparison of symptoms reported by employees who were regularly involved in sieving, weighing and mixing, is shown in Table 2. The overall prevalence of symptomatic allergy in the bread baking group was 3.1%, whereas there was no symptomatic allergy in the cake baking group. However, this difference was not statistically significant ($p > 0.1$ for both occupational asthma and rhinitis). A relatively high proportion of both the bread (17.3%) and cake (10.4%) bakers described work-related irritant symptoms, although again the difference between bread and cake bakers was not significant ($p = 0.2$). The materials implicated by employees as responsible for the symptoms attributable to non-specific irritation, were typically gluten or a bran pre-mix by the bread bakers and baking powder and icing sugar by the cake bakers.

The prevalence of positive skin-prick tests in the bread baking and cake baking groups is shown in Table 3. The percentage who were atopic in both groups was broadly typical of the rate in the general population, *i.e.*, around one-third. In the bread baking group the prevalence of positive skin-prick tests to fungal amylase was around three times that to either wheat flour or soya flour. In contrast, the rate of positive tests to wheat flour and soya flour were approximately equal. Several sensitized individuals had positive skin-

Table 2. Comparison of symptoms between bread baking and cake baking groups

Type of symptom	Bread baking group		Cake baking group	
	No.	Percentage	No.	Percentage
Occupational asthma	2	0.5%	0	0.0%
Occupational rhinitis	10	2.6%	0	0.0%
Respiratory irritation	68	17.3%	8	10.4%
No work-related symptoms	312	79.6%	69	89.6%
Total	392		77	

Table 3. Comparison of skin-prick test findings between bread baking and cake baking groups

Skin-prick allergen positive	Bread baking group total tested = 392		Cake baking group total tested = 77	
	No.	Percentage	No.	Percentage
Atopic	135	34%	31	40%
Wheat flour	25	6%	2	3%
Soya flour	26	7%	1	1%
Rice flour	16	4%	1	1%
Fungal amylase	63	16%	1 ^a	1% ^a

^a This employee previously worked in a bread bakery.

Table 4. Comparison of skin-prick test findings between cake bakeries with and without exposure to amylase-containing flour

<i>Skin-prick allergen positive</i>	<i>Amylase-containing flour exposed group total tested = 46</i>		<i>No amylase-containing flour exposed group total tested = 31</i>	
	<i>No.</i>	<i>Percentage</i>	<i>No.</i>	<i>Percentage</i>
Atopic	21	46%	10	32%
Wheat flour	1	2%	1	3%
Soya flour	0	0%	1	3%
Rice flour	1	2%	0	0%
Fungal amylase	0	0%	1 ^a	3% ^a

^a This employee previously worked in a bread bakery.

Table 5. Summary of bread bakery dust exposure measurements (levels expressed as mg/m⁻³ 8 hour time-weighted average)

	<i>With local exhaust ventilation</i>		<i>Without local exhaust ventilation</i>		
	<i>Sieving</i>	<i>Weighing</i>	<i>Sieving</i>	<i>Weighing</i>	<i>Doughmaking</i>
Total number of samples	27	22	35	26	80
Maximum reading	52.6	51.0	349.5	770.0	142.2
Minimum reading	0.9	0.2	0.9	1.0	0.1
Percentage exceeding 10mg/m ⁻³ (8 h TWA)	52%	9%	46%	27%	10%
Geometric mean	8.2	2.7	11.4	8.2	3.3
Median	10.1	2.8	9.2	7.0	3.2
Standard deviation	13.3	10.3	73.1	146.7	19.5

Table 6. Summary of cake bakery dust exposure measurements (levels expressed as mg/m⁻³ 8 hour time-weighted average)

	<i>Sieving^a</i>	<i>Weighing^a</i>	<i>Mixing^a</i>
Total number of samples	12	8	24
Maximum reading	90	68.5	16.3
Minimum reading	15.9	7.4	0.5
Percentage exceeding 10mg/m ⁻³ (8 h TWA)	100%	88%	13%
Geometric mean	35.7	19.2	3.8
Median	30.6	14.6	3.9
Standard deviation	26	20.7	4.2

^a All without Local Exhaust Ventilation.

prick reactions to more than one allergen, although some reacted to only one of the work-related agents.

The presence of positives to all work-related allergens was much less in the cake baking group than the bread bakers, although the difference was not significant for either wheat flour ($p = 0.2$) or rice flour ($p = 0.2$). The difference in prevalence of sensitization to soya flour was significant at the 5% level ($p = 0.045$). In marked contrast the difference in prevalence of sensitization to fungal amylase was significant at the 0.1% level ($p = 0.0001$). Only one cake baking employee had a positive reaction to fungal amylase. This individual worked in a cake bakery where no fungal amylase-containing flour had been used. However, he had previously spent around one year working in a bread bakery.

Table 4 compares the prevalence of positive skin-prick tests in the two cake bakeries where amylase-containing flour was used, with the bakery where no amylase-containing flour was used. The prevalence of positives to the work-related allergens was low in both groups, *i.e.*, 3% or less, with no

statistically significant difference between the two ($p > 0.2$ for all allergens).

Occupational hygiene

Summaries of dust exposures for the different work activities in bread and cake baking operations are shown in Tables 5 and 6. As stated in the section on Methods, results have been allocated to the main activity during the sampling period, although the employee may have performed either of the other activities for part of the time. In general, sieving gave rise to the greatest exposures, followed by weighing and then mixing.

There was a wide distribution of dust exposures for each of sieving, weighing and mixing activities in both the bread and cake baking groups. This was particularly marked for sieving operations. Furthermore, for each of the activities a substantial proportion of exposures exceeded the current UK occupational exposure limit of 10 mg/m⁻³ (8 hour time-weighted average).

It is worth noting that the total inhalable dust sample

is not a reflection of exposure to a single ingredient for any of the activities. The measured level depends on the dustiness of the ingredients which were being handled and the duration of exposure to each ingredient. For the bread baking operations, handling gluten or bran tends to produce large amounts of dust. In contrast, soya flour or soya-containing improvers give rise to a somewhat lower total inhalable dust exposure as handling these materials generates relatively little dust. In the cake baking operations, icing sugar is noticeably dusty owing to its finely divided physical form.

DISCUSSION

Pathogenesis of symptoms in bakery workers

Although baker's asthma has been recognized for some time, the pathogenesis of the condition and its relation to exposure remains unclear. Until recently it has been assumed that the aetiology of work-related symptoms has been essentially allergic. Whilst allergy undoubtedly plays a part in causation, sensitization is only responsible for part of the symptomatology.^{15,16} In most workplace situations where potential sensitizers are encountered, the allergen is usually present against a background of relatively low dust levels. Bakeries are somewhat unique in that the allergen exposure occurs in the presence of significant dust levels. Perhaps it is not surprising therefore that some of the symptoms amongst the workforce could be due to a non-specific irritation of the respiratory tract from high levels of particulate matter in the atmosphere. This effect is demonstrated by the relative prevalence of non-specific to allergic symptoms in the bread baking group in this study, *i.e.*, around 6:1.

Within the bread baking group, the overall prevalence of work-related symptoms (*i.e.*, both allergic and irritant) is broadly similar to that reported from other bakery populations,^{17,18} at 20.4%. However, the population in this study is not directly comparable with the others, as it selects those employees in the bakery with the greatest regular exposures. One of the other studies¹⁸ covered the total production workforce in a single large plant bakery and hence included some employees with minimal or no dust exposure, *e.g.*, those working on the ovens or on slicing and wrapping. The other study¹⁷ was carried out in a number of small bakeries where the use of bagged ingredients, and hence potential dust exposure, is greater.

In contrast to transient non-specific irritant symptoms, the prevalence of persistent work-related symptoms in the bread baking group in this study is low (asthma 0.5%, rhinitis 2.6%). This finding suggests that symptomatic allergy to baking ingredients is relatively uncommon in plant bakeries, even in the groups who have regular exposure to dusty materials. The apparent low prevalence of occupational asthma compared with rhinitis may be due to the fact that

employees who have developed asthma in the past have been moved away from ingredient work due to the severity of their symptoms, whereas those with rhinitis have been prepared to continue. Apart from this issue, the healthy worker effect is not considered important as a confounding factor. The bakeries have experienced low turnover of employees in recent years and leavers with symptomatic allergy would have come to light either as ill-health retirements or as common-law claims.

Sensitization in bakery workers

Two observations from this study on the difference between the bread and cake baking groups are worthy of comment:

- Symptomatic allergy is absent in the cake baking group, whilst there are some cases in the bread bakers.
- The prevalence of positive skin-prick tests to the work-related allergens in the cake baking group is relatively low.

In considering these differences, a number of factors need to be taken into account. Where sensitization to high molecular weight compounds such as those in bakery environments arises, a combination of a sufficiently high exposure and a reasonably lengthy duration of exposure are generally thought to be necessary for sensitization to develop. Taking into account the total inhalable dust levels, the levels of exposure in the bread and cake groups are broadly similar or, if anything, slightly greater in the cake bakers. Furthermore, the mean duration of exposure to ingredient dusts in the cake bakers (*i.e.*, 4.3 years) is sufficiently long to allow for sensitization to develop.

Although there is no statistically significant difference in symptomatic sensitization between the bread and cake baking groups ($p > 0.1$ for both asthma and rhinitis), the respective probabilities relating to the rates of sensitization to wheat flour, soya flour and fungal amylase are progressively more significant, *i.e.*, wheat flour $p = 0.2$, soya flour $p = 0.045$, fungal amylase $p < 0.0001$. Thus the principal difference between the two groups in terms of sensitization is the presence of fungal amylase sensitization in the bread bakers. If the presence of specific IgE as determined by skin-prick testing is taken as a marker of sensitization, the findings in this study suggest that the relative risk of sensitization to fungal amylase in plant bakeries is around three times that of wheat or soya flour. This conclusion assumes that sensitization to fungal amylase does not arise outside of the bread baking environment and that the skin-prick test solution does not cross-react with another allergen, *e.g.*, wheat or soya. The absence of positive skin-prick tests to fungal amylase in the cake baking group effectively provides a negative control group and would support the absence of other sources of sensitization outside of bread bakeries. The

issue of cross-reactivity with amylases of cereal origin has already been examined and is not thought to occur.¹²

The lack of positive skin-prick tests to fungal amylase in the cake baking group is notable in its own right, since a proportion of this group (46 out of 77) are regularly exposed to fungal amylase-containing flour. Moreover, sensitization is absent despite the relatively high total dust exposures and reasonably lengthy duration of exposure (mean = 4.3 years). The explanation may be that typical sieving, weighing and mixing exposures in cake baking are below the threshold at which sensitization to fungal amylase occurs. This is a plausible interpretation since the concentration of fungal amylase in flours to which it is added (*i.e.*, 0.000125%) is around 200 times less than that in bread improvers. Hence broadly similar exposure levels to total inhalable dust from bread improvers and fungal amylase-containing flour will give much smaller amylase exposures in those exposed to the fungal amylase-containing flour. This is clearly an oversimplification of the workplace exposure situation. Dust exposure from sieving, weighing and mixing over a working shift will inevitably be of a mixed nature, with improvers and fungal amylase-containing flour making up only part of the total. Nevertheless, the concept that exposure to fungal amylase in the cake baking operations is below the threshold for sensitization is a reasonable hypothesis.

Relationship between exposure to fungal amylase and sensitization

It is possible to estimate the theoretical exposures to fungal amylase which might arise from typical bread and cake baking dust exposures. Taking average exposures for these bread baking activities, it is probably reasonable to assume that regular exposure to total inhalable dust from bread baking ingredients might be of the order of 5 mg/m³ 8 hour time-weighted average. This level of exposure produces a sensitization risk for fungal amylase of 16%. Assuming that the relative proportion of fungal amylase in the total dust exposure is 0.02%, a total inhalable dust concentration of 5 mg/m³ gives a theoretical exposure to fungal amylase of 0.001 mg/m³.

Looking at the typical cake baking exposures from sieving, weighing and doughmaking, the risk of sensitization to fungal amylase is at or approaching zero. However, dust exposures for the cake baking activities are generally greater than for their bread baking counterparts. A typical overall exposure might be of the order of 10 mg/m³ 8 hour time-weighted average. Assuming that the relative proportion of fungal amylase in the total dust exposure to cake baking ingredients is 0.0001%, a total inhalable dust concentration of 10 mg/m³ would give an exposure to fungal amylase of 0.00001 mg/m³ (= 10 ng/m³). Such an exposure would seem to be below the threshold for sensitization.

The estimations above are essentially theoretical and assume that there is a reasonably constant and linear relationship between total inhalable dust and fungal amylase-in-air exposures. Although some experimental work has been performed on measurement of fungal amylase-in-air,¹⁹ no data are available to verify the relationship between allergen and total inhalable dust. Nevertheless the work on fungal amylase-in-air did identify the range of exposure to α -amylase as 0–40 ng/m³, over a variety of different types of bakery activity. A recent study in the enzyme manufacturing industry²⁰ has demonstrated that measured exposures of 0.1–1.0 μ g/m³ to a variety of enzymes, including fungal amylase, are associated with a significant risk of sensitization. From our data, theoretical exposures to fungal amylase of this order would be possible in bread bakeries where bread improver is being handled, but not in cake bakeries where exposure arises only from amylase-containing flour.

It is also worth commenting that the initiation of sensitization is probably not a function of cumulative exposure, *i.e.*, 8 hour time-weighted average, and is more likely the result of high short-term exposures. Even if this is the case, the argument for a threshold based on an 8 hour time-weighted average is still sustainable. The reason for this assertion is that the typical short-term exposures which make up the 10 ng/m³ 8 hour time-weighted average in cake bakeries do not appear to result in sensitization.

Relationship between exposure to wheat flour and sensitization

For a number of reasons, it is more difficult to establish a total inhalable dust level for bakery exposures below which sensitization to wheat flour arises. To establish a dose-response relationship, it is necessary to identify clearly demarcated levels of exposure. In a bakery context, individual exposures are widely variable, making dose stratification very difficult. In addition, the use of total inhalable dust as a surrogate for wheat flour aeroallergen has been examined in a number of studies and is not wholly satisfactory.^{21–23}

Our study points to the weak potential of wheat flour to produce sensitization at levels of total inhalable dust up to and in excess of 10 mg/m³. The absence of employees with allergic symptoms and the low prevalences of positive skin-prick tests in both the bread and cake baking groups (6% and 3% respectively), despite frequent excursions of exposure beyond 10 mg/m³, suggest that this level is at or close to the threshold for sensitization.

CONCLUSIONS

Control of total inhalable dust exposure in bakeries to below 10 mg/m³ (8 hour time-weighted average) is likely to be sufficient to prevent sensitization to wheat

flour allergens. Below this level, the risk of transient irritant symptoms should also be minimized.

Prevention of sensitization to enzymes which are added to bread improvers will require more stringent control. It is suggested that exposure to dusts which contain enzymes at typical concentrations found in bread improvers (*i.e.*, > 0.01%) should not exceed 1 mg/m³ (8 hour time-weighted average).

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