Development of a Job Exposure Matrix for flour exposure in the Bakery Industry: Systematic review with field validation

by

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ABSTRACT

Introduction: Flour has been a recognised allergen for many years. Although Alberta has an occupational exposure limit (OEL) for flour dust of 0.5 mg/m^3, recent measurements in Alberta bakeries show that this level is frequently exceeded. Geometric mean (GM) exposure to inhalable particulates was highest among mixers (4.13 mg/m^3) and bakers (1.57 mg/m^3). This study was divided into two main parts. The first part was a systematic review which aimed to create quantitative exposure estimates to flour, based on a worker's job/task description in the bakery industry using data from previously published exposure studies. The second part was a validation study using a questionnaire, with skin prick test and lung function measurements within a number of bakeries in Alberta.

Method: Published and unpublished literature sources that included exposure measurement data within a bakery were extracted. Job/task titles were identified and reclassified into 9 main groups with products classified into 3 main groups. The results were grouped by sampling dates, task, product, number of samples, substance sampled. The grouped results were used to calculate the weighted geometric mean-inhalable dust, wheat allergen and fungal α-amylase by job/task group and product group. Job exposure matrices (JEM) were therefore created for inhalable dust, wheat allergen and fungal alpha-amylase. The JEM were validated through a cross-sectional study, conducted in 8 Alberta bakeries with 57 bakers. The weighted geometric mean was subsequently used to derive exposure indices among a group of current bakers (average exposure, maximum exposure and cumulative exposure) which were used along with duration of bakery exposure and other risk factors such as age, gender, smoking, atopy and family history of allergy to predict the risk of testing positive to skin prick tests for bakery allergens.

Results: Dough formers were the predominant job/task group most exposed to inhalable dust (GM 4.69mg/m^3), wheat allergen (GM 87.13 μg/m^3) and fungal alpha-amylase (GM 43.1ng/m^3) while packers/ shippers and front counter & sales workers had the least exposures. Exposure estimates were calculated for the other job/ tasks in the bakery industry. The bakers surveyed were mostly males with the majority being in the ages of 30 to 45 years. 44% of the bakery workers had a family history of allergy with 37% of bakers were atopic. Among the common allergens skin prick tests to grass and mites were most commonly positive. The prevalence rate of sensitivity to any bakery allergens was 18% but the skin prick tests in this group that was most commonly positive was oats (11%). Sensitivity to bakery allergens was influenced by bakery job duration, cumulative exposure and atopic status, particularly for inhalable flour dust.

Conclusion: It was possible to produce job/task and product specific estimates of exposures. These estimates were associated with the risk of sensitization to bakery allergens. Thus, the job exposure matrices seem to be valid.

PREFACE

This thesis is the first part of the project titled “Flour exposure, sensitization and respiratory health among Alberta bakers” with Prof. Jeremy Beach and Prof Nicola Cherry as co-principal investigators.

Ethics approval was sought from the Health Research Ethics board -Health Panel. Approval was given on April 16, 2015. The project ID was RES0024908.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1 **: INTRODUCTION**

1.1 Characteristics of flour

The American Conference of Governmental Industrial Hygienists (ACGIH) defines "flour as a complex organic dust consisting of wheat, rye, millet, barley, oats or corn cereal, or a combination of these, which have been processed or ground by milling". (1) Wheat and rye are the two most common grains used to make flour. Flour can also be made from beans, peas, chick peas, fruits or nuts. (2) In Canada, wheat is the most common grain used to make flour. (1) Flour is used to make foods for animal and human consumption. Wheat flour is the major flour used in the baking industry and it is used to prepare bakery products such as bread, cake, pizza, cookies, and others.

Wheat grain is made up of the endosperm (protein/starchy part), the germ (protein/fat/vitamin-rich part) and the bran (fiber part). The bran and germ are removed during milling, while the endosperm is finely ground. The bran is milled separately and then added back to the endosperm. The nature of the flour depends essentially on the gluten composition in the flour and the amount of endosperm, germ or bran in the flour. Whole wheat flour is composed of water (14%), protein (9-14%), fat (1-2%), carbohydrates (54-62%), fiber (1.7-2.6%) and minerals (1.2-1.7%). (3)

Proteins in flour occur in four groups: 15% water soluble albumins, 7.5% globulins, 32.5% prolamins (gliadins) and 45% glutelins (glutenin). Gliadins and glutelins interact in the presence of water to form a viscous complex called gluten which plays a key role in the structure and texture of the bread. Gluten is the key protein in the development of the dough's protein matrix that traps air molecules. (4)

A lot of other materials may be added to flour. Wheat flour contains a small amount of naturally occurring alpha-amylase**,** ranging from 0.1 to 1.0$\mu g/m^3$**.** (5) An additional alpha-amylase, which is a dough improver*,* may be added to break up the large polysaccharide chains to low-molecular weight sugars such as glucose and maltose to speed up yeast activity and also to improve the shelf life and quality of the dough. (6) The added alpha-amylase is most often derived from fungal organisms such as Aspergillus oryzae or Aspergillus niger. (7) Flour dust in the bakery industry may contain several other non-cereal components: such as a variety of enzymes (malt enzymes, cellulase, hemicellulase, xylanase), chemical components (such as preservatives, bleaching agents, antioxidants), flavorings, spices, and other additives (such as egg powder, sugar) as well as contaminants such as storage-related mites and microbes. (8)

1.2 The Bread Making Process

The bread making process can be performed traditionally or industrially. (9) The process of making bread in small scale bakeries can be classified into 3 stages. In stage one, known as the mixing stage, flour, water, salt and yeast are first mixed together to make a dough. This is usually done by a mechanical mixer. In stage two, also known as the fermentation stage, the dough is left to rise in a warm, humid, atmosphere. In the final stage or baking stage, the dough is divided, weighed, molded, and baked. Bread is put into the oven on paddles or trays; water vapor is given off as steam during the baking. Employees in small bakeries are often responsible for carrying out the tasks associated with these stages. (10) Based on the degree of automation and a clear division of individual job tasks, a bakery can be classified as traditional or industrial. (11) Industrial bakeries have typically mechanized many of the processes of traditional bakeries; employees therefore tend to work in one area and perform tasks associated with only one stage of the process but can produce several loaves of bread within a short time for mass distribution. Traditional bakeries tend to be small in size with few employees and each worker performs multiple jobs in the bakery.

In 1961, a process of making bread faster, easier and cheaper was introduced in the United Kingdom (UK). This process, known as the Chorleywood baking process involved the use of high speed mixers and dough improvers to change, speed up, control proofing (final rise of the dough before baking) and to increase the shelf life of the final product. Enzymes are critical ingredients of the dough improvers and their increasing use over the past 50 years have led to the baking industry probably being one of the employment sectors with the highest risk of enzyme sensitization. (12) This baking process is now used in the production of 80% of bread in several countries. Apart from bread, many other products such as cakes, biscuits, pastry are made in bakeries which involve the addition of spices, flavorings, coloring agents, resins and gums.

1.3 Sources of flour exposure

Because of the processes in the bakery, a lot of flour dust is generated. Burstyn et al. identified specific tasks such as flour dusting (the action of throwing flour onto the dough and work surface to prevent dough from sticking to a surface), weighing and ingredient mixing to be the tasks that contribute the most to bakers' flour dust exposure. (13) Maintenance personnel are exposed to flour during equipment repair. Elms et al, (14) also suggested that the type of bakery facility and assignment of job description is an important determinant of elevated exposure to flour dust.

1.4 The size and characteristics of the flour particle

Small flour dust particles that can stay airborne may be inhaled through the nose or the mouth. The probability of inhalation depends on particle aerodynamic diameter, air movement round the body and breathing rate. The International Standards Organization (ISO 1995) (15) has defined sampling terms for use in assessing the possible health effects of airborne particles in the workplace. Particles can be categorized into three depending on the part of the airway passage where deposition of the particles occurs. These are inhalable (fraction of a dust cloud that can be breathed into the nose or mouth with aerodynamic diameter <100 μm), thoracic (fraction that can penetrate the airways and enter the lungs, < 50 μm) and respirable fractions (fraction of inhaled airborne particles that can penetrate beyond the terminal bronchioles into the gas-exchange region of the lungs, < 16 μm with majority < 10 μm).

Lillienberg et al. (16) measured the size of the airborne flour dust particle using an Institute of Occupational Medicine (IOM) dust sampler in five bakeries and two flour mixing factories. They showed that flour particles have a bimodal distribution of aerodynamic diameters. The smallest particles were around 5 μm in size, and the largest ones around 15-30 μm with over 50% of the particle mass having an aerodynamic diameter over 15 μm. Sandiford et al. (17) also sampled a UK bakery and flour mill to determine the size of air borne flour particle and found that 9%, and 52% of the particles in the bakery dough-brake (equipment for kneading bakery and pastry dough, softening and homogenizing them through a process that removes the air trapped inside the dough during the mixing) and roll-production areas respectively had a diameter ≤ 6 μm, respectively, and 19% of the particles in the flour mill packing area were of this size. The investigators concluded that in dusty areas up to 20% of the airborne flour particles are of a diameter likely to allow them to be deposited in the lower airways (bronchial airways and alveoli). Burdoff et al. (5) using the IOM personal inspirable sampler estimated that 39% of flour breathed in constitutes the thoracic fraction with 19% being the respirable fraction.

Wherever the particles are deposited in the airway, they have the potential to cause harm either locally or subsequently elsewhere in the body. The mucociliary transport system clears particles from the airway but if particles remain in the airway for a long time, they have an increased potential to cause disease. (18)

1.5 Job tasks in the Bakery

Some of the general tasks in the bakery include;

Packing and handling of ingredients

Pouring of packaged ingredients into mixers

Mixing of ingredients and flour usually by a machine

Removal of dough from mixer

Division and forming of dough by manual or mechanical means

Placing raw dough into ovens

Removal of products from ovens

Operation of finishing equipment; bread slicer, packaging equipment (19) (20)

Various job tasks have been defined in the bakery industry by several authors: Burstyn et al. (1997), Burdoff et al. (1994), Elms et al. (2003), Houba et al. (1997). To be able to classify bakery workers into groups, bakery workers had to be categorized into exposure groups in order that workers within each group will have the same or uniform exposure. For some of the job/tasks, different names had been used by different authors for similar job/tasks in the published papers. These classifications were therefor proposed to ensure uniformity. With some modifications, the categorizations proposed are summarized in Table 1.1 below.

Table 1-1 Proposed job categorization and definition of job tasks in the bakery

	Jobs/Tasks	Definition
Production Tasks	Baker (oven worker)	Mainly involved in tasks such as bread and roll production, monitoring the movement of product in and out of the oven
	Confectioner	Involved in producing pastries, cookies, muffins, cakes and tarts. They usually handle very small amounts of flour
	Weigher/mixer	Tips flour and ingredients, like solid fats, spices, yeast, bread improver, salt, and water into mixing machines
	Dough former	Manipulates the shape of the dough and cuts dough
	Other Production Tasks	Involved in other jobs apart from the above such as line managers, supervisors and quality control
	All Production Tasks	Workers who perform various multiple tasks in the bakery, especially in small bakeries.
Non-Production Tasks	Packers/ shippers	Are involved in slicing, wrapping and packing/packaging of the bakery products
	Front counter staff & other	Workers selling products of the bakery and attending to customer needs
	Cleaning & maintenance	Workers who clean the bakery and services any defective equipment

Several studies [Nieuwenhuijsen et al. (1994), Baatjies et al. (2010), Burdoff et al. (1994)] in both industrial and traditional bakeries have looked at the causes of high dust exposures. Some have found bakery size and tasks to be associated with high exposure levels. These studies show that dough makers, bakers, weighers/ mixers have the highest dust exposure in the bakery. Burdoff et al. (5) noted that dough makers had the highest exposure level of 5.46 mg/m^3

followed by bread-formers, 2.69 mg/m^3 and oven workers, 1.17 mg/m^3 whiles packers and confectionary workers had 0.53 mg/m^3. He further reported that task group was the main source of variance which accounted for 61-69% of the variability. Baatjies et al. (21) on the other hand, reported that significant predictors were large bakery sizes, bread baking and use of cereal flours. She also noted that the bread bakers had the highest GM exposure of 1.33 mg/m^3 followed by confectioners with 0.65 mg/m^3 with the lowest being a counterhand with 0.28 mg/m^3 in a supermarket bakery. Houba et al. (22) also identifies the specific job in the bakery as the most important source of variability. Nieuwenhuijsen et al. (23) reported that in the bakeries, workers in the dough brake had the highest flour dust exposure with a geometric mean (GM) of 6.4 mg/m^3, followed by dispense /mixing with 5.0 mg/m^3 and then the roll production with 2.4 mg/m^3.

With regards to wheat allergen, Nieuwenhuijsen et al. (24) recorded a concentration of 45.5 µg/m^3 up to 252 µg/m^3 in a bakery. Bulat et al. (11) found that workers in traditional bakeries in bread production as well as pastry production had high level of exposure of 22.33 µg/m^3 and 14.48 µg/m^3 respectively.

A study by Elms et al. (14) found that mixers and weighers had significantly higher levels of fungal alpha-amylase (3.2-29.1ng/m^3), compared with other job categories. Houba et al. (25) also found that the highest fungal alpha-amylase exposures occurred among dough makers producing bread/crispbakes (GM 18.1 ng/m^3). This was followed by dough makers in wheat bread production (GM 0.8 ng/m^3), as well as bread and mixed bakers in small bakeries (0.2-0.3 ng/m^3).

It has been noted that in the bakery, significant exposures to flour and other chemical substances are likely to occur in areas where there is weighing and adding of ingredients, mixing the ingredients with flour, flouring the work surface, processing the dough, turning, and dividing the dough, cleaning the equipment and cleaning the work surfaces (26)

1.6 Health effects of flour dust exposure

Bakery work is one of the occupations where a high level of occupational exposures occurs. The adverse health effects of exposure to flour have been recognized for many years. The first description of the effects of flour dust exposure was made by Bernardino Ramazzini, a

Florentine physician, among 18th century bakers and millers, in his treatise —De Morbis Artificium. (27) The health risk associated with a flour dust depends on the dustiness or dose and exposure duration, breathing rate and volume of flour dust inhaled. The main health effects of flour dust exposure can be categorized into five and are discussed below:

1.6.1 Sensitization

The symptoms of flour dust exposure can arise as a result of high dust exposure leading to inflammation (irritation) of the eyes, nose, the lungs and skin. The symptoms can also be due to allergy, where sensitization can occur at low levels of flour exposure. Flour dust can therefore be an irritant as well as an allergen. The process of sensitization is gradual, and it appears weeks or even years after exposure has started. (28) This is known as the latency period for the development of sensitization, which is affected by whether an individual has become sensitized to common non-bakery allergens, also known as atopy. Sensitization has been defined as a positive skin prick test, presence of specific IgE to occupational allergens or a positive challenge test. When a baker is sensitive it implies that he/she has developed specific Immunoglobulin (Ig) E antibodies to any of several flour dust allergens. The pathway for symptom development is through an IgE mediated mechanism and symptoms can appear immediately or may be delayed when a sensitized baker is exposed to flour.

It is widely documented that flour allergens from wheat, rye and barley and fungal alpha-amylase are the most notable allergens known for the development of respiratory sensitization or allergy. (29) Storage mites have also been described as an important source of sensitization. (30) (31) Reubesch and Dueholm (32) noted that storage mites could be important in bakers' sensitization. Armentia et al. (30) also noted that storage mites can contaminate wheat flour and could be an important cause of allergic symptoms due to inhalation. They concluded that Lepidophygus destructor was the most important species of mite found in most samples of wheat and caused a substantial prevalence of mite's allergy. De Zotti et al. (33) on the other hand noted that sensitization to storage mites could not be important in the occupational allergic response. They did not see storage mites to be particularly important in causing an allergic response among bakers as there was no difference in the risk of sensitization for bakers when compared with non-bakers. In both groups, positive skin reactivity to storage mites was often associated with other common allergens. Though there were few cases with sensitization to storage mites alone, this group of bakers had not developed work related symptoms. They were of the strong opinion that storage mites were widely distributed in the environment and that the positive skin response among bakers was an indicator of atopy rather than a response to a specific occupational allergen.

The prevalence rates for sensitization vary between 5% and 28% among bakery workers for wheat flour and 2-6% for fungal alpha-amylase. The wide variation in sensitization rates could be the result of the use of different methods in various studies. It could also result from use of non-standardized bakery allergens, different origins and concentrations of bakery allergen extracts used for the skin prick tests as well as different cut off points. (34)

Flour dust contains several allergenic substances, and these vary depending on conditions of storage, and the composition of the flour. More than forty different allergens have been identified in flour. (35) It has also been shown recently that it is not only flour itself that has allergenic properties but also impurities introduced by insects, and molds have allergenic effects. (36) (37) Endotoxins (toxin found within the outer membranes of certain gram-negative bacteria, which are released only when the cell membranes are disrupted) in the flour dust have also been implicated in the pathogenesis of several allergic diseases. (38)

1.6.2 Upper respiratory symptoms

Rhinitis (inflammation of the nose) and hay fever (allergic rhinitis) are among the earliest upper respiratory problems developed by flour workers and the incidence rates of hay fever and rhinitis are highest during the first years of bakery work. Symptoms of rhinitis include nasal congestion, runny nose, frequent sneezing, itchy nose, and post nasal drip. A study among Swedish trainee bakers estimated incidence rates of 29.4 cases per 1 000 pyrs (person years) for rhinitis. (39) Rhinitis is a significant risk factor for adult-onset asthma especially if exposure to the workplace irritant persists. Malo et al. (40) reported that rhinitis symptoms were common among subjects with occupational asthma (OA), with 92% of patients with OA reporting symptoms of occupational rhinitis (OR). They also noted that symptoms of OR developed before those of OA in affected subjects. Conjunctivitis (itchy and watery eyes) can occur as a comorbid condition with rhinitis.

1.6.3 Lower Respiratory symptoms

According to Zock et al. (41) bakers and flour confectioners are among the occupations exposed to high molecular weight allergens leading to lower respiratory disorders. In comparison to office workers, bakers more often had chest tightness/wheezing (OR, 3.11), chronic bronchitis (OR, 2.19), and chronic obstructive pulmonary disease (OR, 2.73). In the study by Musk et al. (31) they reported that out of 279 bakery employees, 35% reported chest symptoms and 13% were work related and lower respiratory symptoms such as cough, difficulty in breathing, wheezing, tightness in the chest and shortness of breath were common among flour workers.

1.6.4 Asthma

The most severe reaction to flour exposure is asthma, also known as baker's asthma. Baker's asthma results from immunological sensitization following allergic reactions to airborne flour allergens. Baker's asthma can affect the ability of bakers to work and their overall quality of life, and can progress to death. DeMers and Orris (42) showed that US bakers appeared to have markedly higher mortality rates than expected, suffering from the typical asthma-like symptoms. The typical symptoms of asthma include cough, wheezing, chest tightness and shortness of breath. Bakers' asthma may develop months or years after exposure and risk increases with increasing exposure (43). In baker's asthma, the symptoms usually become worse during the working day and throughout the workweek. The symptoms decrease on days off and during vacations. Baker's asthma has been reported to occur with incidence rates of between 1 and 10 cases per 1,000 person-years. (44) (45) According to a study on the Finnish Registry of Occupational Diseases, from 1989-1995, published by Karjalainen et al. (46) bakers were the most common occupation to report occupational asthma, with an incidence rate of 444/100,000 among men and 408/100,000 among women. Ninety seven percent of the cases in bakers were caused by flour. McDonald et al. (47) also showed based on data from the Surveillance of Work-related and Occupational Respiratory Disease (SWORD) project, that bakers had one of the highest incidences of reported occupational asthma in the United Kingdom (286/million working population/year). According to Brisman, (48) bakery workers were reported to have an occupational asthma prevalence of 5-17%. Work-related asthma can be divided into two main groups. These are occupational asthma (OA) and work-exacerbated asthma (WAA). OA refers to cases of asthma caused by specific agents in the workplace and this can further be grouped into sensitizer-induced asthma (caused by sensitization to a substance) and irritant-induced asthma also known as reactive airways dysfunction syndrome (RADS). WAA refers to asthma cases that worsen when at work. (49) (50). Brisman et al. (45) reported that exposures ≥3mg/m^3 were associated with a higher risk of asthma in bakers who make dough, whereas the risk of rhinitis was increased at concentrations ≥1mg/m^3. This indicates an increased risk in most bakery job/ tasks. The dose at which sensitization starts to occur has however not been determined. As a consequence of flour exposure, workers who develop severe symptoms and sensitivity to common allergens may leave their job in the bakery industry. (51)

It has now been documented that the health effects of flour not only affect the baker in the workplace but can transcend into their homes. It has been noted that parental occupational exposure to flour has been associated with increased likelihood of childhood asthma, because family members were exposed to flour sensitizers, which are 'taken home' by bakers on contaminated skin and clothes. A recent study by Tagiyeva et al. (52) showed that the problem of exposure to cereal allergens derived from flour dust concerns not only bakers but their family members as well and they recommended the need for further investigation to establish the health consequences.

1.6.5 Hand Eczema

Bakers do develop work-related skin symptoms. The work of bakers entails skin exposure especially of the hands to flour and moisture which can cause skin irritation, contact urticaria and protein dermatitis. Contact allergy could arise from flour additives such as antioxidant, spices and flavoring agents. (53) (54) According to Brisman et al. (55) Swedish bakers, mainly working during the 1970s and 1980s had a threefold increased risk of hand eczema. He also noticed a synergistic effect of atopy and occupational exposure. Schwensen et al. (56) found bakers to have the highest incidence rate of contact dermatitis among all food related occupations.

The health effects of flour have been shown to be associated with intensity of exposure leading to inflammation, atopy and sensitization. Zuskin et al. (57) showed that in a confectionery plant, with workers (288) compared to controls (127 not working in the plant), there was a higher prevalence of acute respiratory symptoms (cough, shortness of breath, burning or dryness of the throat and eye irritation) in confectionary workers than in controls. Most of the symptoms were caused by irritation of the respiratory tract and did not show any significant association with immunological tests. Smith et al. (58) in their study of 679 workers employed in a flour mill and packing plant, also concluded that the majority of 147 workers who complained of upper respiratory symptoms were from short term exposure to high levels of wheat flour dust from non-specific irritation.

A number of studies have also been conducted which showed that development of symptoms is related to sensitization. Elms et al. (6) assessed the prevalence of sensitization of a range of fungal enzymes used in the bakery and determined their relationship to sensitization and work-related symptoms. They noticed an increased prevalence of nasal symptoms in individuals sensitized to enzymes- alpha-amylase and mixed enzymes. Nieuwenhuijsen et al, (7) also investigated the relation between exposure to fungal alpha-amylase in flour and sensitization to fungal alpha-amylase using skin prick test. The results showed a significant relation between exposure to fungal alpha-amylase and sensitization to fungal alpha-amylase and that workers were exposed to fungal alpha-amylase at concentrations that resulted in high rates of sensitization. De Zotti et al. (33) surveyed 226 employees from 105 Italian bakeries and pastry shops. Skin prick tests for common allergens, flour, and storage mites showed that 12% of the respondents were positive for wheat flour and 7.5% for fungal alpha-amylase. Atopy was shown in 24% of respondents whiles half of the respondents reported work related asthma, 10% chronic bronchitis and 18% rhinoconjunctivitis. They further demonstrated that only flour-exposed workers had sensitization to wheat flour when compared to 119 white collar office workers. They found that the risk of work related symptoms was associated with sensitization to wheat allergen or fungal alpha-amylase, and with atopy, but not with sensitization to storage mites, work seniority, or smoking.

1.7 Risk factors for developing sensitization to bakery allergens

Atopy has been shown to be a very strong determinant for sensitization to flour allergens among bakers. (59) The reported odds ratios (OR) for atopy range from 5.1 to 20.8. (60) Atopy is often defined as a positive skin prick test to one or more common allergens such as grass pollen, house dust mites, cat and dog furs etc. According to Nordman, atopy denotes the exceptional capacity of the body to produce immunoglobulin (Ig)E antibody when exposed to common environmental allergens. (61) Atopy is sometimes used to denote a clinical condition, or may refer to an immunologic mechanism, but it is used more often used for a combination of both. The term atopy was introduced in 1923 by Coca & Cooke (62), and was originally meant to describe individuals with a familial tendency to become sensitized. An individual's atopic status may be high or low, meaning that subjects classified as high atopics have multiple sensitivity, or reacts to two or more allergens, whereas those with limited or isolated sensitivity have a lower status. (63)

Atopic status can be evaluated by positive skin prick testing to common allergens or by analyzing a blood sample for specific IgE to common allergens such as grass pollen, house dust mites, cat and dog furs etc. The titres of positivity for IgE depended on the laboratory and reagents used for testing. The prevalence of positive skin reactions to common environmental allergens has been studied in various populations and has been estimated to be between 25 to 50 % of the population. The wide variability in results could be because skin reactivity is dependent on age, quality and number of allergen extracts, testing techniques, and, in particular, the criteria for interpreting a test as positive. (64)

Atopy is a very common characteristic of a population. It may be inferred that those individuals who are capable of producing IgE antibody to common allergens, would become sensitized more easily than others to allergens known to cause an IgE-mediated allergy such as the flour dust. Bakers who are atopic have the tendency to develop more work-related symptoms compared to non atopics. In the study by Jarvinen et al (65) on 234 bakers, they noted that 25% were suffering from some kind of atopic disease, and 9% were found to have asthma. The authors concluded, on the premise that people who already had rhinitis and/or asthma before starting work in a bakery tended to deteriorate, and that atopics were unsuitable for bakery work. Herxheimer et al. (66) on the other hand noted that some bakers who turned skin positive to flour extracts during the first year of exposure sometimes became negative during subsequent years. It can however be concluded that bakers who are atopic and have a strong family history of allergy are more likely to be sensitized to flour than non atopics.

The level of exposure is also an important risk factor for development of sensitization. (60) The induction of sensitization has been shown to be dose dependent. The prevalence of sensitization and symptoms was noted to increase with increasing wheat allergen concentrations. (21) Further studies investigating the shape of the relationship between flour dust exposure and, more specifically, wheat allergen levels suggest that the dose–response relationship with sensitization may be non-linear and levels off or even decline at higher exposure levels. (67) Furthermore, there have been no clear indications of an exposure level below which the risk for sensitization is zero or negligible. Some studies have suggested that the healthy worker effect (HWE) is the likely explanation for the non- linear or inverted relationship observed at high levels of exposure. Others have postulated that this may be due to the blocking effect or protective effect of IgG4 antibodies. Studies by Jeal et al. (68) demonstrated the shape of the dose-response curve to be bell-shaped for sensitization in both atopic and nonatopic individuals. They however admit that though there were fewer susceptible (atopic) individuals in the higher exposure jobs, the pattern of risk they noted in the susceptible population was the same as that in the non-susceptible group. Thus, they believed that it was unlikely that selection bias explained the pattern of exposure–response that they observed. They further indicated that it was not likely that a selection bias of nonatopic individuals into heavily exposed jobs could explain the exposure–response pattern seen in their study. Baatjies et al. (69) in their study of supermarket bakers also noted that the prevalence of sensitization and symptoms increased with increasing wheat allergen concentrations up to 10 mg/m^3 followed by declining risks at higher exposures. (bell shaped curve). They found a non-linear bell-shaped exposure relationship for symptoms and probable occupational asthma and that an increase in wheat allergen concentration was significantly associated with IgG4 production in wheat sensitized as well as non-sensitized workers.

Short-term exposures to high concentration of flour dust are known to be frequent in bakeries and may be essential in the progression to sensitization. Peak exposures have been noted to contribute to time-weighted averages and overall exposures in the bakery. Lillienberg et al. (70) examined the peak exposure concentrations of flour and frequency of peaks in dough makers and bread formers. They noted that tipping flour, mixing dough and manual handling of flours were the dustiest tasks where concentrations varied from a few mg/m^3 up to 100 mg/m^3. The duration of the peaks were 3-4 min and 2-6 peaks per hour were recorded. Nieuwenhuijsen et al. (71) also found that cleaning the bins in bakeries also resulted in high peak values (total dust) of 390 mg/m^3.

Age and gender have not been found to be risk factors for sensitization except in the study by Musk et al. (31) In that study age was inversely associated with nasal symptoms, but not with chest symptoms. De Zotti however found that skin sensitization to flour allergens was significantly associated with work seniority. In his study, Houba et al. (72) noted that symptoms were more common in men than in women, but proffered that this was probably due to differences in duration and level of exposure.

Smoking has been noted to be a risk factor in the development of sensitization but this finding has not been corroborated in other publications. De Zotti et al. (33) in Italy found that sensitization was significantly associated with cigarette smoking but smoking was not relevant to development of work related symptoms. In the study by Cullinan et al. (73), smokers had more work-related symptoms than non-smokers, but no independent association was found between smoking and work related symptoms.

Atopy and intensity of exposure appear to be the most important risk factors for work related symptoms and eventually bakers' asthma. (60) Cullinan et al. (73) found that work- related symptoms which started after first employment at a bakery, were related to flour aeroallergen exposure intensity. This suggests that peak exposure is relevant. The relations with eye or nose and skin symptoms were however independent of atopic status and cigarette smoking. Some authors have also estimated that the mean latency period for the development of work- related respiratory symptoms to be between 4 to 13 years. (74) (75) Work related symptoms have been defined as symptoms that improve when the affected person is away from work for two or more days. (76)

Even though it is recognized that exposure leads to sensitization, it should be noted that the general population exhibits some background sensitization. Gautrin et al. (77) demonstrated sensitization prevalences to wheat of 1.2% for animal health apprentices and 4.1% for dental hygiene apprentices by skin testing these groups without any significant occupational exposures. Biagini et al. (78) in his NIOSH study of 534 blood donors also demonstrated that prevalences of specific immunoglobulin E (IgE) to wheat was 3.6%, flour 5.8%, and alpha-amylase 1.0%. “Cross-reactivity of allergens or the phenomenon where a reaction to one allergen will strengthen the reaction to a second unrelated allergen” can occur if they are chemically and functionally related. Van Kampen et al. (79) demonstrated cross-reactivity between lupine (a legume) flour and wheat flour in the sera (blood) of 116 symptomatic bakers. Baldo et al. (80) showed that the sera from subjects sensitized to wheat and rye flour reacted with seed extracts of 12 different cereals, including wheat, rye, barley, and oats.

1.8 Other health effects on Bakers

Bakers may also be exposed to a variety of chemical, physical and psychological hazards at the workplace. Respirable irritants such as flavoring chemicals (diacetyl or 2,3 butanedione and 2,3-Pentanedione) are common in the bakery. Flavoring Chemicals can be inhaled in the volatile form or as the powder form during the production process. These chemicals cause irritation of the eyes, skin, and respiratory tract. Butter flavoring chemicals used in the bakeries such as butter, margarine and vegetable oil-based cooking products, and other dairy products have been documented as the cause of “popcorn” lung (a form of bronchiolitis obliterans, a severe obstructive lung disease. This was first described in workers who mix and package flavored microwave-popcorn or are involved in other flavoring manufacturing) amongst exposed workers. (81)

Ergonomic injuries (musculoskeletal injury) such as back and neck pain can result from improper manual handling of bags of flour. Bakery flour or ingredients typically come in large packages of about 25kg or more. Workers must regularly lift products such as bags of flour while adding them to the mixing process. (20) Work-related upper limb disorders (WRULDs) could result from repetitive work processes. Several tasks in the bakery industry involve repetitive movements that are associated with musculoskeletal injuries. Examples include kneading, cake decorating, sheeting of dough, bad postures (e.g., sitting or standing for long hours) and packing operations, and these may lead to musculoskeletal disorders. (82)

Bakery cleaners use a variety of chemicals for cleaning. The Material Safety Data Sheet (MSDS) for these cleaning chemicals shows some of the chemical ingredients in them. Bakery pan cleaners contain silicic acid 2 mg/m^3, descalers contain hydrochloric acid/ sulfuric acid disodium salts and oven cleaners, sodium hydroxide and quaternary ammoniums. (26) Excessive inhalation of these chemicals can cause atypical pneumonia or chemical pneumonitis in bakery cleaners.

Bakery workers can develop noise induced hearing loss from noisy equipment. Noise levels for workers in bakeries have been reported by Work Safe BC (83) to range between 85-90 dBA. They found that dough mixers can have a level of 85 dBA, and bread slicers 85-90 dBA. According to the Alberta occupational health and safety code (OH&S) (84), "where workers are exposed to noise levels exceeding 85 dBA, a written noise management program must be undertaken. These include education, noise control, warning signs, use of hearing protection and audiometry". In a bakery where the 8 hour OEL noise levels exceed 85dBA, combined with prolonged shift length, noise exposure amongst bakers may be an issue and workers are likely to develop noise induced hearing loss.

Shift work in the bakery may cause psychological stress (85) . Bakers start their daily shifts very early in the morning, may work 40 hours based on a five-day week and often have to work in shifts. Those working at large bakeries may have to work at night. Prolonged shifts without proper management of the shift work may lead to psychological distress. Other studies (86) (87) (88) showed higher relative risk of heart disease and stroke in female rotating shift workers after 6 and 15 years, respectively and also an increased risk of heart disease in male shift workers after 10 years of shiftwork.

Bakery workers who work at high temperatures may develop health effects such as heat rash, heat cramps, fainting, heat exhaustion, heat stroke and death. The relative high temperatures that could results from generation of heat by the bakery machines and the high levels of relative humidity may cause fatigue and thermal exhaustion in bakeries. (89)

In a bakery where dust is not properly controlled, dust clouds in a working area may reduce visibility, and the floor deposited dust may cause the floor to be slippery. Dust, therefore, increases the risk of accidents in a bakery. (82)

1.9 Diagnosis of flour allergy

The diagnosis of flour allergy-induced respiratory disease is often based on a typical occupational history, results of allergy testing with either a skin prick test and or RAST (radioallergosorbent test), and a positive work-related inhalation test. Work-related asthma (WRA) should be considered in all individuals with new-onset or worsening asthma, and a careful occupational history should be obtained. Diagnostic tests such as serial peak flow recordings, methacholine challenge tests, immunologic tests, and specific inhalation challenge (in which flour extracts induce immediate asthmatic reactions) tests could also be done. (90)

1.10 Exposure measurements

1.10.1 Measurement of allergen levels

Immunoassays are customarily used to quantify allergen levels. Several immunoassays have been developed to measure allergen exposure levels in a bakery. These include RAST (radioallergosorbent-test) which was developed by Sandiford et al. using immunoglobulin G (IgG) antibodies. (17) ELISA (enzyme linked immunosorbent assay) using an anti-wheat IgG4 serum pool from bakery workers was developed by Houba et al, (34). These tests, RAST and ELISA have enabled the measurement of the total spectrum of allergens in wheat flour. Houba et al. (25) further developed a sandwich immunoassay using affinity purified polyclonal rabbit antibody with Sander et al, (91) developing an assay based on monoclonal antibodies. Even though all these methods meet specificity, validity, sensitivity, and reproducibility requirements, and have been used by other researchers, the allergen concentrations measured may differ, because each method uses a different allergen and antibody preparation method. (60) Using these methods a number of potential occupational allergens have been identified in a bakery environment. These tests were used to measure wheat allergens and fungal alpha-amylase levels in the papers extracted.

Occupational allergens can be classified as high molecular weight (HMW) allergen or low molecular weight allergens (LMW). Most HMW agents are complex mixtures of polypeptides that act as complete antigens and stimulate IgE synthesis (e.g. animal allergens, flour, latex). Bakers and confectioners are exposed to HMW allergens (flour allergens vary between 10-60 Kilo Dalton-kDa) and they appear to mostly predispose to the development of disease through an

IgE mediated mechanisms. (92) The major allergens (about 15 kDa) of flours belong to the group of the alpha-amylase inhibitors which prevent insect alpha-amylases from harming the cereal. The glycosylated forms of these proteins have been suggested to be the most potent allergens. (93)

LMW allergens tend to be chemical in nature. LMW chemicals, such as acid anhydrides, isocyanates, persulfates, and reactive dyes may act as haptens (a small molecule that, when combined with a larger carrier such as a protein, can elicit the production of antibodies that bind specifically to it) and stimulate IgE production by combining with endogenous proteins to form a hapten-protein conjugate. However, many LMW agents, including glutaraldehyde may cause OA but induce specific IgE antibodies in only a minority of affected workers. (94)

1.10.2 Measurement of flour dust levels

Dust sampling has been the tool used for exposure assessment in the baking industry. In sampling, a known volume of air is drawn through a sampling head with filter, and the dust particles are retained on the filter and weighed gravimetrically at a designated laboratory to determine the concentration of the flour dust. The sampling is typically done over a work shift. Thus, sampling depends on the sampling head used, the flow rate and the duration of the sampling. The type of the sampling head used is determined by the size of the particles sampled or the type of fraction required to be sampled. The IOM, United Kingdom Atomic Energy Authority (UKAEA) 7 hole Sampling Head, Conical Inhalable Sampler (CIS), Personal air sampler 6 (PAS-6), SKC Button Aerosol Sampler (Casella) and Pre-Loaded Cassettes of which the 37 mm membrane filter loaded into a plastic cassette is the commonest, have been used for inhalable fraction sampling.[1] (95) Miniature cyclones (size selective heads) have been used to measure respirable fractions (23) whiles the thoracic dust fractions have been measured with Respicon multistage impactors. The main route of entry of flour dust into the body is through the nose or mouth. Therefore, sampling is done to mimic the amount of dust that will be inhaled by the exposed worker. The sampler is thus placed in the breathing zone of the worker which by definition is “a hemisphere of 300 mm radius extending in front of the face and measured from the midpoint of a line joining the ears.” (96) Samples collected unto filters in the breathing zone

[1] The pre-loaded cassettes could also be used to measure total dust.

of a worker are termed "personal samples" and can be directly linked to workplace exposure standards. After an air sample is collected, it is analyzed. The inhalable flour dust samples are usually stored at ambient temperatures in sealed containers to prevent additional exposure to moisture during storage and shipment. The analysis in most cases is done in a special designated laboratory where the filters are weighed to get the mass of the samples collected. The volume of air is derived from the flow rate of the sampler and duration of sampling. The concentration of the flour in the personal sample is calculated by dividing the mass over the volume of air. The unit is mg/m^3.

Lillienberg & Brisman found that there was a linear correlation between the IOM sampler and the traditional Millipore cassette, but the IOM collected almost twice as much flour dust as the conventional total dust sampler. (16) A recent study conducted by Golder Associates on some Alberta bakeries showed that inhalable samplers collected 2.5 times more particulates than total samplers with the result that workers are more likely to be considered overexposed if inhalable samplers are used to assess worker's exposure to flour dust. (97) It is, however, preferable to sample the inhalable dust fraction since this is the fraction around the breathing zone of workers most likely to penetrate and deposit in the airways and hence to cause diseases. Area sampling usually gives lower dust concentration results than personal sampling and therefore it is preferable to do personal sampling because it determines the exposure of different individuals or task groups.

The distribution of total dust is often lognormal, and geometric means (GM) and deviations are more commonly reported compared to arithmetic means (AM) with a standard deviation and range. (28) The relation between total dust levels and flour aeroallergen was shown by Nieuwenhuijsen to be linear with a slope of 0.59. A plot of geometric means of flour aeroallergen against geometric means of inhalable dust for the various exposure groups showed an almost linear relation especially in a flour mill. (23) It has however been shown that dust levels only partially correlate with actual allergen concentrations and thus, monitoring of dust exposure may not be a valid approach for estimating flour allergen exposure levels of bakery workers. Occupational titles in the bakeries have been shown to be the most important determinant of inhalable dust exposure levels and job titles explained 43-50% of the variability in dust exposures. (71) In other studies noted, the type of product manufactured, the size of the bakery and the task performed could be determinants of the levels of exposure. (22) (98)

1.11 Prevention of work related symptoms

Exposures in the bakery can be reduced in several ways. The hierarchy of control can be applied to exposure reduction. It may be difficult to eliminate or substitute any product for wheat flour to make bread. A lot of engineering control processes can be applied in the bakery to reduce exposure. Generally engineering controls reduce exposures to employees by removing the hazard from the process or placing a barrier between the hazard and the employee. Engineering control was noted by Page et al. (43) to be very effective at protecting employees. The basic types of engineering controls are: process control, enclosure and or isolation of emission source and ventilation control. Process control involves changing the way a job activity or process is done to reduce the risk. For example, spraying of water over a dusty surface to keep dust levels down or mixing flour dust with water to prevent dust from being generated, termed "wet method". Enclosure or isolation control keeps the floor dust away from the worker. This is not very practical in a bakery. Ventilation control brings in air or removes air filled dust in the work environment. Examples include local exhaust ventilation systems and pneumatic transfer systems. (99) Where engineering controls are not successful at reducing the hazard, administrative controls can be implemented in addition. Administrative controls refer to programs, policies and work practices instituted by management to reduce or prevent hazardous exposures. The effectiveness of administrative controls depends on employer commitment and employee’s willingness to recognize and implement these work practices. Regular monitoring and review of the policies are necessary to ensure that policies are followed consistently and implemented successfully. Administrative controls include timing of work such as job rotation and job rest schedules, policies, such as standard operating procedures and other rules and work practices such as training, housekeeping, equipment maintenance, and personal hygiene practices. Following engineering and administrative controls, if the hazard persists, then the baker would have to wear a PPE. PPE refers to Personal protective equipment and they serve to provide a barrier between the baker and the flour dust. In the bakery, PPE include protective clothing such as gloves, eye protection, face shields, respirators, and footwear. Wearing of PPE is the least effective means for controlling flour dust because they tend to be uncomfortable thus making workers non-compliant. The PPE may fail to protect the worker, for example torn gloves. Proper use of PPE requires a comprehensive program of bakery worker education and training on their use. Though there are no legal requirement for a bakery to institute a medical surveillance program for employees, employees should be encouraged to report work-related skin, eye, nasal and respiratory symptoms to their management.

Baatjies et al. (100) noted in her paper on interventions to reduce exposure, that the greatest reduction in flour dust was associated with control measures, such as the use of mixer lid (67%), divider oil (63%) and focused training (54%). She further emphasized that the greatest reduction (80%) was observed when a combination of these interventions was used in the bakery. Fraser et al. (101) also noted that the most effective method of decreasing dustiness of flour improvers was to increase the vegetable oil content of the improver from 2% to 4% and this was associated with a 77% decrease in airborne wheat flour. Fishwick et al. (102) also indicated that workers who were educated on the effect of flour exposure had less work related symptoms compared to the non-educated workers. Other work practices, such as use of local exhaust ventilation and wearing respiratory protection devices when performing dusty work, will reduce flour dust exposure. In the long term, work place surveillance can reduce the risk of disease by removing an affected person from exposure. De Zotti et al. (103) further noted that excluding young atopic people with symptoms from starting a job involving exposure to high molecular weight agents through pre-employment medical screening may be a good preventive measure, since such people were more likely to lose their jobs more easily because of absence or diminished work performance due to illness. He was also of the opinion that young workers could also easily change their jobs. However, this could be considered discriminatory but he did not think discriminatory screening might be a problem in young bakers because of above reasons. In some situations, workers with a preexisting atopy may need to change their work or stay away from the bakery trade at all. It is therefore imperative that concerted efforts are made to reduce flour dust exposure in bakeries.

1.12 The need for flour Job Exposure Matrix

The American Conference of Governmental Industrial Hygienist (ACGIH) recommends a Threshold Limit Value - Time Weighted Average (TLV-TWA) of 0.5mg/m^3 inhalable particulate matter for occupational exposure to inhalable flour dust to protect against both sensitization (in both atopic and non-atopic workers) and symptoms resulting from both sensitization and irritation. (104) This limit has been difficult to achieve in many of the published studies. A review of various studies published show that flour dusts measured in bakeries were often far in excess of this limit. (60) This study which will compile exposure measurements of previously published studies will give details of previous exposures and give an indication of compliance with this TLV.

Recent work conducted by Golder Associates for Alberta Jobs, Skills, Training, and Labor (JSTL) in 2014 on flour exposure in Alberta bakeries showed that current GM exposure to total dust in the bakeries sampled was 3.29 mg/m^3 for bakers who worked as mixers and 0.31 mg/m^3 for other bakery workers. For inhalable particulates, mixers were exposed to 4.13 mg/m^3, bakers 1.57 mg/m^3 and other bakery workers had 1.06 mg/m^3. (97) This study showed that flour exposure in the province may be far higher than the current Alberta occupational exposure limit (OEL) for flour which is based on the ACGIH TLV. It has been suggested that this level may be difficult to achieve and this threshold limit may need to be revised or more needs to be done to meet this target. The Golder study also looked at exposures in 3 job categories; bakers, mixers and other workers. This study will expand on this work and to determine exposure with respect to other job categories in the bakery industry.

A large number of studies of the respiratory symptoms, skin sensitization and lung function have been carried out in a variety of countries but very few measured dust levels or studied the association between these and symptoms. Where they have been measured, not enough information about the relationship between dust levels and health effects is available to establish a clear dose response relationship. (104)

Collection of exposure data in the bakery industry serves several purposes. Exposure data is used to provide evidence for setting of statutory occupational exposure limits (OEL), to determine compliance with OELs, to obtain exposure estimates for epidemiological studies and as well as to assess the effectiveness of control measures. (105) However, measurement of flour dust exposure in the bakery industry is very expensive. Although occupational exposure data on flour have been measured in several countries, these data have been poorly integrated so that estimates of disease risk and attribution of disease causation are usually difficult to do. This study will seek to develop a flour job-exposure matrix (flourJEM) for bakery workers to estimate occupational flour exposure levels, making optimal use of the available published exposure data. The flourJEM will provide empirically based quantified estimates of flour exposure levels and job tasks. This exposure assessment application will contribute to improved understanding and prediction of flour-related diseases and attribution of disease causation. (106)

The job exposure matrix will therefore show the average exposure to flour dust published in various countries over the years which can guide the consideration of new OEL for flour in Alberta. Another would be to have the OEL review to be informed by health considerations. The flourJEM could also be used to assign exposure in any epidemiological study on flour workers in future.

Various JEM have been developed for asbestos, (106) silica, (107) and low back pain, (108) among others but none has been developed and published for flour exposure. This will be the first JEM to flour in the baking industry

1.13 Study goal and objectives

The primary goal of this study was to develop and validate a Job Exposure Matrix (flourJEM) to flour exposure in the Bakery Industry in Alberta.

The objectives are:

1. Develop an exposure matrix and obtain best estimates of exposures of bakery workers to flour and flour antigens by task and product.
2. Provide temporal trends of flour dust exposure measures from 1990 to present
3. Demonstrate how a validation of the flour JEM with skin prick sensitivity tests could be undertaken (by comparing the exposure matrix against likelihood of a positive skin prick test to bakery antigens among a population of Alberta bakers).

1.14 Research question

Is it possible to create a tool to estimate quantitative exposure to flour, based on a worker's job/task description in the bakery industry using previously published exposure studies?

Chapter 2 : SYSTEMATIC REVIEW AND DEVELOPMENT OF FLOUR JOB EXPOSURE MATRIX

2.1 Introduction

Flour exposure in bakeries has been known for many years to lead to the development of occupational allergies, eye disease, skin disease and respiratory system disease. (109) It has also been established that the intensity and duration of exposure leads to work related symptoms and sensitization. (69) Studies have demonstrated that bakery size, job and tasks at the bakery are significant predictors of flour dust particulate and wheat allergen exposure. (110) (111) Quantitative measurements of flour exposure of bakers have been conducted and published in several papers. Measurement of flour exposure is however an expensive undertaking and therefore not frequently undertaken at various bakeries especially smaller ones. A Job Exposure Matrix on flour (flourJEM) exposure will be a semi-quantitative way of estimating exposure and possibly relating it to health outcome. (112) This systematic review therefore aimed to estimate quantitative exposure to flour within task-based job description in the bakery industry using previously published exposure studies. The review was reported in accordance with a modified Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, where appropriate (113).

2.2 Methods

The development of a flourJEM began with a systematic search of published exposure data on flour measurements. For the initial construction of the flourJEM, information was collected on:

- Data on flour exposure within bakeries
- Job tasks/titles used in the published literature associated with specific exposure data
- Product of bakery
- Type of samples and number of samples taken
- Year(s) of data collection

2.2.1 Eligibility Criteria

Published literature sources that included exposure measurement data within a bakery were used for the development of the flourJEM. Papers that did not have exposure measurements were excluded as were published papers on flour mills or any exposure outside bakeries. No restriction based on dates was applied.

2.2.2 Information Sources

Sources of information were from published literature in journals. A search strategy was developed and used to conduct an internet based search on electronic databases. Using Medline (1966 – Present) as an example, the search query developed was: (Baker OR bakers OR baker* OR bakery OR pastry making OR pastry maker OR pastry arts OR confectioner OR patisserie) AND (flour OR wheat OR rye OR bread improver OR amylase OR cellulase OR xylanase OR dust). When the search query was used on PubMed and limiting it to humans and the English language, numerous papers were identified. The search query was adapted for Embase, ISI Web of Science, CINAHL, SCOPUS and Google Scholar. Hand searches of old journals in the John W. Scott Health Sciences library of the University of Alberta and references in published literature to identify further exposure measurements study were conducted. Duplicate papers were removed and then the titles and abstracts of the studies identified by the electronic database searches were screened independently by two reviewers (myself and Christopher McDonald). All papers possibly containing exposure data were included for a full review while published papers, not related to the flour exposure in bakeries were excluded based on title and abstracts.

2.2.3 Data collection process and data items

A standardized extraction form was developed and used to extract data from published articles. The extraction form and the data extracted is shown as appendix I. Information collected from each paper included the name of the lead author and year of publication of the paper and where available, sampling equipment and the flow rate, area or personal sample taken, type of business where the sample was taken from, date of sampling, the job task performed, the products of the bakery, number of samples taken, the type of substances sampled and the results of the sampling (arithmetic or geometric means and their standard deviations, median and ranges). Exposure data on total flour dust particulate, thoracic fraction, respirable dust, inspirable dust, wheat allergens, rye allergens, fungal alpha-amylase, cellulase, xylanase, beta (1→3) glucan and total proteins were extracted where available. The last search was conducted on June 29th, 2015. The two reviewers independently reviewed each selected paper to determine which to fully extract and include. Where there were disagreements, a third reviewer (supervisor) determined whether the paper should be included. Data were then extracted independently by the two reviewers and the data verified by comparing the two extractions again if the two reviewers disagreed a third reviewer resolved the issue. Some quality assessment of the papers was done to exclude some papers and also to reduce bias. However, there was no tool to formally assess the bias in the published studies. The criteria used for the exclusion of some papers were: papers with no exposure measurement, papers based on flour sensitivity, papers based on clinical scenarios, papers with repeated data and papers with flour dust particle measurements (counters).

2.2.4 Summary measures and synthesis of results

The main outcome in the published papers was the flour dust exposure levels of specific groups of bakery workers. The exposure measured could be either area samples or personal samples. Personal samples were measured around the breathing zone of the worker. Flour was sampled through sampling pumps collecting onto sampling cassettes/filters and exposure level was measured gravimetrically. The exposure level was recorded as either the arithmetic mean (AM) with or without the arithmetic standard deviation (ASD), and or the geometric mean (GM) with or without the geometric standard deviation (GSD) or as a range. The results from the extraction was compiled into a table in word format and then compiled in an excel format for analysis.

2.2.5 Occupational Classification

Standard occupational job titles had not been used in the published papers. Papers used classifications that best suited their research needs. According to Corn & Esmen, (114) workers can be grouped based on exposure zones in which workers share four attributes; work similarity, similarity with respect to hazardous agents, environmental similarity, and identifiability. Based on this, and agreement by co-principal investigators/supervisors and frequency of job titles used in the papers, the jobs were first classified as either production or non- production based tasks and the job titles grouped under them. Under production based tasks, the following job titles were identified; baker/oven worker, confectioner, weighing and mixing, dough former, other production related tasks and those performing all production tasks. Under non-production tasks, the following job titles were identified; packers and shippers, front counter sales, and cleaners & maintenance. The job titles and the papers with the job titles as well as reclassification of the jobs are shown as appendix II, III and IV.

2.2.6 Product classification

From the literature search, it was found that most products produced in a bakery could be classified under three main products. These were bread and bread related products, confectionery/cakes or sugary based products and bakeries producing both products. The products produced by the various bakeries were therefore reclassified into bread, confectionary, and those producing both bread and confectionary product, labelled as mixed. The products and the papers in which they are published are shown as appendix V.

2.2.7 Period of Data collection

Most papers published the date of sample collection or sampling year. For the few that did not publish them, it was estimated. From the papers that published date of sample collection, the dates were analyzed and found that the average time of data collection to publication was 4 years. This was used to impute year of collections for those papers which did not have a collection date by simply subtracting 4 years from the date of publication. If the date of sampling included a range of years, the mid-point was used in the calculation as the date of the sampling. The sampling year was used to calculate JEM by 5 year intervals and to look at the trends of estimates of inhalable dust measurement. The period of data collection ranged from 1972 to 2013.

2.2.8 Conversion of sample results

The results were grouped by sampling dates, task, product, number of samples, substance sampled and by whether the data were presented as geometric or arithmetic means. For some of the exposure data, various units of measurements were used. For example, some measurements of fungal amylase were recorded as ng/ml, ng/m^3 or ng/cm^3. All the units had to be standardized to µg/m^3 before compilation in the Excel. They were therefore converted to microgram/meters cubed (µg/m^3). The grouped results and the standardized units were used to calculate the weighted geometric means of the inhalable dust, wheat allergen and fungal alpha-amylase.

2.2.9 Construction of the initial matrix

The flourJEM was compiled as a table with the job titles in the production and the non-production tasks. The products were bread products, non-bread products (confectionery) and a mixture of bread and non-bread products. The tasks in the bakeries were baker/oven worker, confectioner, weigher and mixer, dough former, other production based tasks, all production tasks, packing/shipping, front counter and sales, and cleaner & maintenance. Weighted geometric means were calculated for inhalable dust, wheat allergen and fungal alpha-amylase for each task category by the formula shown.

Formula for estimating weighted geometric mean ($\bar{x}$) (115)

$$\bar{x} = \exp\left(\frac{\sum_{i=1}^{n} wi \ln\ xi}{\sum_{i=1}^{n} wi}\right)$$

Where *x* is the geometric mean and *w* is the number of samples taken in the bakery. ln is the natural logarithm and $\bar{x}$ is the weighted geometric mean.

If the number of samples was not included in the paper, a weight of 1 was assigned to the corresponding value to be able to calculate the weighted means. In this way, all the extracted data could be utilized.

Using the above formula and working in excel and SPSS, the samples were sorted or grouped by task, product, type of sample, number of samples and their GM/AM. With this grouping the weighted geometric mean was calculated using the above formula. The results were tabulated by task and product a presented in Tables 2.9 to 2.11. Data on 9 job tasks (baker, confectioner, weigher & mixer, dough former, other production tasks, all production tasks, packer/shipper, front counter, and cleaner & maintenance) and 3 products (bread, confectionery and mixed) were extracted and used to develop the flourJEM. From the 46 papers selected, job exposure matrices were developed.

2.2.10 Construction of the final matrix

Three approaches were tried for the development of flourJEM.

1. Using all the extracted data as they are for each separate GM and AM and using all of them for the calculations. In this case, there were separate results/tables for GM and AM.

2. Using only the papers that published results both for the GM and AM for each measurement and using that to generate a flour JEM table.

3. Using the conversion factor calculated below to convert all AM to GM and to recalculate the means only as GM. In this case, there will be no results for AM

The first flourJEM was constructed for total dust, wheat allergen and fungal alpha amylase. It was noticed that there were more inhalable dust measurements and therefore total dust was changed to inhalable dust. Thus, a new table for inhalable dust had to be recalculated. There were results for GM and AM in the tables but there were a lot of empty cells because of lack of exposure measurements (appendix VI). There was also a difficulty as to whether to report the flourJEM as GM or AM. Upon deliberations, it was decided to report the flourJEM as GM. There was the suggestion to try to create flourJEM using papers which published both the results of the GM and AM for the same job/task exposure measurements. Initially a subgroup of 20 papers that reported both the geometric and arithmetic means was used to develop the flourJEM. 15 papers published results for inhalable dust, 9 for wheat allergen and 7 papers published studies on fungal amylase. Some papers published exposure data on more than one exposure type. These papers published results of the arithmetic and geometric mean for the same task and product. Using these papers, a comparison was made of the same arithmetic mean and geometric mean for the same type of measurement by task and product. It was noted that the exposure levels in these papers were high and the number of measurements was rather small. It was therefore decided to maximize the use of the available information by including all the extracted data in the construction of the JEM. It was decided to use the GM for the calculations since flour exposure data are generally lognormally distributed. (116) Though a paper described the relationship between the arithmetic mean and geometric mean or a way of converting AM to GM as [GM=AM exp(-0.5(ln GSD)^2)], (117), papers that published AM results only did not have results for geometric standard deviation (GSD) which made it impossible to do the conversion or use this formula,   The formula was also tried on papers that published both results for AM and GM. Though the formula gave good results for the conversion, it could not be used at this time. A conversion factor was therefore calculated using the ratio of the GM to the AM for each task and product. The ratio of GM/AM was averaged and used as the conversion factor which was then applied to AM to convert them to GM which was used in the calculation of the final JEM. The conversion factor for flour dust was 0.5644 (GM=0.5644*AM). For wheat allergen, the conversion factor was 0.3115 (GM=0.3115*AM) and for fungal amylase was 0.4308 (GM=0.4308*AM). The resulting JEM was therefore only reported as the GM for flour, wheat allergens and fungal alpha-amylase, which are the data presented in Tables 2.9 to 2.11.

In summary, this was how the JEM was constructed.

1. The JEM was created using all available data. Initially a table was created using total flour dust. Later it was seen that using inhalable dust was better. Subsequently inhalable dust instead of total dust was created. There were separate tables for GM and AM. Subsequently, tables were created using only the 20 papers that published both results for GM and AM. There were a lot of empty cells in the separate GM/AM tables and that of the tables reporting both GM and AM.
2. Following several discussions, it was decided that using the GM would give the best results
3. We noticed that we could not use the reported approaches to estimate GM from the formulas outlined above since some of the papers did not report the standard deviations, thus an alternate approach had to be used.
4. We subsequently calculated a conversion factor and applied it to all the AM
5. Grouped all the data by sampling year, task, product, number of samples and calculated the weighted GM
6. Presented the results in tables for inhalable dust, wheat allergen and fungal alpha-amylase.

2.3 Results

2.3.1 Study Selection

1,937 papers were initially identified from the electronic databases searched. 512 duplicates were removed. Based on the titles and abstracts, 1,142 were removed because the titles and abstracts clearly showed that there were no exposure measurements. 284 full articles were assessed of which 229 were discarded because they had no data despite the abstract suggesting that they did. Eventually 55 published articles met the inclusion criteria and were selected and used in the creation of the flourJEM. One unpublished or grey literature source was identified in addition. The grey literature was the Golder report which was a report on worker exposure to inhalable and total flour dust in Alberta bakeries.

The list of 55 papers is presented as appendix II. All the papers selected had exposure measurement which reported either the arithmetic mean or the geometric mean, their standard deviations or the ranges. Results from over 23,000 samples were reported in the 55 papers included, dating from the 1970's to 2014. The reported data were extracted into a table and compiled in excel and SPSS for further analysis.

The papers selected for extraction are presented as a modified Prisma flow diagram in figure 2.1 below.

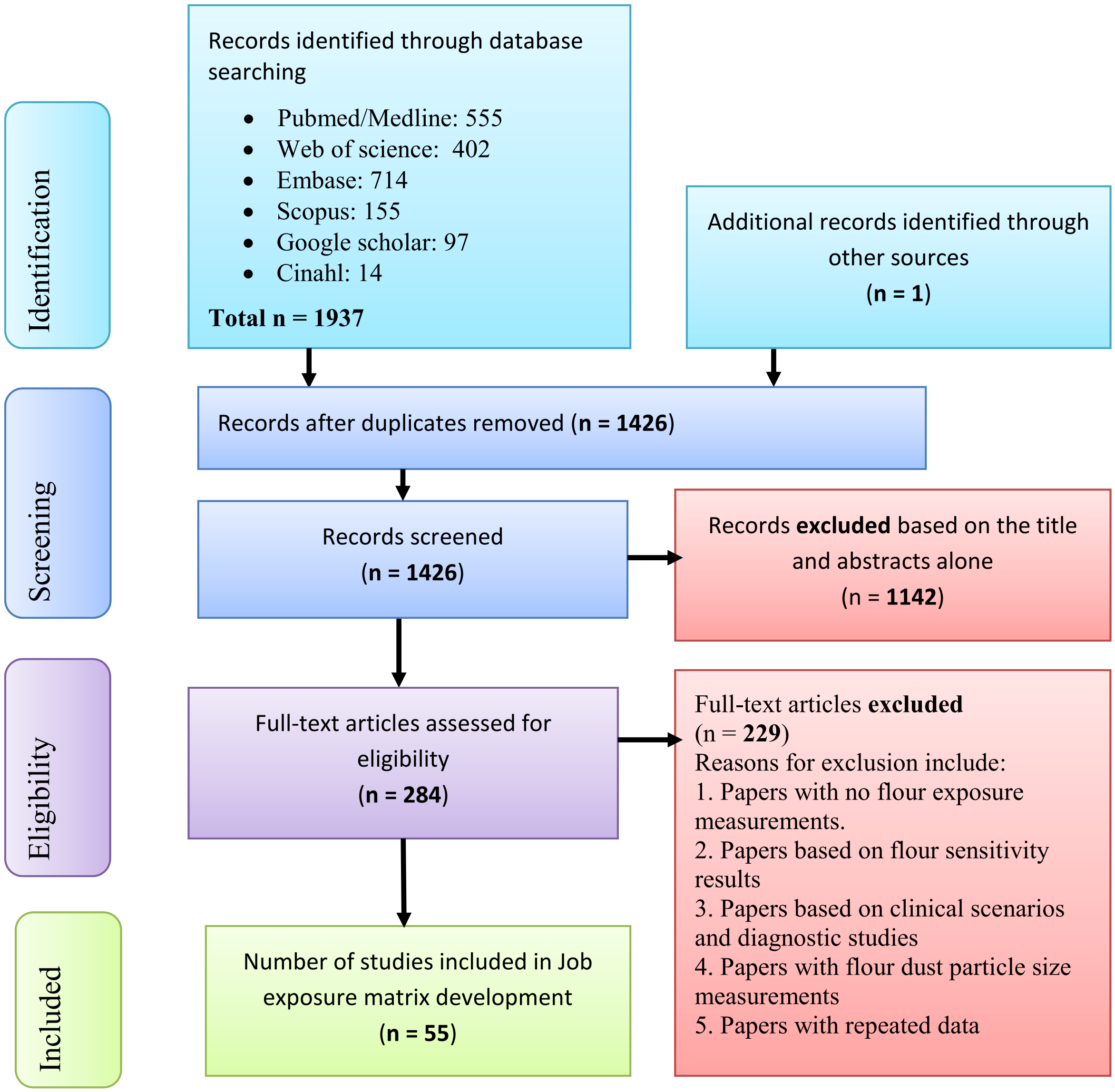

Figure 2-1 Modified Prisma flow chart illustrating the process followed to identify the 55 papers

2.3.2 Study Characteristics

The years of publications of the papers were from 1976 to 2014. From the 55 papers extracted, 46 papers were used for the analysis after cleaning the data. Reasons for exclusion included measurement of wipe samples, repeated data in the papers, results of dataram, which counts flour particles, results expressed as particle size fractions and data not reported as arithmetic or geometric mean or individual results. Most of the exposure assessments were conducted in large bakeries (345), small bakeries (199) followed by medium sized and multiple type bakeries as shown in Table 2.1.

Table 2-1 Size of bakeries and frequency

Size of Bakery	Frequency	Percent
Bakery (small)	199	22.6
Bakery (medium)	168	19.1
Bakery (large)	345	39.2
Bakery (multiple types)	167	19.0
Undefined	1	.1
Total	880	100.0

There was one unspecified bakery. These categorizations were extracted from the published papers. The size of the bakery was defined as extracted in the papers. In most papers, a bakery was small if it employed less than 20 staff, medium if staff were more than 20 but less than 100 and large sized if the employees were greater than 100.

Inhalable dust measurements were recorded in 364 instances, total dust in 152, respirable dust measurements in 12 as seen in Table 2.2. At least 12 sampling heads were used in the exposure measurements in bakeries whiles a few papers did not report the type of sampling heads used (Table 2.3). The most frequent sampling heads used were the PAS6 and the IOM.

Table 2-2 Substance sampled by frequency

Substance sampled	Frequency	Percent
Inhalable dust	364	41.4
Total dust	152	17.3
Respirable dust	12	1.4
Fungal alpha-amylase	168	19.1
Wheat allergen	124	14.1
Rye allergen	15	1.7
Total proteins	28	3.2
Other enzymes	17	1.9
Total	880	100.0

Table 2-3 Sampling heads and their distribution

Sampling head	Frequency	Percent
37 mm cassette	135	15.3
7 hole	158	18.0
Cyclone Casella	1	.1
DO cyclone	2	.2
Hexhlet two stage	2	.2
IOM	241	27.4
PAS6	246	28.0
Unknown	43	4.9
Respicon Inhalable	28	3.2
TEOM3600	7	.8
25 mm cassette	10	1.1
PM10 chempass	3	.3
PM2.5 chempass	4	.5

Four main filter types with various pore sizes were used in the sampling. These were cellulose, glass fiber, PVC (Polyvinyl chloride) and Teflon. Teflon was the most frequently used filter type with various sizes of Teflon from 0.45 µm to 2 µm. These are presented in Table 2.4.

Various sampling times were noted in the papers from 15-minute sampling to 8-hour sampling. The largest proportion was 8 hour samples as shown in Table 2.5. Approximately 79% of the samples recorded were personal with 18% being area samples, Table 2.6.

Table 2-4 Types of filter types and pore sizes

Filter type &pore size	Frequency	Percent (%)
Cellulose 0.8µm	33	3.8
Glass fiber	7	.8
Glass fiber GF/A	159	18.1
Glass fiber GF/C	13	1.5
PVC	141	16.0
PVC with Accu-cap	28	3.2
Millipore AA	14	1.6
Teflon (unspecified)	3	.3
Teflon 0.45 µm	48	5.5
Teflon 1 µm	257	29.2
Teflon 1.2 µm	100	11.4
Teflon 2 µm	7	.8
Unknown	70	8.0
Total	880	100.0

Table 2-5 Sampling time and distribution

Sampling Time (hours)	Frequency	Percent
0.25	8	.9
0.5	28	3.2
0.75	5	.6
2	9	1.0
1	52	5.9
1.5	15	1.7
3	12	1.4
3.5	3	.3
4	78	8.9
5	38	4.3
5.5	2	.2
6	29	3.3
6.5	8	.9
7	147	16.7
8	392	44.5
16	1	.1
unknown	53	6.0
Total	880	100.0

Table 2-6 Distribution of sampling type

Sampling type	Frequency	Percent
Personal (P)	703	79.9
Area (A)	158	18.0
Combined P & A	19	2.2
Total	880	100.0

The largest proportion of samples were taken in bread manufacturing bakeries (410) followed by bakeries producing mixed products (321) and then lastly from bakeries producing only confectionery products as seen in Table 2.7. Substances sampled were mostly inhalable dust with a few total dust and respirable dusts. Other substances sampled and reported on were fungal alpha-amylase, wheat allergen, total proteins and other enzymes. On average, approximately 27 samples were taken from each bakery.

Cross tabulation of substance sampled by product (Table 2.7) showed that most inhalable dust measurements were taken in bread manufacturing bakeries. Similarly, most fungal alpha-amylase samples were taken in bakeries producing only bread product but wheat allergen samples were taken in bakeries producing mixed products. More samples were taken from weighers and mixers followed by dough formers and this was mostly in bread producing bakeries (Table 2.8).

Table 2-7 Substance sampled by type of product

Substance sampled * Product Cross tabulation				
	Product			Total
Substance sampled	Bread	Confectionery	Mixed	
Inhalable dust	179	66	119	364
Total dust	73	3	76	152
Respirable dust	7	4	1	12
Fungal alpha-amylase	70	41	57	168
Wheat allergen	46	29	49	124
Rye allergen	3	3	9	15
Total proteins	16	2	10	28
Other enzymes	16	1	0	17
Total	410	149	321	880

Table 2-8 Job task by product

Task * Product Crosstabulation				
	Product			Total
Job tasks	Bread	Confectionery	Mixed	
Baker/Oven worker	58	23	38	119
Confectioner	3	48	4	55
Weighing & Mixing	143	19	67	229
Dough Former	72	8	25	105
Other Production	25	4	10	39
All Production tasks	46	35	41	122
Packer/Shipper	47	9	48	104
Front counter	14	3	87	104
Cleaner	2	0	1	3
Total	410	149	321	880

Table 2-9 Job exposure matrix for inhalable dust exposure

		BAKED GOODS PRODUCED			Overall n-Weighted GM
		Bread	Confection/cakes	Mixed	
	TASK	Inhalable Dust Geometric Mean Exposure (mg/m^3)			
PRODUCTION TASKS	Oven Worker/Baker	1.56 13 papers, n=733	1.38 6 papers, n=890	1.75 4 papers, n=163	1.49
	Confectioner	0.3 1 paper, n=21	0.86 8 papers, n=341		0.83
	Weigher & Mixer	3.58 11 papers, n=625	3.16 6 papers, n=305	3.34 10 papers, n=1106	**3.39**
	Dough Former	2.32 5 papers, n=133	1.98 3 papers, n=76	4.69 4 papers, n=207	**3.44**
	Other Production Tasks	0.74 7 papers, n=154	0.60 2 papers, n=42	1.20 3 papers, n=173	0.94
	All Production Tasks	1.14 6 papers, n=267	2.89 4 papers, n=313	1.73 9 papers, n=3266	1.78
NON-PRODUCTION	Packer/Shipper	0.41 8 papers, n=290	0.49 4 papers, n=67	0.65 6 papers, n=289	0.53
	Front Counter & Sales	0.72 3 papers, n=61	1.93 2 papers, n=9	1.18 9 papers, n=888	1.16
	Cleaner & Maintenance	0.75 1 paper, n=1	- 0 papers, n=0	1.33 2 papers, n=32	1.31
	Overall n-Weighted GM	1.87	1.77	1.97	

n = number of samples

Table 2-10 Job exposure matrix for wheat flour allergen exposure

		BAKED GOODS PRODUCED			Overall n-Weighted GM
		Bread	Confection/cakes	Mixed	
	TASK	Wheat Allergen Geometric Mean Exposure (µg/m^3)			
PRODUCTION TASKS	Oven Worker/Baker	18.57 9 papers, n=577	5.56 4 papers, n=700	3.57 3 papers, n=128	10.72
	Confectioner	- 0 papers, n=0	11.99 5 papers, n=245	35.53 2 papers, n=44	**15.57**
	Weigher & Mixer	11.34 3 papers, n=166	6.72 3 papers, n=128	18.38 6 papers, n=391	14.50
	Dough Former	39.06 1 paper, n=13	19.80 2 papers, n=69	87.13 2 papers, n=61	**50.27**
	Other Production Tasks	0.48 3 papers, n=115	0.30 2 papers, n=42	0.78 2 papers, n=88	0.80
	All Production Tasks	3.39 2 papers, n=80	20.55 2 papers, n=63	1.32 6 papers, n=1405	2.21
NON-PRODUCTION	Packer/Shipper	0.86 4 papers, n=213	0.59 2 papers, n=54	0.38 2 papers, n=143	0.66
	Front Counter & Sales	2.02 2 papers, n=50	0.06 1 paper, n=3	1.24 7 papers, n=493	1.30
	Cleaner & Maintenance	- 0 papers, n=0	- 0 papers, n=0	1.30 2 papers, n=25	1.30
Overall n-Weighted GM		11.3	7.97	6.17	

Table 2-11 Job exposure matrix for fungal alpha-amylase exposure

		BAKED GOODS PRODUCED			Overall n-Weighted GM
		Bread	Confection/cakes	Mixed	
	TASK	Fungal α-Amylase Geometric Mean Exposure (ng/m^3)			
PRODUCTION TASKS	Oven Worker/Baker	0.45 6 papers, n=345	0.49 4 papers, n=681	0.20 2 papers, n=108	0.45
	Confectioner	- 0 paper, n=0	0.26 4 papers, n=161	- 0 paper, n=0	0.26
	Weigher & Mixer	6.84 5 papers, n=209	0.25 4 papers, n=136	3.15 3 papers, n=58	**4.09**
	Dough Former	43.1 1 papers, n=21	0.34 1 papers, n=55	3.98 2 papers, n=50	**5.64**
	Other Production Tasks	- 0 papers, n=0	- 0 papers, n=0	0.35 2 papers, n=94	0.35
	All Production Tasks	1.25 6 papers, n=262	2.59 2 papers, n=63	0.57 4 papers, n=735	0.86
NON-PRODUCTION	Packer/Shipper	0.2 5 papers, n=99	0.15 1 papers, n=32	0.24 3 papers, n=162	0.22
	Front Counter & Sales	- 0 papers, n=0	- 0 papers, n=0	0.21 5 papers, n=424	0.21
	Cleaner & Maintenance	- 0 papers, n=0	- 0 papers, n=0	- 0 papers, n=0	0.1[2]
	Overall n-Weighted GM	2.55	0.53	0.60	

[2] This figure was used to represent empty cells for the cleaner & maintenance

2.3.3 Comment on the flour JEM

Tables 2.9 to Table 2.11 show the results of the job exposure matrix for inhalable dust, wheat allergen and fungal alpha-amylase. These tables were reported as the GM since the AMs had been converted to GMs. The n-weighted GM by task and product was also calculated. The number of papers and the number of samples taken have also been showed in the tables. Prior to the calculation of the final table, the various JEM created from the beginning are shown in appendix VI.

From the JEM, generally workers producing mixed products were the most exposed to inhalable dust. This was followed by those producing bread and confectionery products. Workers producing confectionery/cakes were the least exposed to inhalable dust. Dough formers were the job tasks most exposed to inhalable dust (GM 4.69mg/m^3 for those producing mixed products). The weighers & mixers were the second highest exposed group (GM 3.58mg/m^3) and this was for those producing bread products followed by confectionery products. Job tasks with least exposure were the confectioners. Overall, dough formers were the most exposed for all those producing bread, confectionery and mixed products. This was followed by weighers and mixers, those performing all tasks in bakeries and bakers/oven workers. The range of exposure for inhalable dust varied from GM 0.3mg/m^3 to GM 4.69 mg/m^3.

Wheat allergens exposures were predominant in bakeries where bread products were made compared to mixed products and confectionery/cakes. However, the dough formers producing mixed products had the highest exposure level of wheat allergens at GM 87.13 µg/m^3. Dough formers in bread producing bakeries had the second highest level of wheat allergen exposure (GM 39.06 µg/m^3). Confectioners producing mixed products had the third highest level of GM 35.53 µg/m^3 as shown in Table 2.10. The range of exposure varied from GM 0.06µg/m^3 to GM 87.13 µg/m^3. Packers/shippers were the least exposed to wheat allergens (GM 0.06 µg/m^3) irrespective of what they were producing, dough formers on the average had the highest exposure (GM 50.27 µg/m^3) to wheat allergens.

Dough formers in bread producing bakeries were exposed to the highest levels of fungal alpha-amylase GM 43.1ng/m^3 followed by weighers and mixers producing bread products GM 6.84 ng/m^3 and then dough formers producing mixed products (GM 3.98ng/m^3). Generally, workers producing bread products had the highest exposure followed by those producing mixed products and confectionery products. Dough formers on the average had higher exposures (GM 5.64 ng/m^3) irrespective of the product being produced followed by weighers & mixers (GM 4.09 ng/m^3) with the least being front counter assistants. This is to be expected since fungal alpha-amylase is more prevalent in bakeries producing bread products than in those producing mixed products and confectioneries. The range of exposure varied from GM 0.20 to 43.1ng/m^3.

There were fewer measurements of fungal amylase by tasks and therefore more empty cells for the job exposure matrix. No measurements were made of fungal alpha-amylase exposure for those performing the cleaning/maintenance tasks.

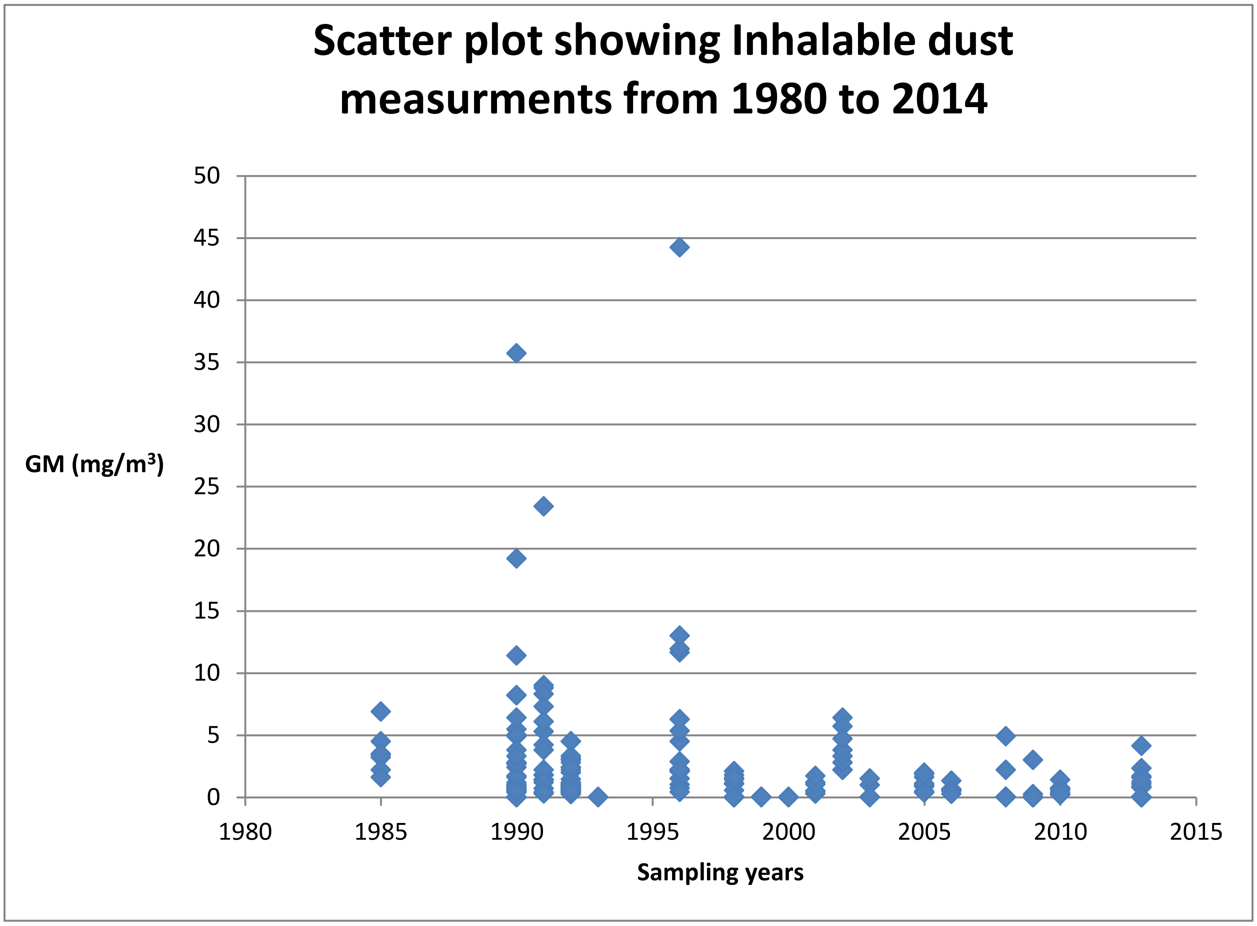

Figure 2-2 Inhalable dust measurements by years

The scatter plot in figure 2.2 shows the inhalable dust measurements from 1985 to 2014. The scatter plot shows that the concentration of inhalable dust measured in the bakeries and published The plot does not include total dust measurements. It shows that majority of the inhalable dust measurements were below 5mg/m^3 with a few between 5mg/m^3 to 10 mg/m^3. A few recorded inhalable dust measurements were greater than 10mg/m^3 especially for those recorded in the 1990's. The figure shows that the exposures measured had reduced from 1985 to 2013. There were a few measurements in the 1990-1995 periods which were exceedingly high and beyond the average. Generally, most inhalable dust measurements were about the 5mg/m^3 average.

2.4. Discussion of Systematic Review

The JEM for this study had 9 different task groups, with ranges of exposure for inhalable dust varying from GM 0.3 mg/m^3 to GM 4.69 mg/m^3. These findings expand on previous research in a number of ways. Utilizing additional more specific task groups expands upon previous studies, such as the one by Golder Associates in Alberta (2014) which used 3 groups; bakers, mixers and others. In the Golder study, the mixers worker groups were found to have the highest overall potential for worker overexposure to flour dust but in this JEM, dough formers were the predominant task group most exposed to inhalable dust, wheat allergen and fungal alpha-amylase while packers/ shippers and front counter & sales workers had the least exposure. Mixers and dough formers have generally been known to be exposed to high levels of flour dust. Smith et al. (118) noted that activities such as sieving, weighing and mixing are associated with high dust exposures but the singular act of flour dusting performed by dough formers, makes them very prone to very high dust exposure levels.

This study is also the first to be developed using published data for flour exposures in the bakery industry; previous published research had relied on actual exposure measurement to classify job/ tasks groups such as those by Houba et al. (22), Burdoff et al. (119) This work has demonstrated using various approaches that it was possible to classify bakery workers into groups with distinguishable levels of exposure to inhalable flour dust and within each task group, there was a considerable difference.

An additional matrix for wheat allergen and fungal amylase was also developed for the very first time. This allows this work to expand upon previous studies by Bulat et al. which found wheat allergen exposures in traditional bakeries and Elms et al. who noted that assignments of job/tasks could identify individuals with highest exposures to fungal alpha-amylase. In these studies, however, the job/ tasks classifications were limited.

The levels of flour exposure measured are consistent with similar studies, for example the aforementioned work by Golder Associates. The range of inhalable dust is similar to that measured recently in Alberta bakeries with a range of GM 1.06 to 4.13 mg/m^3. The JEM ranges of exposure for inhalable dust varied from GM 0.3 mg/m^3 to GM 4.69 mg/m^3.

The GM wheat allergen exposures ranged from 0.06 µg/m^3 to GM 87.13 µg/m^3. This range is lower compared to that reported by Meijster et al. (120) 0.1–5365 µg/m^3 for traditional bakeries and 0.1–7571 $\mu g/m^3$ for industrial bakeries. Likewise, Nieuwenhuijsen recorded a high concentration of 45.5 $\mu g/m^3$ up to 252 $\mu g/m^3$ in a bakery. Our results were higher compared with Bulat who found that workers in traditional bakeries in bread production as well as confectionery production had levels of exposure of 22.33 $\mu g/m^3$ and 14.48 $\mu g/m^3$ respectively.

For fungal alpha-amylase the range from the JEM was between 0.1 to 43.1 ng/m^3. Elms et al. found that mixers and weighers had levels of fungal alpha-amylase of 3.2-29.1 ng/m^3, compared with other job categories. In our study, dough formers had the highest with range of 0.34 to 43.11ng/m^3. Baatjies on the other hand recorded very low levels of 0.4 to 1.7 ng/m^3 but in her study, about 80% of samples were below the limit of detection.

Chapter 3 : VALIDATION OF THE JOB EXPOSURE MATRIX

3.1 Introduction

A number of studies have shown that high exposures to flour from performing certain bakery jobs are associated with a higher risk of either respiratory symptoms or sensitization. (121) (122) (24) For instance, Brisman et al. (123) reported that exposure ≥3mg/m^3 were associated with a higher risk of asthma in dough makers or bread formers, whereas ≥1mg/m^3 was associated with rhinitis, suggesting an increased risk in most bakery jobs. It is recognized that there is a dose response relationship between flour exposure and the likelihood of symptoms and sensitization. The validity of the job exposure matrix (JEM) developed from the exposure systematic review will be tested by its success in predicting sensitization to bakery related allergens. The main aim of this chapter is to see whether various estimates of exposure derived from individual workers using the JEM relate to sensitivity as assessed by skin prick tests. The objectives are:

1) To describe the prevalence of work related sensitization (by skin prick tests) among bakery workers in Alberta.

2) To assess if the likelihood of being sensitized to any bakery allergen is affected by estimates of exposure (bakery job duration, average bakery job exposure, maximum bakery job exposure and cumulative job exposure),

3) To identify whether these estimates of exposure are modified by inclusion of personal or workplace confounders.

This work is part of the flour exposure, sensitization and respiratory health among Alberta bakers study (Alberta Bakers' study).

3.2 Study location

The study was carried out at various bakeries in Alberta, but mostly in Edmonton and Calgary. Over 180 bakeries were contacted, but only 8 responded favorably. Data were collected from these 8 bakeries among current workers. All production and non-production workers at these bakeries with current exposure to flour were invited to participate.

3.3 Study design

The part of the study used for this thesis was a cross sectional study of current bakery workers. Investigators provided briefing sessions for all available workers. This was done immediately prior to the study being carried out at the workplace. Those willing to participate were given a consent form prior to their taking part in the study. A listing of current workers and the nature of their work (i.e. job title) was made available to the study team at each workplace. A schedule for inviting each individual was then agreed on with the host bakery/company so as to minimize disruption to the production process and to take account of work cycles and shift patterns.

3.3.1 Sample size determination

Even though an initial estimate of 16 bakeries were targeted with over 300 workers, recruitment of bakers for this study proved more difficult than anticipated. At the time of the analysis for this report, only 57 participants had been recruited.

3.3.2 Sampling Method

No sampling methodology was carried out. Bakeries were identified through information from the Alberta Food Processors Association contact list (34) and from the Alberta Agricultural list of bakeries (26). These bakeries were approached by mail but a large proportion declined to participate or did not respond. A second and third letter was sent to these bakeries with limited responses. It was therefore decided to write to bakeries whose address could be found online or in the yellow pages in Alberta. A total of 103 bakeries were sourced from yellow pages and written to as well as being contacted by phone. However, this methodology was not particularly successful either as no bakery was recruited from this approach. At the end of over a year of approaching the bakeries, only 57 participants from 8 bakeries were successfully recruited.

3.3.2.1 Inclusion Criteria

All bakeries producing bread, confectioneries and mixed products were included in the study.

3.3.2.2 Exclusion Criteria

Flour Mills, restaurants and sugar confectioneries were excluded from the study.

3.4 Study tool

A respiratory symptom and health questionnaire was developed for this study based on the previously validated European Community Respiratory Health Survey (ECRHS) questionnaire (appendix VII). The questionnaire included questions on date, place of interview, personal details, education, current state of health, medications taken, chest symptoms in the last 12 months, asthma, rhinitis, smoking, occupational information, personal and family history of allergic diseases, job title, job tasks, job duration per week, products produced, use of personal protective devices and exposure to different flour and flour ingredients.

3.5 Data collection

Data were collected from the period of August 2015 to July 2016. Approximately 35-45 minutes was required for each participant. All study procedures took place in a room or space provided by the company. Once informed written consent was provided by workers, data were collected in response to the questions in the questionnaire (appendix VII). Skin prick tests and spirometry test were subsequently performed.

3.6 Assessment of sensitization

Skin prick tests were applied to the volar aspect of each participants' forearm. Skin prick tests included common environmental allergens. These were mixed grass pollens (Kentucky Blue/June grass pollen, Orchard grass pollen, Redtop grass pollen, Sweet Vernal grass pollen, Timothy grass pollen), mold mix (Altenarius, Aspergillus, Hormodendrum herbarum, Penicillin), mite mix (Dermatophagoides pteronyssinus, Dermatophagoides farinae), tree mix (Alder, Ash, Birch, Elm, Maple, Oak, Hickory, Poplar and Sycamore), dog and cat. Workplace specific antigens tested included wheat, rye, barley, soybean, maize, oat, buckwheat, egg, Aspergillus and baker's yeast. Negative and positive controls were also applied. Positive control was histamine dihydrogen chloride and negative control was 1% glycerinated saline solution. Skin test solution was applied to the skin from a Dipwell tray using a Duotip test needle which was a plastic bifurcated needle. Skin prick tests were read 10-15 minutes after application and their longest diameters as well as the diameter at right angles using a ruler were measured. A skin test was considered positive if it had a mean wheal diameter of $\geq$ 3mm. Participants were given a copy of their results after the testing. Testing positive to the common environmental allergens via skin prick tests was used as a measure of atopic status.

Sensitization to work related allergens was defined as a 3mm or greater wheal following skin prick testing to one or more bakery related allergens listed above.

3.7 Assessment of exposure to flour

The details collected on the questionnaire along with the job-task-product exposure matrix developed from the systematic review of exposure as part of this project were used to estimate a number of bakery exposure metrics that could be compared with health outcomes. These comprised:

- Duration of exposure/Total bakery years worked. The total bakery years worked was calculated in an Excel spreadsheet using the date of interview as the last day of work in respect of this study. The number of days was derived using simple subtraction of the first date of work and the last day of work in that job. The total number of days worked in a bakery job was then derived by simple addition of the various bakery jobs. The total bakery days was then divided by 365.25 days (assuming 365.25 days in a year) to get the total bakery years or duration of exposure.
- Cumulative exposure. Cumulative exposure was calculated using the job exposure matrix from project 1 in this thesis which gave GM exposures based on job tasks and products produced. Cumulative exposure was calculated by multiplying GM exposure by the number of years worked in each job. Information on other jobs not bakery related was excluded from the cumulative job exposure calculations. Cumulative job exposure was derived from exposures in jobs 1 to 6. No one had more than 6 bakery jobs. This is similar to Brisman et al. (123) and Jacobs et al. (124).
- Average exposure. The average exposure was generated by dividing the cumulative exposure by the duration of job exposure.
- Maximum exposure. The maximum exposure was identified from the job tasks with the highest exposure from the bakery jobs 1 to 6.

These metrics were available for inhalable dust, as well as for wheat allergen and fungal α-amylase, although the data were less complete for the latter two. In the application of the JEM, the empty cells were represented by the n-weighted GM of the task group. For example, there was no GM for confectioner producing mixed products in the inhalable dust exposure. Since the average for the confectioner was 0.83, this GM was used for confectioner producing mixed products. In the fungal alpha-amylase table, there was no exposure measure for the cleaner/maintenance. The lowest value of 0.1 compared to the other means was assigned to it.

3.8 Statistical Analysis

Answers from the questionnaires were extracted onto coding sheets and converted to text files. The text files were inputted into SPSS (Statistical Package for Social Science). Several lines of syntax were written to make the test file readable in SPSS which was used in data analysis.
Prevalence of the skin prick tests outcomes were calculated. The results of the skin prick tests were then cross tabulated against the various exposure metrics to validate the utility of the job/task exposure matrix in estimating exposure. Differences between categorical variables were tested for significance. Non-parametric tests were used to test for the significance of median. Chi-square tests were performed for categorical variables. The associations between sensitization to bakery allergens, and the various exposure metrics including duration of job exposure, cumulative job exposure, average job exposure and maximum task exposure were examined among bakers by logistic regression analyses. Analyses were adjusted for age, gender, smoking status, family history of allergy and atopy. All tests were two-sided, p values ≤ 0.05 were considered to be statistically significant, as well as odds ratios with 95% confidence intervals that excluded 1.0. All statistical analyses were completed in Microsoft Excel (2010) or SPSS (SPSS v. 24, Chicago, IL, USA).

3.9 Ethical consideration

Ethical approval was sought from the Health Research Ethics board -Health Panel at the University of Alberta under the project titled; Flour exposure, sensitization and respiratory health among Alberta bakers. Approval was given on April 16, 2015. The project ID was RES0024908.

3.10 Results

Baseline characteristics

A total of 57 bakery workers from eight different baking establishments were recruited. The majority of the establishments taking part were small (7/8) with 10 or less bakers working there. One was a medium size establishment with 49 workers available to participate. The participation rate in the small bakeries was difficult to estimate accurately as many included among their staff family members or friends who would help out when needed. Of those who were on the premises on the day of testing, participation was over 90%. In the medium size bakery, the participation rate was 43%.

For the 57 bakery employees surveyed, the average time working in the baking industry for the whole group was 15 years. 26 bakers had previously had a period of employment in the bakery with an average job duration of 6.7 years. 15 had three previous employment in the bakery with average job duration of 5.2 years. 7 participants had four previous bakery employment with average job duration of 6.5 years. 3 had five previous bakery employment with average duration of 2.9 years whilst only 1 had six previous bakery employment with 8 years working in the bakery. Participants had a wide range of experience of working in a bakery, from less than a year to 54 years.

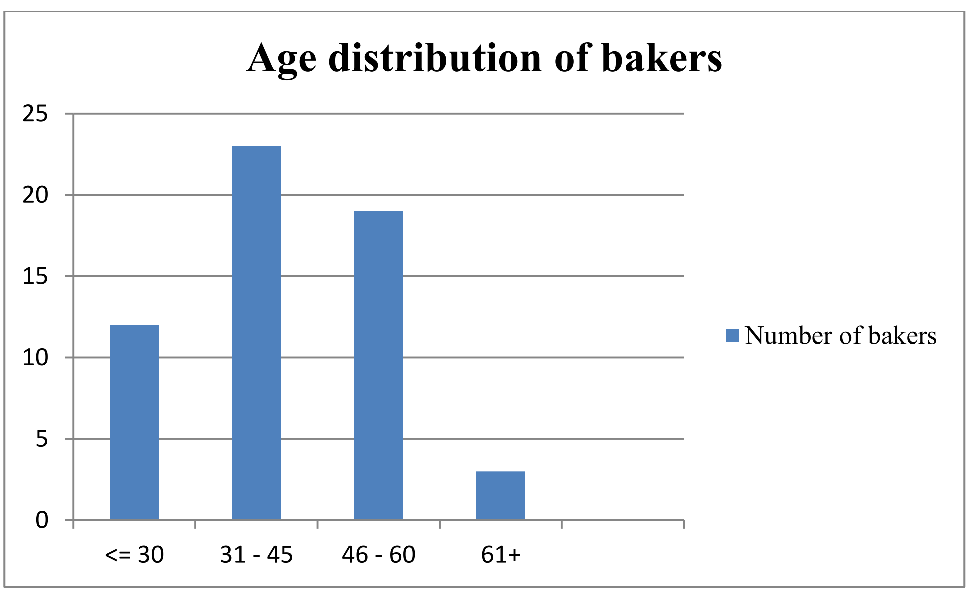

Figure 3-1 Age distribution of the bakers

The age distribution of participants is shown in figure 3-1. The mean age of bakers was 41 (± 14.2) years. Age ranged from 16 years to 86 years. The age distribution of 31 to 45 years accounted for the majority, 40% with the 45 to 60-year group about 33%

The characteristics of the participants are shown in Table 3.1. Two thirds of participants were males. Twelve of the 57 were current smokers. For those 12 workers who smoked, the mean age for starting to smoke was 18.5 ± 3.2 years. Most of the workers were married or living as married (61.4%) compared to those who were single. Most (96.5%) of the workers attained basic high school certificate or level of education with 56.1 % attending high school outside of North America. Most of the workers (82.5%) claimed they were in good health but 38.6% were taking prescribed medications.

Table 3-1 Baseline characteristics of bakery workers

Baker's Characteristics	Frequency	Percentage (%)
Gender		
Females	19	33.3
Males	38	66.7
Marital Status		
Single/separated/widowed/divorced	22	38.6
Married/living as married	35	61.4
Attended High school		
Yes	55	96.5
No	2	3.5
Highest Grade Completed in North America		
Grade 12	20	35.1
< Grade 12	5	8.8
Not Applicable	32	56.1
Enjoying Good Health		
Yes	47	82.5
No	10	17.5
Taking any medications		
Yes	22	38.6
No	35	61.4
Smoking		
Smokers	12	21.1
Non-smokers	45	78.9
Family History of Allergy		
Any Family History	25	43.9
No Family History	32	56.1
Atopic Status		
Atopic	21	36.8
Non-atopic	36	63.2
	Mean (Years)	**SD**
Age	41.4	± 14.2
Duration of bakery exposure	15.1	± 12.9

Twenty-one (21) workers tested positive to common allergens such as mites, trees, grass, cats and dogs and were described as being atopic. (14 tested positive to grass, 5 to mold, 13 to mites, 6 to trees, 5 to dogs and 10 to cats). Thus, 63% of workers were not atopic. Five individuals had a positive skin prick tests to wheat, rye or barley, although it was not the same five individuals for each. The skin prick test with the greatest frequency of positive results was oats and at least one individual had a positive reaction to each of the allergens tested. Overall, 10 participants (18%) reacted to one or more of the bakery specific allergens. The prevalence of positive results to each of the skin prick test is shown in table 3.2.

Table 3-2 Prevalence of skin prick tests

Condition (N=57)	Number	%
+ve[3] skin test wheat	5	9%
+ve skin test rye	5	9%
+ve skin test barley	5	9%
+ve skin test soya bean	4	7%
+ve skin test maize	4	7%
+ve skin test oats	6	11%
+ve skin test buckwheat	4	7%
+ve skin test egg	2	4%
+ve skin test aspergillus	3	5%
+ve skin test bakers' yeast	3	5%
+ve skin test any bakery allergen	10	18%

Table 3.3 shows a comparison of skin test results to potential confounders namely age, gender, smoking status, family history of allergy and atopic status. There were no significant differences between the median ages for those who tested positive for any of the bakery allergens compared to those who tested negative, using a Mann-Whitney test at a significant level of $p< 0.05$.

[3] +ve implies positive skin prick test

Comparison of the significance of the other parameters could not be done using a Pearson Chi-square test result because the cell count for majority of them was less than 5. The Fisher Exact test was therefore used to test for significance. There was a significant association between skin test results to bakery antigens and atopy at $p<0.05$. Significant differences were noted between skin test positivity (STP) to wheat, barley, soy, maize, oat, buckwheat, egg and testing positive to any bakery allergen.

Table 3.4 shows results from a cross tabulation of skin prick test for the bakery associated allergens against the different measures of exposure to inhalable bakery dust: duration of exposure, average exposure, maximum exposure, and cumulative exposure. Exposure was significant for those with a positive skin test to 'any one or more antigen' for all except the average measure of exposure. The difference in the median was tested for significance using the Mann-Whitney test. For duration of bakery exposure, significant association was found for rye and any bakery allergen. For average exposure, significant association was found for buckwheat. For maximum exposure, a significant association was found for any bakery allergen whiles for cumulative exposure, significant association was found for rye, buckwheat and any bakery allergen.

Table 3.5 shows a similar cross tabulation for wheat allergen and Table 3.6 shows the cross tabulation for fungal alpha-amylase. Note that the duration of bakery exposure was the same for inhalable dust, wheat allergen and fungal alpha-amylase. The difference was significant for rye and for any bakery allergen with respect to cumulative exposure for wheat allergen. For average exposure, the difference was significant for buckwheat. For fungal alpha-amylase, none of the exposures were significantly associated with any of the metrics of exposure to bakery allergen except duration, which as noted above was actually the same comparison as in the prior two tables.

Table 3-3 Comparison of skin prick test results to various confounders

		Age of bakers			Gender		Smoking Status		Family history of allergy		Atopic status	
		Median	*Minimum*	*Maximum*	*females*	*males*	*Smoker*	*Non-Smoker*	*No family history*	*Any family history*	*Non-Atopic*	*Atopic*
Wheat	Neg	41	16	86	18	34	11	41	25	27	35	17
	Pos	47	38	52	1	4	1	4	1	4	1	4**
Rye	Neg	40	16	86	18	34	11	41	25	27	34	18
	Pos	48	38	53	1	4	1	4	1	4	2	3
Barley	Neg	41	16	86	18	34	11	41	25	27	35	17
	Pos	47	35	52	1	4	1	4	1	4	1	4**
Soy	Neg	41	16	86	18	35	11	42	25	28	36	17
	Pos	43	35	47	1	3	1	3	1	3	0	4**
Maize	Neg	41	16	86	18	35	11	42	25	28	36	17
	Pos	43	35	47	1	3	1	3	1	3	0	4**
Oat	Neg	41	16	86	18	33	11	40	23	28	36	15
	Pos	43	35	55	1	5	1	5	3	3	0	6**
Buckwheat	Neg	40	16	86	19	34	11	42	26	27	36	17
	Pos	46	39	52	0	4	1	3	0	4	0	4**
Egg	Neg	41	16	86	19	36	11	44	26	29	36	19
	Pos	46	39	52	0	2	1	1	0	2	0	2**
Aspergillus	Neg	41	16	86	19	35	11	43	26	28	36	18
	Pos	47	39	52	0	3	1	2	0	3	0	3
Baker's Yeast	Neg	41	16	86	19	35	10	44	26	28	35	19
	Pos	52	39	53	0	3	2	1	0	3	1	2
Any one or more	Neg	38	16	86	18	29	10	37	23	24	34	13
	Pos	47	35	55	1	9	2	8	3	7	2	8**

**significant at a $p<0.05$ using the Fisher Exact test for the chi square test and the Mann-Whitney test for the median age. Neg- Negative. Pos-Positive

Table 3-4 Comparison of exposure, using different metrics of inhalable dust between those with and without positive skin prick tests to different bakery allergens

Allergen	negative	positive	negative	positive	negative	positive	negative	positive
	Duration of Bakery Exposure: median (min-max) years		Average Exposure: median (min-max) mg/m^3		Maximum Exposure: median (min-max) mg/m^3		Cumulative Exposure: median (min-max) mg/m^3/years	
Wheat	10(0.1-53.7)	21.6(16.5-29.8)	1.4(0.4-3.7)	1.1(0.8-1.7)	9.4(2.4-35.8)	12.3(3.4-19.0)	14(0-117)	26(16-37)
Rye	**10(0.1-53.7)**	**25(16.5-38.4)***	1.4(0.4-3.7)	1.2(0.9-3.0)	9.4(2.4-35.8)	13.8(3.4-19.0)	**14(0-79)**	**28(20-117)***[4]
Barley	10.2(0.1-53.7)	21.6(3.7-29.8)	1.4(0.4-3.7)	1.1(0.8-1.7)	9.4(2.4-35.8)	10.9(3.4-13.8)	14(0-117)	26(5-37)
Soybean	10.3(0.1-53.7)	22.3(3.7-27.5)	1.4(0.4-3.7)	1.3(0.8-1.8)	9.4(2.4-35.8)	11.0(10.9-12.3)	14(0-117)	22(5-50)
Maize	10.3(0.1-53.7)	22.3(3.7-27.5)	1.4(0.4-3.7)	1.3(0.8-1.8)	9.4(2.4-35.8)	11.0(10.9-12.3)	14(0-117)	22(5-50)
Oats	10.3(0.1-53.7)	20.5(3.7-38.1)	1.4(0.4-3.7)	1.3(0.8-1.7)	8.4(2.4-35.8)	12.2(10.9-19.0)	14(0-117)	24(5-62)
Buckwheat	10(0.1-53.7)	24.6(19.4-30.4)	**1.4(0.4-3.7)**	**1.7(0.8-1.8)***	9.4(2.4-35.8)	12.4(10.9-15.6)	**14(0-117)**	**44(16-52)***
Egg	10(0.1-53.7)	20.5(19.4-21.6)	1.4(0.4-3.7)	1.3(0.8-1.7)	9.4(2.4-35.8)	12.4(10.9-13.8)	14(0-117)	27(16-38)
Aspergillus spp	10.2(0.1-53.7)	22(19-28)	1.4(0.4-3.7)	1.7(0.8-1.8)	9.4(2.4-35.8)	11.0(10.9-13.8)	14(0-117)	37(16-50)
Baker's yeast	10.2(1-53.7)	21.6(19.4-38.4)	1.4(0.4-3.7)	1.7(0.8-3.0)	9.4(2.4-35.8)	13.8(10.9-18.8)	14(0-79)	37(16-117)
Any one or more	**9.4(0.1-53.7)***	**16.4(3.7-38.4)***	1.4(0.4-3.7)	1.5(0.8-3.0)	**7.8(2.4-35.8)***	**12.2(3.4-19.0)***	**12(0-79)***	**33(5-117)***

[4] Significant at $p<0.05$ using the Mann-Whitney test. Bold numbers and asterisk indicates significance

Table 3-5 Comparison of exposure using different metrics of wheat allergen between those with and without positive skin prick tests to different bakery allergens

Allergen	negative	positive	negative	positive	negative	positive	negative	positive
	Duration of Bakery Exposure: median (min-max) years		Average Exposure: median (min-max) mg/m^3		Maximum Exposure: median (min-max) mg/m^3		Cumulative Exposure: median (min-max) mg/m^3/years	
Wheat	10(0.1-53.7)	21.6(16.5-29.8)	4.8(0.4-46)	6.5(1.3-26.1)	31.6(0.6-348.5)	111.5(10.6-390.8)	42.5(0.4-1508.2)	175.8(28.6-431.1)
Rye	**10(0.1-53.7)**	**25(16.5-38.4)***	4.0(0.4-47.0)	7.0(1.3-39.3)	31.6(0.6-348.5)	111.5(10.6-390.8)	**42.5(0.4-1004.4)***	**194.6(28.6-1508.2)***
Barley	10.2(0.1-53.7)	21.6(3.7-29.8)	4.8(0.4-47.0)	6.5(1.3-16.4)	31.6(0.6-348.5)	111.5(10.6-130)	42.5(0.4-1508.2)	60.8(28.6-194.6)
Soybean	10.3(0.1-53.7)	22.3(3.7-27.5)	4.1(0.4-47.0)	10.5(3.1-16.4)	27.6(0.6-348.5)	123.6(111.5-130)	40.1(0.4-1508.2)	118.3(59.1-388.9)
Maize	10.3(0.1-53.7)	22.3(3.7-27.5)	4.1(0.4-47.0)	10.5(3.1-16.4)	27.6(0.6-348.5)	123.6(111.5-130)	40.1(0.4-1508.2)	118.3(59.1-388.9)
Oats	10.3(0.1-53.7)	20.5(3.7-38.1)	5.6(0.4-47.0)	5.0(1.3-26.1)	35.5(0.6-348.5)	120.7(9.2-390.8)	40.1(0.4-1508.2)	60.0(28.6-431.1)
Buckwheat	10(0.1-53.7)	24.6(19.4-30.4)	**5.7(0.4-47.0)**	**2.2(0.4-47.0)***	36(0.6-390.8)	64.5(0.6-390.8)	48(0.4-1508.2)	49.6(28.6-388.9)
Egg	10(0.1-53.7)	20.5(19.4-21.6)	5.7(0.4-47.0)	2.2(1.3-3.05)	36(0.6-390.8)	64.5(10.6-390.8)	48(0.4-1508.2)	43.8(59.1-59.1)
Aspergillus spp	10.2(0.1-53.7)	22(19-28)	5.7(0.4-47.0)	3.1(1.3-14.1)	36(0.6-390.8)	117.2(10.6-130)	46.2(0.4-1508.2)	59.1(28.6-388.9)
Bakers yeast	10.2(1-53.7)	21.6(19.4-38.4)	5.7(0.4-47.0)	4.1(1.3-39.1)	36(0.6-390.8)	130(10.6-348.5)	46.2(0.4-1508.2)	59.1(28.6-1508.2)
Any one or more	**9.4(0.1-53.7)***	**16.4(3.7-38.4)***	4.1(0.4-47.0)	6.8(1.3-39.3)	27.6(0.6-348.5)	114.3(9.2-390.8)	**37(0.4-1004.4)***	**118.3(28.6-1508.2)***

Table 3-6 Comparison of exposure using different metrics of fungal alpha-amylase between those with and without positive skin prick test to bakery allergens

Allergen	negative	positive	negative	positive	negative	positive	negative	positive
	Duration of Bakery Exposure: median (min-max) years		Average Exposure: median (min-max) mg/m^3		Maximum Exposure: median (min-max) g/m^3		Cumulative Exposure: median (min-max) (mg/m^3/years)	
Wheat	10(0.1-53.7)	21.6(16.5-29.8)	0.4(0.1-19.6)	0.3(0.1-0.8)	3.8(0.4-129.3)	4.6(0.8-6.3)	4.0(0.0-295.7)	7.0(2.2-17.1)
Rye	**10(0.1-53.7)**	**25(16.5-38.4)***	0.4(0.1-19.6)	0.4(0.2-2.6)	3.6(0.4-129.3)	4.8(1.0-15.9)	3.8(0.0-295.7)	7.7(5.2-97.7)
Barley	10.2(0.1-53.7)	21.6(3.7-29.8)	0.4(0.1-19.6)	0.3(0.1-0.8)	4.3(0.4-129.3)	3.2(0.8-4.8)	4.2(0.0-295.7)	5.2(1.5-17.1)
Soybean	10.3(0.1-53.7)	22.3(3.7-27.5)	0.4(0.1-19.6)	0.4(0.1-7.7)	4.0(0.4-129.3)	4.0(0.8-129.3)	4.2(0.0-295.7)	5.0(1.5-208.2)
Maize	10.3(0.1-53.7)	22.3(3.7-27.5)	0.4(0.1-19.6)	1.3(0.8-1.8)	4.0(0.4-129.3)	4.0(0.8-129.3)	4.2(0.0-295.7)	5.0(1.5-208.2)
Oats	10.3(0.1-53.7)	20.5(3.7-38.1)	0.4(0.1-19.6)	1.3(0.8-1.7)	3.6(0.4-129.3)	4.3(0.8-6.3)	4.2(0.0-295.7)	7.3(1.5-18.0)
Buckwheat	10(0.1-53.7)	24.6(19.4-30.4)	0.4(0.1-19.6)	0.7(0.1-7.7)	3.6(0.4-129.3)	4.9(0.8-129.3)	4.2(0.0-295.7)	16(2.2-208.2)
Egg	10(0.1-53.7)	20.5(19.4-21.6)	0.4(0.1-19.6)	0.5(0.1-0.8)	4.0(0.4-129.3))	12.4(10.9-13.8)	4.2(0.0-295.7)	9.7(2.2-17.1)
Aspergillus spp	10.2(0.1-53.7)	22(19-28)	0.4(0.1-19.6)	1.7(0.8-1.8)	3.8(0.4-129.3)	4.6(0.8-129.3)	4.2(0.0-295.7)	17.1(2.2-208.2)
Bakers yeast	10.2(1-53.7)	21.6(19.4-38.4)	0.4(0.1-19.6)	0.8(0.1-2.6)	3.8(0.4-129.3)	4.6(0.8-15.9)	4.2(0.2-295.7)	17.1(2.2-97.7)
Any one or more	**9.4(0.1-53.7)***	**16.4(3.7-38.4)***	0.4(0.1-19.6)	0.5(0.1-7.6)	3.6(0.4-129.3)	4.7(0.8-129.3)	3.8(0.0-295.7)	12(1.5-208.7)

Regression analysis: A univariate logistic regression analysis was undertaken to identify associations between having one or more positive skin prick test to bakery allergens and the different exposure metrics and potential confounders. Although some of these including age, gender, smoking and family history did not show a significant association, they were included in the multiple logistic regression models since they were considered biologically important and notable confounders.

Table 3-7 Association between exposure to inhalable dust, covariates and testing positive or negative to any bakery allergen

Variable	OR (95% CI)	p-value
Age	1.03 (0.98 – 1.08)	0.28
Gender Female Male	5.59 (0.65 – 47.86)	0.12
Marriage Married/living as married Single/separated/widowed/divorced	0.27 (0.57 – 15.49)	0.20
Smoking status Smoker Non-Smoker	1.08 (0.20 – 5.92)	0.93
Family History (Hx) of allergy No family Hx Any family Hx	2.24 (0.52 – 9.71)	0.28
Atopic Status Non-Atopic Atopic	10.46 (1.96 – 55.92)	**0.006***
Duration of bakery exposure	1.08 (1.02 – 1.08)	**0.01***
Cumulative bakery exposure	1.04 (1.01 – 1.08)	**0.02***
Average bakery job exposure	1.32 (0.46 – 3.78)	0.61
Maximum bakery job exposure	1.09 (0.98 – 1.21)	0.13

*Significant level p<0.05 OR-Odds Ratio CI- confidence interval

Age and duration of bakery exposure were noted to be correlated with a Pearson correlation coefficient of 0.69 (p-value 0.00) but it was still decided to keep both in the models calculated and shown below. Atopic status and family history of allergy was weakly correlated with Pearson correlation coefficient of 0.12 (p-value 0.38)

The tables below show the OR for the covariates in the adjusted model for inhalable flour dust (Table 3.8), wheat allergen (Table 3.9) and fungal alpha-amylase (Table 3.10). Atopy seemed to make a significant contribution to the likelihood of testing positive to any bakery allergen in the adjusted models. This is true for all the bakery exposure variables (duration of bakery exposure, average bakery job exposure, maximum bakery job exposure, cumulative bakery exposure). For wheat allergen, average exposure and cumulative exposure showed some significant ORs with age and gender.

Table 3-8 Logistic regression models showing OR for covariates and exposure metrics for inhalable dust with positive skin prick positive for any bakery allergen

Exposure metric – inhalable bakery dust	Duration of Bakery Exposure: (years)		Average Exposure: (mg/m^3)		Maximum Exposure: (mg/m^3)		Cumulative Exposure: (mg/m^3/yrs)	
	OR	**95%CI**	**OR**	**95%CI**	**OR**	**95%CI**	**OR**	**95%CI**
Age	0.92	0.80-1.06	1.08	0.99-1.16	1.08	0.99-1.17	1.02	0.93-1.12
Gender	3.01	0.16-57.01	11.35	0.72-178.61	10.62	0.61-184.28	4.80	0.27-86.87
Atopy	**40.77**	**2.67-624.85***	**14.11**	**1.83-108.83***	**15.48**	**1.86-128.63***	**32.01**	**2.33-440.26***
Family history	1.23	0.15-10.31	2.99	0.47-18.95	3.02	0.44-20.78	1.77	0.22-14.58
Non-smoker	3.15	0.32-30.82	3.61	0.38-34.07	2.73	0.29-25.47	4.38	0.35-55.14
Exposure	**1.22**	**1.03-1.45***	1.81	0.44-7.42	1.12	0.97-1.29	**1.06**	**1.01-1.10***

*Significance at p-value <0.05

Table 3-9 Logistic regression models showing OR for covariates and exposure metrics of wheat allergen

Exposure metric – wheat allergen	**Duration of Bakery Exposure: (years)**		**Average Exposure: (mg/m^3)**		**Maximum Exposure: (mg/m^3)**		**Cumulative Exposure: ($mg/m^3/yrs$)**	
	OR	**95%CI**	**OR**	**95%CI**	**OR**	**95%CI**	**OR**	**95%CI**
Age	0.92	0.80-1.06	**1.09**	**1.0-1.19***	**1.11**	**1.00-1.22***	1.01	0.98-1.17
Gender	3.01	0.16-57.01	13.28	0.74-239.29	**21.87**	**1.03-465.05***	11.04	0.58-210.56
Atopy	**40.77**	**2.67-624.85***	**16.82**	**1.94-146.08***	**18.33**	**1.85-181.82***	**30.41**	**2.35-393.84***
Family history	1.23	0.15-10.31	4.02	0.56-28.94	3.94	0.49-31.87	2.74	0.37-20.22
Non-smoker	3.15	0.32-30.82	5.43	0.48-61.45	8.35	0.61-115.03	9.08	0.58-142.67
Exposure	**1.22**	**1.03-1.45***	1.07	0.98-1.17	**1.01**	**1.00-1.02***	**1.00**	**1.00-1.01***

*Significance at p-value <0.05

Table 3-10 Logistic regression models showing OR for covariates and exposure metrics for fungal alpha-amylase

Exposure metric – Fungal alpha-amylase	**Duration of Bakery Exposure: (years)**		**Average Exposure: (mg/m^3)**		**Maximum Exposure: (mg/m^3)**		**Cumulative Exposure: (mg/m^3/yrs)**	
	OR	**95%CI**	**OR**	**95%CI**	**OR**	**95%CI**	**OR**	**95%CI**
Age	0.92	0.80-1.06	1.07	0.99-1.15	1.07	0.99-1.15	1.06	0.98-1.16
Gender	3.01	0.16-57.01	13.38	0.88-204.14	12.94	0.84-200.34	11.20	0.67-186.38
Atopy	**40.77**	**2.67-624.85***	**11.94**	**1.74-81.85***	**12.05**	**1.73-83.74***	**12.33**	**1.73-16.72***
Family history	1.23	0.15-10.31	2.50	0.41-15.33	2.69	0.45-16.17	2.77	0.46-16.72
Non-smoker	3.15	0.32-30.82	3.70	0.41-33.59	3.65	0.39-34.10	3.51	0.38-32.48
Exposure	**1.22**	**1.03-1.45***	0.93	0.69-1.26	1.00	0.97-1.02	1.00	0.99-1.02

*Significance at p-value <0.05

Table 3.11 to Table 3.13 show the ORs for each of the exposure metrics for each exposure estimated using multivariate logistic regression models (duration of bakery exposure, average bakery job exposure, maximum bakery job exposure, cumulative bakery exposure) and the outcome of testing positive compared with testing negative to any bakery allergen. These have been estimated initially without covariates included (left hand column) and then with all covariates included (right hand column) adjusted for covariates (age, gender, smoking, family history and atopy). These models have been estimated for inhalable dust (Table 3.11), wheat allergen (Table 3.12) and fungal alpha-amylase (Table 3.13).

For exposure to inhalable dust, the odds of testing positive to any bakery allergen increased significantly with duration of bakery exposure (OR 1.08, p-value 0.01 95%, CI- 1.02-1.14) and for cumulative exposure (OR 1.04, p-value 0.02, 95% CI-1.01-1.07). After adjusting for age, gender, smoking, family history of allergy and atopy, duration of bakery exposure (OR 1.22, p-value 0.02 95%, CI- 1.03- 1.45) and cumulative exposure (OR 1.06, p-value 0.02, 95% CI 1.01-1.10) were still found to be significant.

For wheat allergen exposure, the odds of testing positive to any bakery allergen increased slightly with maximum exposure (OR 1.01, p-value 0.07 95%, CI- 1.00-1.01) in the unadjusted model. Though there was no increase in the OR in the adjusted model, maximum exposure was still found to be significant (OR 1.01, p-value 0.04 95%CI-1.00-1.02) for wheat allergen. The odds of the duration of bakery exposure remained the same in the wheat allergen and fungal alpha-amylase models.

There was no change in the odds of testing positive for maximum exposure and cumulative exposure of fungal alpha-amylase for bakers who participated in the study. There was however a marginally and insignificant decreased odds (OR 0.93, p-value 0.64 95% CI 0.69-1.26) with average exposure after adjusting for age, gender, smoking, family history of allergy and atopy. Overall there was no change in the odds for average exposure in the inhalable dust, wheat allergen and fungal alpha-amylase models. An OR of 1 was not considered as significant irrespective of the p-value since essentially there was no change in odds.

Table 3-11 Logistic regression analysis for association between testing positive for any bakery allergen and different exposure metrics for inhalable dust

	Bakery Allergen PN Test			
Exposure metric – inhalable bakery dust	**Unadjusted Model OR (95% CI)**	**p-value**	**Adjusted Model*** OR (95% CI)**	**p-value**
Duration of Bakery Exposure	1.08 (1.02-1.14)	0.01*	1.22 (1.03-1.45)	0.02*
Average Exposure	1.32 (0.46-3.78)	0.61	1.81 (0.44-7.42)	0.41
Maximum Exposure	1.09 (0.98-1.21)	0.31	1.12 (0.97-1.21)	0.13
Cumulative Exposure	1.04 (1.01-1.07)	0.02*	1.06 (1.01-1.10)	0.02*

***Adjusted for age, gender, smoking, family history and atopy. *Significant level p<0.05

Table 3-12 Logistic regression analysis for association between testing positive to any bakery allergen and different exposure metrics for wheat allergen

	Bakery Allergen PN Test			
Exposure metric – wheat allergen	**Unadjusted Model OR (95% CI)**	**p-value**	**Adjusted Model*** OR (95% CI)**	**p-value**
Duration of Bakery Exposure	1.08 (1.02-1.14)	0.01*	1.22 (1.03-1.45)	0.02*
Average Exposure	1.03 (0.97-1.10)	0.29	1.07 (0.98-1.17)	0.11
Maximum Exposure	1.01 (1.00-1.01)	0.07*	1.01 (1.00-1.02)	0.04*
Cumulative Exposure	1.00 (1.00-1.01)	0.09	1.00 (1.00-1.01)	0.03

***Adjusted for age, gender, smoking, family history and atopy. *Significant level p<0.05

Table 3-13 Logistic regression analysis for association between testing positive to any bakery allergen and exposure metrics of fungal alpha-amylase

	Bakery Allergen PN Test			
Exposure metric – fungal alpha-amylase	**Unadjusted Model OR (95% CI)**	**p-value**	**Adjusted Model*** OR (95% CI)**	**p-value**
Duration of Bakery Exposure	1.08 (1.02-1.14)	0.01*	1.22 (1.03-1.45)	0.02*
Average Exposure	0.98 (0.78-1.24)	0.85	0.93 (0.69-1.26)	0.64
Maximum Exposure	1.00 (0.98-1.03)	0.70	1.00 (0.97-1.02)	0.84
Cumulative Exposure	1.00 (1.00-1.02)	0.32	1.00 (0.99-1.02)	0.81

***Adjusted for age, gender, smoking, family history and atopy. *Significant level p<0.05

3.11 Comments on cross sectional study

There were more males than females among the bakers included in this study. The biggest proportion of bakery workers were in the age group (31-45) with fewer in other age groups. For bakery participants in the study, more than half didn't attend high school in North America which might suggest a significant immigrant population in the bakery trade. Almost 44% of the bakery workers had a family history of allergy. The prevalence of atopy among the bakers was 37%. Among those who were atopic, the largest proportion had positive skin tests to grass and dust mites. The prevalence rate of sensitivity to any bakery allergens was 18% but more participants were sensitive to oats (11%). There was a significant difference in the median exposure to inhalable dust for those bakers who tested positive for rye, buckwheat and for any bakery allergen compared to those who tested negative. Duration of bakery exposure, cumulative exposure and to a lesser extent maximum exposure, seem to be relevant determinants of sensitivity to any bakery allergen. Atopic status seems to significantly increase the odds of testing positive for any bakery allergen with respect to inhalable flour dust, wheat allergen and fungal alpha-amylase. Smoking did not increase the odds and was not independently related to a positive skin test.

3.12 Discussion of findings of Cross sectional study

Prevalence of STP to any bakery allergens (18%) was considerably lower in bakery workers in this study compared to Baatjies et al. (125) in her cross-sectional study of bakers who noted that the overall prevalence of sensitization to any of the bakery allergens was 33%. The most common sensitizers on skin prick test she noted were cereal flours wheat (16%) and rye (16%). In our study, the common sensitizers were oat (11%), wheat (9%) and rye (9%). Though her results were reported a higher prevalence than what we found in our study, this could be due to a number of factors such as geographical location, types of flour used by bakers in our study. Baatjies studied 517 workers while we studied only 57. Our results is however similar to Houba et al. who tested 178 bakery workers and found that 15% had a positive skin test to one or more occupational allergens, 8% to wheat flour, and 5% rye flour. (72)

Atopy has by far been noted to be the most important risk factor for sensitization to workplace allergens. Baatjies et al. found a level of atopy of 42%. De Zotti et al. (126) also noted that skin sensitization to occupational allergens was significantly associated with atopy. From previously published papers (60), atopy appears to be a very strong determinant for sensitization to flour allergens with reported odds ratios (OR) for atopy ranging from 5.1 to 20.8. In our study of bakers, the prevalence of atopy was 37% which was quite high. A significant contribution of atopy was noted in this thesis as well since the OR was significantly high in the models ranging from 11 to 41. According to Norman, (61) bakers who are atopic have increased capability of producing IgE antibody to common allergens, hence would easily become more sensitized to allergens known to cause an IgE-mediated allergy as in bakers.

Houba et al. (22) studied a population of 393 bakery workers and found a strong and positive association between wheat flour allergen exposure and wheat flour specific sensitization but this association was much stronger in atopics. In this study, the prevalence positive skin prick test to wheat flour was low compared to some others and the OR for the exposure metrics was only marginally significant. Houba et al. reported that a subgroup of 169 workers also showed a strong and positive association between allergen exposure levels and fungal alpha-amylase specific sensitization.

Jacobs et al. (67) noted that the average and cumulative exposure were significantly associated with wheat sensitization, work-related respiratory symptoms and asthma in atopic workers. Our study showed that duration of bakery job and cumulative exposures may affect the likelihood of being sensitized to any bakery allergen.

In a review by Houba et al. (60) he noted that age and gender have not been shown to be associated with sensitization among bakery workers. Our study noted that age and gender showed significance in testing positive with respect to average exposure and maximum exposure only for wheat allergen.

Our study did not show a significance between smoking or family history of allergy to the development of skin test positivity. Harris- Roberts et al. (127) noted that current smoking (OR 4.7, 1.1–20.8) was a significant risk factor for sensitization to wheat flour but this study did not find such similarity. De Zotti also noted that skin sensitization to occupational allergens was significantly associated with smoking habit in Italy. Other studies by Baatjies and Houba did not find a significant association with smoking.

Chapter 4 **: OVERALL DISCUSSION AND CONCLUSION**

4.1 Overall discussion of the study

This study essentially led to the creation of three (3) JEM's. They were for inhalable flour dust, wheat allergen and fungal alpha-amylase. These flourJEM will help in the job delineation in the bakery industry. It was shown clearly in the papers published that there was no standard classification of bakery job/tasks. Hopefully these 9 bakery tasks identified in this JEM would have captured all the various tasks in the bakery, particularly in an industrial bakery. This could help in identifying job tasks which have high exposures and so help target remediating efforts at such jobs/tasks. As resources are limited, management could prioritize which areas to direct resources to decrease exposures in the bakery.

The JEM for inhalable dust, wheat allergen and fungal amylase can be used as a guide when setting up of occupational exposure limits for wheat allergen and fungal alpha amylase.

The JEM was applied to a number of bakers in Alberta. This showed that with the exposure measurements noted with the JEM, the odds of testing positive to bakery allergens increased significantly with duration of bakery exposure for inhalable dust, wheat allergen and fungal alpha amylase. Thus, the longer a baker is exposed in the bakery, the more likely he/she will become sensitive to bakery allergens. As has been noted, this could be modified by atopic status of the baker. The relatively low odds ratio could be a reflection of the low power of the study from the small sample size of 57 bakers.

The JEM might be useful for future study especially in estimating dose/exposure in epidemiological studies. The JEM presumably can be used to try to define a safe level of exposure – i.e. a threshold, for whatever health outcome is studied.

The majority of the exposures in the JEM for inhalable flour dust exceed the current Alberta OEL of 0.5 mg/m^3. The data previously reported in the Golder study shows that setting the OEL at this level may be difficult to achieve and much needs to be done in Alberta bakeries to reduce exposure. However, if we were to use the JEM to estimate exposure in a study of bakery workers, every oven worker/baker, weigher/mixer, and dough former will inevitable have exposure exceeding the current OEL and so would be considered at risk of developing symptoms. Consequently, it would be difficult to use such data to argue for a decrease in the OEL, although if these groups had no health effect the data could be used to argue for an increase in the OEL. The packer/shipper and other production groups in the bakery and confectionery have exposures below the Alberta OEL. Further study of this group will be needed to estimate or define a 'No observed adverse effect level' (NOAEL) which is what is needed to set an OEL.

This JEM may be useful in making an argument about increasing or not increasing the OEL. Further measurement of exposure in Alberta bakeries might be needed to understand the extent of exposures in Alberta bakeries.

4.2 Limitations of the study

The number of workers surveyed for the validation component of the thesis was fairly small. This small sample size has the potential to decrease the power of the analyses, and could have led to errors in identifying associations between metrics of exposure and sensitization. In fact, an association was identified between cumulative exposure, estimated utilizing the JEM, and sensitization, suggesting that in this case the low numbers were not a major problem. Some other associations between exposure metrics and sensitization may however have been missed, but the fact the cumulative exposure metric to inhalable dust does come up as positively associated with the health outcome suggests at least a stronger association with this metric if this were the case.

One major limitation of using task group to define exposure may be classification of job/task groups. There could have been misclassification of job/tasks, since the classifications were defined according to our interests and not to follow any standardized classification system. This could underestimate or overestimate the results. (128) (129). Within bakeries, especially in small bakeries, workers usually move from task to task during a single shift. This phenomenon however, according to Burdoff et al. (119) may not pose large problems in assignment of subjects to exposure groups since job/task groups in the bakery were significantly different in terms of exposure.

Several sampling heads, filters and pore sizes were used in the measurement of airborne particulates. This heterogeneity could affect the accuracy of the JEM. Gorner et al, (130), experimentally tested five inhalable aerosol samplers (IOM, CIP 10-1, 37mm closed face cassette, Accu-cap, and button cap). The results showed fairly high sampling efficiency for the IOM and CIP 10-I v2 samplers and slightly lower efficiencies for the Button and CIP 10-I v1 samplers. The closed face cassette (4-mm orifice) produced the poorest performances of all the tested samplers. However, the relationship between the various sampling heads has not been defined yet and the impact it would have on the JEM cannot be determined. Likewise, the differences in the size of the filters and its impact cannot be determined.

As has been noted by Karpinski (1) and the Golder report (97), the inhalable sampling method appears to introduce a positive bias to results. On average, based on the sampling data, inhalable samplers collected about 2.5 times more particulate than total samplers. The result is that workers would be more likely to be considered overexposed if inhalable sampling methods are used to assess worker exposure to flour dust.

There were no results for some of the exposures in the JEM for inhalable dust, wheat allergen and fungal alpha-amylase. It was decided to use the n-weighted mean to represent empty cells. This could affect the accuracy of the JEM.

4.3 Recommendations

It is recommended that personal dust samples measurements of inhalable flour dust, wheat allergens and fungal amylase be measured in the bakeries that participated in the study.

These measured exposures can be related to the symptoms as well as the lung function capacity of these bakers since a number of studies have shown that exposure to inhalable dust, wheat flour allergens and fungal alpha-amylase can be directly associated with respiratory and work-related symptoms and decreased pulmonary function.

4.4 Conclusion

This study has been able to estimate exposures for various job/tasks in the bakery industry. The job exposure matrix was also used in a validation study to show the likelihood of skin test positivity to bakery allergens using various exposure metrics and other predictors. The JEM is therefore valid and can be used in future epidemiologic studies. Using this JEM could likely lead to high exposure estimates. Also this validation is far from perfect and further work needs to be done on it. It is hoped that the JEM will lead to a discussion by researchers and industry practitioners to standardize the job/tasks in the bakery industry.

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Appendices

Appendix I. Extraction sheet and extracted data for FlourJEM

Reference #
Author (year)
Date of sampling
Sampling Equipment/flow rate
Personal or Area Samples
Type of business
Task
Product
Number of samples
Substance sampled
Geometric Mean (µg/m^3)
Geometric Mean (Standard Deviation)
Arithmetic Mean (µg/m^3)
Arithmetic mean (Standard Deviation)
Median (µg/m^3)
Range (µg/m^3)
Comments

Author (year)	Date of sampling	Sampling Equipment/ flow rate	(P)ersonal or (A)rea	Type of business	Task	Product	Number of samples	Substance sampled	GM (GSD)	AM (SD)	Median (range)	Comments
Baatjies (2010)		PAS 6 Gillian Gil Air Pump 2 L/min Teflon filter	P	18 Supermarket Bakery	Bread baker		112	Total Flour dust particulate	1.33mg/m^3 (2.25)	1.83mg/m^3	(0.25-7.29)	Wheat allergens (rabbit anti-wheat IgG4) Fungal alpha-amylase polyclonal rabbit IgG antibodies Rye allergens (rye seed extract IgE detection) LOD for flour dust is 0.08mg Analysis of bulk samples (two rye flour, eight wheat flour, and 16 premix products) for enzymes
								Wheat allergens	13.66µg/m^3(2.66)	20.67µg/m^3	(1.79-69.65)	
								Rye allergens	5.14µg/m^3 (2.89)	8.24µg/m^3	(0.30-31.08)	
								Fungal Alpha amylase	0.15ng/m^3 (2.32)	0.38ng/m^3	(LOD-19.62)	
					Confectioner		38	Total Flour dust particulate	0.65mg/m^3 (2.08)	0.85mg/m^3	(0.11-3.33)	
								Wheat allergens	5.82µg/m^3(2.25)	7.81µg/m^3	(0.82-30.68)	
								Rye allergens	2.04µg/m^3 (2.41)	2.98µg/m^3	(0.24-12.96)	
								Fungal Alpha amylase	0.12ng/m^3 (2.14)	0.29ng/m^3	(LOD-6.54)	
					Bakery Supervisor		13	Total Flour dust particulate	0.56mg/m^3 (2.05)	0.72mg/m^3	(0.20-2.67)	
								Wheat allergens	4.99µg/m^3 (1.93)	6.18µg/m^3	(2.28-17.79)	
								Rye allergens	1.74µg/m^3 (1.97)	2.16µg/m^3	(0.61-6.84)	
								Fungal Alpha amylase	0.10ng/m^3 (1.17)	0.10ng/m	(LOD-	
					Bakery Manager		13	Total Flour dust particulate	0.51mg/m^3 (2.34)	0.72mg/m^3		
									3.41µg/m^3 (4.01)	7.93µg/m^3		
									1.99µg/m^3 (4.06)	2.52µg/m^3		
									0.12ng/m^3 (1.58)	0.14ng/m^3		

					Counterhand Overall		35 211	Wheat allergens Rye allergens Fungal Alpha amylase Total Flour dust particulate Wheat allergens Rye allergens Fungal Alpha amylase Total Flour dust particulate Wheat allergens Rye allergens Fungal Alpha amylase	0.28mg/m^3 (1.89) 1.16µg/m^3 (4.81) 0.39µg/m^3 (4.57) 0.11ng/m^3 (1.40) 0.81mg/m^3 (2.61) 6.71µg/m^3 (4.09) 2.42µg/m^3 (4.30) 0.13ng/m^3 (2.08)	0.35mg/m^3 2.80µg/m^3 0.98µg/m^3 0.12ng/m^3 1.27mg/m^3 13.71µg/m^3 5.36µg/m^3 0.29ng/m^3	1.17) (0.12-2.48) (0.32-40.28) (0.09-9.32) (LOD-0.51) (0.11-1.96) (0.002-29.86) (LOD-10.92) (LOD-0.64) (0.11-7.29) (0.002-69.65) (LOD-31.08) (LOD-19.62)	showed very low fungal alpha-amylase concentrations (0.75–100 ng mg1) in seven premix products and two rye products and was undetectable in remaining products.

Baatjies (2014) (Pre interventi on/ Baseline)		PAS 6 Gillian Gil Air Pump 2 L/min Teflon filter	P	18 Supermarket Bakeries	Bread Baker Confectioner Baker Supervisor Bakery Manager Counterhand Overall		98 28 9 9 32 176	Inhalable Flour Dust Wheat Allergen Rye Allergen Inhalable Flour Dust Wheat Allergen Rye Allergen Inhalable Flour Dust Wheat Allergen Rye Allergen Inhalable Flour Dust Wheat Allergen Rye Allergen Inhalable Flour Dust Wheat Allergen Rye Allergen	1.39mg/m^3 (2.23) 13.66µg/m^3 (2.76) 5.17ng/m^3 (2.86) 0.73mg/m^3 (1.95) 6.76µg/m^3(1.98) 2.31ng/m^3 (2.19) 0.61mg/m^3 (2.24) 5.34µg/m^3 (1.90) 1.9ng/m^3 (1.83) 0.60mg/m^3 (2.58) 4.91µg/m^3(4.55) 1.75ng/m^3 (4.50) 0.28mg/m^3 (0.91) 1.18µg/m^3 (4.98) 0.40ng/m^3 (4.75) 0.86mg/m^3 (2.64) 7.07µg/m^3 (4.21)	1.89mg/m^3 21.06µg/m^3 8.41ng/m^3 0.94mg/m^3 8.48µg/m^3 3.17ng/m^3 0.82mg/m^3 6.53µg/m^3 2.33ng/m^3 0.87mg/m^3 10.72µg/m^3 3.37ng/m^3 0.36mg/m^3 2.91µg/m^3 1.03ng/m^3 1.35mg/m^3 14.49µg/m^3	(0.25-7.29) (1.79-69.64) (0.30-31.08) (0.29-3.33) (1.71-30.66) (0.53-12.96) (0.20-2.67) (2.33-17.80) (0.88-6.84) (0.12-2.47) (0.32-40.28) (0.10-9.32) (0.11-	paper uses data from Baatjies 2010 and re anylazes the exposure levels after implementatio n of preventive measures

								Inhalable Flour Dust Wheat Allergen Rye Allergen	2.57ng/m^3 (4.43)	5.67ng/m^3	1.95) (0.00-29.85) (0.00-10.92) (0.11-7.29) (0.00-69.64) (0.00-31.08)	
Baatjies (2014) (Post interventi on		PAS 6 Gillian Gil Air Pump 2 L/min Teflon filter	P	15 Supermarket Bakeries	Bread Baker Confectioner Baker Supervisor Bakery		88 87 87 57 56 56 11 11 11 8	Inhalable Flour Dust Wheat Allergen Rye Allergen Inhalable Flour Dust Wheat Allergen Rye Allergen Inhalable Flour Dust Wheat Allergen Rye Allergen	0.74 mg/m^3 (2.16) 7.51 µg/m^3 (2.89) 2.67 ng/m^3 (2.70) 0.41 mg/m^3 (2.06) 2.73 µg/m^3 (3.51) 0.91 ng/m^3 (3.03) 0.23 mg/m^3 (3.43) 1.77 µg/m^3 (3.81) 0.60 ng/m^3 (3.60) 0.20 mg/m^3 (2.80)	0.97 mg/m^3 11.84 µg/m^3 4.27 ng/m^3 0.51 mg/m^3 4.85 µg/m^3 1.54 ng/m^3 0.36 mg/m^3 4.16 µg/m^3 1.22 ng/m^3 0.35 mg/m^3	0.79*(0.04–4.07) 10.03*(0.18-48.56) 3.63*(0.21-29.37) 0.43*(0.05-1.68) 3.50*(0.06-20.49) 1.18*(0.09-6.48) 0.23*(0.01-1.01)	* Represent Geometric Mean corrected for Intervention group

					Manager Counterhand Overall		8 8 44 44 44 208 206 206	Inhalable Flour Dust Wheat Allergen Rye Allergen Inhalable Flour Dust Wheat Allergen Rye Allergen Inhalable Flour Dust Wheat Allergen Rye Allergen	2.25 µg/m^3 (4.12) 0.42(5.86) 0.22 mg/m^3 (2.09) 0.79 µg/m^3 (2.86) 0.23 ng/m^3 (2.51) 0.43 mg/m^3 (2.56) 3.12 µg/m^3 (4.17) 1.01 ng/m^3 (4.17)	5.48 µg/m^3 1.62 ng/m^3 0.29 mg/m^3 1.32 µg/m^3 0.36 ng/m^3 0.64 mg/m^3 7.04 µg/m^3 2.42 ng/m^3	2.49*(0.35-18.40) 0.80*(0.13-3.77) 0.21*(0.05-1.56) 2.76*(0.54-20.08) 0.49*(0.03-8.80) 0.23*(0.03-1.23) 1.07*(0.06-10.63) 0.30*(0.03-2.88) 0.38*(0.01-4.07) 2.82*(0.06-48.56) 0.78*(0.03-29.37)	
Beretic-Stahuljak (1976)		Hexlet Two stage dust sampler	P	Bakery	Bakers		11 11 24	Total Dust Total Dust Total Dust			(0.50-0.99) (1.00-	

							15 18 5 7 4 4 2 6 4 0 1 91 21	Total Dust Total Dust Total Dust Total Dust Respirable Fraction Respirable Fraction Respirable Fraction Respirable Fraction Respirable Fraction Respirable Fraction Respirable Fraction Total Dust Respirable Fracion	1.85 1.13	2.25 1.20	1.49) (1.50-1.99) (2.00-2.49) (2.50-2.99) (3.00-3.49) (3.50-3.99) (0.50-0.74) (0.75-0.99) (1.00-1.24) (1.25-1.49) (1.50-1.74) (1.75-1.99) (2.00-2.24)	
Bogdanovich (2006)		PAS-6 Teflon filter	P	5 Industrial bakeries	Dough Maker Oven-Baker		7 5	Fungal alpha amylase Fungal alpha	0.3ng/ml 0.4 ng/ml		(0.1-1.7) (0.3-1.9)	Results in ng/ml using enzyme linked immunosorben

		2 L/min			Manager Technical Maintenance Cleaner		2 2 1	amylase Fungal alpha amylase Fungal alpha amylase Fungal alpha amylase	9.8 ng/ml 0.3 ng/ml 0.03 ng/ml		(0.3-365.0) (0.1-1.4) 0.03	t assay
Bohadana (1994)		1 L/min Closed face	P	Industrial Bakery	Croissant Maker Oven handler Frozen dough handler General baker Special baker		4 6 2 4 5	Inspirable Dust Inspirable Dust Inspirable Dust Inspirable Dust Inspirable Dust		0.69mg/m^3 (0.17) 1.11mg/m^3 (0.87) 2.13mg/m^3(NP) 3.37mg/m^3 (3.66) 41.3mg/m^3 (39.5)	(0.54-0.85) (0.45-2.73) (1.89-2.37) (0.66-8.70) (10.1-98.1)	NP – not provided
Brant (2005)		IOM head 2 L/min	P	20 store bakeries	Baker* Manager*		27 1 8	Total Inhalable dust Fungal alpha amylase	1.2 mg/m^3 0.5mg/m^3	3.3ng/m^3	(2GSD:0.9-1.5) (2GSD:0.	*Only one fungal alpha amylase sample taken The LOD for fungal alpha amylase was

					Confectioner Bakery Assistant* Total		1 21 33 1 89	Total Inhalable Dust Fungal alpha amylase Total Inhalable Dust Total Inhalable Dust Fungal alpha amylase Total inhalable dust	0.3mg/m^3 0.3mg/m^3 0.5mg/m^3	12.4ng/m^3 3.9ng/m^3	3-1.0) (2GSD:0.2-0.4) (2GSD:0.2-0.5) (2GSD: 0.4-0.6)	1ng/ml
Bulat (2004)		PAS6 head 2 L/min Teflon filter	P	Industrial Bakery Traditional	Baker Packaging Bread		22 20 22 31 32 32	Inhalable dust flour Wheat flour Alpha-amylase allergens Inhalable dust flour Wheat flour Alpha-amylase	1.06mg/m^3 (3.61) 6.15µg/m^3 (3.57) 0.47ng/m^3 (7.19) 0.56mg/m^3 (2.09) 2.79µg/m^3 (2.25) 0.15ng/m^3 (1.74)		1.39 (0.17-8.52) 5.24(1.46-100.29) 0.19(0.11-136.16) 0.49 (0.22-2.17)	

			P	Bakery	production		29	allergens	2.10mg/m^3 (2.42)		2.43(0.46-48.44)	
							30		22.33μg/m^3(2.97)		0.12(0.11-1.24)	
							29	Inhalable dust flour	0.61g/m^3 (3.89)			
								Wheat flour				
					Pastry production		57		1.11mg/m^3 (2.55)		1.83 (0.30-13.30)	
							60	Alpha-amylase allergens	8.71μg/m^3 (4.16)			
							59		0.47ng/m^3 (4.04)		22.89(1.99-171.23)	
								Inhalable dust flour			0.40(0.11-17.65)	
							135		1.80mg/m^3 (2.30)			
					Bread and pastry			Wheat flour				
							138		14.48μg/m^3(3.75)			
								Alpha-amylase allergens				
					production		130		0.50ng/m^3 (4.47)		1.34 (0.23-8.70)	
				Traditional Bakery								
			A				77	Inhalable dust flour	1.55mg/m^3 (2.15)		9.75(0.58-150.72)	
					Dough Making		78	Wheat flour	14.76μg/m^3(3.47)		0.28(0.10-51.13)	
							71	Alpha-amylase allergens	0.33ng/m^3 (3.37)			
							59		1.42mg/m^3 (2.33)		1.89 (0.17-13.37)	
					Work Table		60	Inhalable dust flour	13.91μg/m^3(5.16)			
							55		0.34ng/m^3 (3.58)		18.34(0.46-205.96)	
								Wheat flour				
								Alpha-amylase allergens			0.29(0.10-37.46)	
								Inhalable dust				

								flour Wheat flour Alpha-amylase allergens			1.55 (0.14-8.96) 19.17(0.73-98.67) 0.22(0.10-7.29) 1.53 (0.15-6.64) 19.94(0.43-179.35) 0.21(0.10-6.08)	
Burdorf (1994)		IOM head Cellulose filter 2 L/min	P	12 Swedish Bakeries(two small bakeries < 10 workers), seven medium-sized bakeries (10-50) and three large bakeries (more than 100)	Doughmaker		34	Inhalable flour dust	5.46mg/m^3 (2.09)	6.90mg/m^3	(1.20-16.90)	
					Bread-Former		62	Inhalable flour dust	2.69mg/m^3 (1.96)	3.39mg/m^3	(0.60-14.20)	
					Oven Worker		10	Inhalable flour dust	1.17mg/m^3 (2.43)	1.59mg/m^3	(0.20-4.00)	
					Confectionary		7		0.58mg/m^3 (2.56)	0.86mg/m^3		
					Packer		9	Inhalable flour dust	0.48mg/m^3 (2.40)	0.63mg/m^3	(0.20-3.00)	
					Mixed Task		7	Inhalable flour	2.73mg/m^3 (1.74)	3.09mg/m^3	(0.10-	

								dust			1.40)	
					Total		129		2.48mg/m^3 (2.77)	3.83mg/m^3		
							61	Inhalable flour dust	0.25µg/m^3 (2.52)	0.36µg/m^3	(1.20-4.90)	
								Inhalable flour dust			(0.10-16.90)	
							40		90.00µg/m^3 (1.76)	104.90µg/m^3		
							3	Fungal and cereal alpha amylase(0.03% of total)	23.15µg/m^3 (2.03)	27.30µg/m^3	(0.03-1.67)	
								Total proteins(9% of total)			(22.00-340.0)	
								Water soluble proteins(2.3% of total)			(12.00-49.00)	
Burstyn (1997)	1995-1996	Seven Hole Sampler Teflon filter 2 L/min	P	7 bakeries: 5 small-medium sized with 6-25 workers 2 large with 50 and 130 workers	**Total**		180	inhalable dust	2.1mg/m^3 (5.1)	8.2mg/m^3	(0.1-110)	
					Puff pastry		14	inhalable dust	11.65mg/m^3 (3.8)	23mg/m^3	(1.8-66)	
					bread and buns		17	inhalable dust	4.50mg/m^3 (6.7)	18mg/m^3	(0.3-110)	
					croissants		8	inhalable dust	2.87mg/m^3 (3.2)	5.3mg/m^3	(0.9-15)	

					cinnamon buns		6	inhalable dust	2.21mg/m^3(3.1)	3.6mg/m^3	(0.6-9.1)	
					pizza, pita, tortilla		3	inhalable dust	2.08mg/m^3 (1.6)	2.2mg/m^3	(1.3-3.1)	
					bagels		9	inhalable dust	1.5mg/m^3 (3.7)	2.9mg/m^3	(0.2-9.9)	
					crumpets		6	inhalable dust	1.01mg/m^3 (3.1)	2.0mg/m^3	(0.3-8.5)	
				By Equipment	cakes and pastry		25	inhalable dust	0.73mg/m^3 (3.4)	1.4mg/m^3	(0.1-5.3)	
					dough-brake		6	inhalable dust	44.23mg/m^3 (1.4)	46mg/m^3	(30-66)	
					reversible sheeter+/manual		19	inhalable dust	5.34mg/m^3 (4.0)	14mg/m^3	(0.2-110)	
				Type of mixers	automated		17	inhalable dust	2.23mg/m^3 (3.7)	4.2mg/m^3	(0.3-15)	
							3	inhalable dust	13.00mg/m^3			
				Preventing dough adhesion	horizontal mixer		30	inhalable dust	6.26mg/m^3			

					vertical mixer		5	inhalable dust	0.43mg/m^3			
					use of divider oil		12	inhalable dust	11.95mg/m^3			
					flour to prevent adhesion							
Burstyn (1998)	1995-1996	Seven Hole Sampler Teflon filter 2 L/min	P	7 bakeries:	Total		180	alpha amylase antigen	2.8ng/m^3 (10.4)	22.0ng/m^3	(<LOD-307.1ng/m^3)	Wheat LOD = 1 µg/m^3
								wheat antigen	21µg/m^3 (10)	109µg/m^3	(<LOD-1018µg/m^3)	Amylase LOD = 0.1 ng/m^3
				5 small-medium sized with 6-25 workers	Puff pastry		14	alpha amylase antigen	25.6ng/m^3			
								wheat antigen	173µg/m^3			
				2 large with 50 and 130 workers	croissants		8	alpha amylase antigen	19.2ng/m^3			
								wheat antigen	107µg/m^3			
					bread and buns		17	alpha amylase antigen	6.0ng/m^3			
								wheat antigen	34µg/m^3			
					cinnamon buns		6		9.5ng/m^3			
									32µg/m^3			
							3	alpha amylase antigen	1.2ng/m^3			

					pizza, pita, tortilla			wheat antigen	63µg/m^3			
					bagels		9	alpha amylase antigen wheat antigen	5.5ng/m^3 21µg/m^3			
					crumpets		6	alpha amylase antigen wheat antigen	1.3ng/m^3 7µg/m^3			
				Bread Forming equipment	cakes and pastry		25	alpha amylase antigen wheat antigen	0.5ng/m^3 6µg/m^3			
					dough brake		6	alpha amylase antigen wheat antigen	44.1ng/m^3 325µg/m^3			
				Type of mixers	reversible sheeter/manual		19	alpha amylase antigen wheat antigen	5.9ng/m^3 96µg/m^3			
					automated		17	alpha amylase antigen wheat antigen	4.1ng/m^3 31µg/m^3			
					horizontal		3	alpha amylase antigen wheat antigen	192ng/m^3 231µg/m^3			

				Preventing dough adhesion	mixer vertical mixer use of divider oil flour to prevent adhesion		30 5 12	alpha amylase antigen wheat antigen alpha amylase antigen wheat antigen alpha amylase antigen wheat antigen alpha amylase antigen wheat antigen alpha amylase antigen wheat antigen	3.8ng/m^3 67µg/m^3 0.3ng/m^3 1µg/m^3 22.1ng/m^3 153µg/m^3			
Creely (2006)	1985-2003 1985 1986 1987				All All All All All		1451 8 0 26 0	Inhalable flour dust Inhalable flour dust Inhalable flour dust Inhalable flour dust Inhalable flour	3.4mg/m^3 (4.1) 4.3 mg/m^3 (2.2) - 9.8 mg/m^3 (2.5) -	9.71 mg/m^3 5.4 mg/m^3 - 13.3 mg/m^3 -	3.5(0.005-1148.7) (0.8-13.8) - (1.0-39.6)	

	1988				All		0	dust	-	-	-	
	1989				All		86	Inhalable flour dust	2.5 mg/m^3 (2.9)	4.0 mg/m^3	-	
	1990				All		73		3.9 mg/m^3 (2.9)	6.1 mg/m^3	(0.1-22.0)	
								Inhalable flour dust				
	1991				All		1		23.0 mg/m^3 (-)	23.0 mg/m^3	(0.2-23.7)	
	1992				All		5	Inhalable flour dust	2.1 mg/m^3 (1.3)	2.1 mg/m^3	(23.0-23.0)	
	1993				All		0		-	-		
								Inhalable flour dust			(1.3-2.6)	
	1994				All		32		4.4 mg/m^3 (4.5)	11.3 mg/m^3		
											-	
	1995				All		62	Inhalable flour dust	3.0 mg/m^3 (2.8)	4.8 mg/m^3		
											(0.1-96.5)	
	1996				All		30		1.4 mg/m^3 (4.4)	3.1 mg/m^3		
								Inhalable flour dust			(0.2-24.7)	
	1997				All		87		1.9 mg/m^3 (3.8)	4.1 mg/m^3		
											(0.0-21.7)	
	1998				All		91	Inhalable flour dust	2.2 mg/m^3 (4.2)	6.0 mg/m^3		
											(0.0-31.6)	
	1999				All		172		3.1 mg/m^3 (5.1)	18.3 mg/m^3		
								Inhalable flour dust			(0.1-70.1)	
	2000				All		144		2.9 mg/m^3 (4.8)	8.0 mg/m^3		
											(0.0-1148.7)	
	2001				All		301	Inhalable flour dust	4.5 mg/m^3 (4.1)	11.6 mg/m^3		
	2002				All		333		3.8 mg/m^3 (3.9)	10.3 mg/m^3	(0.0-83.0)	
								Inhalable flour dust				
	2003				All		283		3.5 mg/m^3 (3.6)	7.9 mg/m^3	(0.0-175.0)	
	1985-2003				Bakery Workers		67	Inhalable flour dust	6.9 mg/m^3 (5.8)	42.4 mg/m^3	(0.0-571.9)	
							143		4.5 mg/m^3 (3.4)	8.5 mg/m^3		
	1985-2003				Dough Shapers/Dusters			Inhalable flour dust				
							662		3.4 mg/m^3 (4.3)	9.2 mg/m^3		
	1985-2003						75	Inhalable flour dust	2.2 mg/m^3 (3.3)	4.0 mg/m^3		
					Oven Operators		90		1.6 mg/m^3 (3.6)	3.4 mg/m^3		
	1985-2003							Inhalable flour dust				
					Mixers/Weighers		1148		3.2 mg/m^3 (3.9)	7.8 mg/m^3		
	1985-											

	2003 1985-2003 1985-2003				Packers/slicers All			Inhalable flour dust Inhalable flour dust Inhalable flour dust Inhalable flour dust Inhalable flour dust Inhalable flour dust Inhalable flour dust Inhalable flour dust Inhalable flour dust				
Elms (2005)		IOM head 2 L/min	P	Bakeries	Baker/table/dough break Mixer/siever/weigher Cleaner		108 59 6	Inhalable flour dust Inhalable flour dust Inhalable flour dust	3.3mg/m^3 (3.4) 4.7mg/m^3 (3.4) 3.8mg/m^3 (3.5)		3.6mg/m^3 (BLD-47.0) 5.2mg/m^3 (BLD-30.6) 4.4mg/m^3	Total samples 208 Median exposure 3.7mg/m^3 BLD = 0.2mg/m^3

							35		2.2mg/m^3 (2.8)		(0.4-14.3)	
					Other(Packers, drivers, administrative , counter hand)			Inhalable flour dust			2.1mg/m^3 (BLD-30.8)	
				Size of Bakery			55		2.8mg/m^3 (3.1)			
					Micro bakery(1-9 employees)		74	Inhalable flour dust	2.2mg/m^3 (3.8)			
					Small bakery(10-49)						3.0mg/m^3 (BLD-28.1)	
							35	Inhalable flour dust	5.7mg/m^3 (2.6)			
					Medium bakery(50-249)		44		6.4mg/m^3 (2.2)		2.2mg/m^3 (BLD-30.6)	
								Inhalable flour dust				
					Large bakery(>250 employees)						5.2mg/m^3 (1.2-47.0)	
								Inhalable flour dust				
											7.6mg/m^3 (1.1-27.7)	

Golder (2014)	2013	total dust : 2 L/min Polyvinyl chloride (PVC) 37mm filter cassette inhalable dust: IOM aerosol sampler PVC filter 2 L/min	P P & A	1 Large 2 Medium 5 Small All Facilities	Bakers Mixers		8 8 19 21 25 25 52 (30 (P) & 22 (A)) 54 (33 (P) & 21 (A)) 16 18 6 6	Total Particulate Inhalable Particulate Total Particulate Inhalable Particulate Total Particulate Inhalable Particulate Total Particulate Inhalable Particulate Total Particulate Inhalable Particulate Total Particulate Inhalable	0.43mg/m^3 (2.57) 0.86mg/m^3 (2.33) 1.35mg/m^3 (4.15) 2.34mg/m^3 (2.68) 0.38mg/m^3 (2.54) 0.83mg/m^3 (2.87) 0.58mg/m^3 (3.47) 1.25mg/m^3 (3.06) 0.73mg/m^3 (2.86) 1.57mg/m^3 (2.70) 3.29mg/m^3 (1.56) 4.13mg/m^3 (1.62) 0.31mg/m^3 (2.45)	0.71mg/m^3 (0.89) 1.37mg/m^3(1.74) 2.76mg/m^3 (2.55) 3.79mg/m^3 (4.24) 0.62mg/m^3 (0.89) 1.58mg/m^3 (2.33) 1.42mg/m^3 (1.98) 2.41mg/m^3 (3.37) 1.38mg/m^3 (1.78) 2.60mg/m^3 (2.80)	0.13-3.00mg/m^3 0.30-5.90mg/m^3 0.09-8.60mg/m^3 0.25-19.0mg/m^3 0.04-4.60mg/m^3 0.17-19.0mg/m^3 0.04-8.60mg/m^3 0.17-19.0mg/m^3	

			A P		Others(maintenance, QA/QC, floaters, cleaners, shippers)		8 9 22 21 30 33	Particulate Total Particulate Inhalable Particulate Total Particulate Inhalable Particulate Total Particulate Inhalable Particulate	1.06mg/m^3 (1.55) 0.44mg/m^3 (3.70) 0.79mg/m^3 (3.47) 0.78mg/m^3 (3.35) 1.68mg/m^3 (2.49)	3.57mg/m^3 (1.20) 4.62mg/m^3 (2.09) 0.41mg/m^3 (0.24) 1.16mg/m^3 (0.50 1.23mg/m^3 (2.22) 2.16mg/m^3 (4.30) 1.56mg/m^3 (1.78) 2.57mg/m^3 (2.54)	0.16-6.3mg/m^3 0.25-11.00mg/m^3 1.30-5.00mg/m^3 2.50-7.20mg/m^3 0.085-0.70mg/m^3 0.61-2.1mg/m^3 0.04-8.6mg/m^3 0.17-19.00mg/m^3 0.09-6.30mg/m	

											^{3} 0.26-11.00mg/m^3	
Houba (1996)		PAS6 Head Teflon filter 2 L/min	P	Large Bakeries	Doughmakers		105 76	Total Dust Exposure Wheat Antigen Exposure	3.0mg/m^3 5323ng/m^3		(0.4-37.7mg/m^3) (33-252407ng/m^3)	Contains information on the wheat antigens to total dust ratio
					All-round staff		66 54	Total Dust Exposure Wheat Antigen Exposure	0.9mg/m^3 992ng/m^3		(0.1-26.8mg/m^3) (33-68159ng/m^3)	
					Oven Staff		81 71	Total Dust Exposure Wheat Antigen Exposure	0.6mg/m^3 322ng/m^3		(0.1-5.1mg/m^3) (33-28079ng/m^3)	
					Slicers,packers,transport		132 109	Total Dust Exposure Wheat Antigen Exposure	0.4mg/m^3 77ng/m^3		(0.1-2.8mg/m^3) (33-7736ng/m^3)	
					Production managers		20 17		0.6mg/m^3 505ng/m^3			
					Maintenance/cleaners		27 20		0.7mg/m^3 242ng/m^3			
				Small Bakeries			36		3.3mg/m^3			

				Wheat bread production sites Confectioners Crispbake production site	Bread baker Mixed Baker Confectioner **Total** Dough maker Oven Staff Dough maker Oven Staff		31 57 55 22 16 546 449 37 32 34 30 32 25 21 21 29	Total Dust Exposure Wheat Antigen Exposure Total Dust Exposure Wheat Antigen Exposure Total Dust Exposure Wheat Antigen Exposure Total Dust Exposure Wheat Antigen Exposure Total Dust Exposure Wheat Antigen Exposure Total Dust Exposure	5989ng/m^3 2.0mg/m^3 2729ng/m^3 0.7mg/m^3 614ng/m^3 1.0mg/m^3 684ng/m^3 4.5mg/m^3 16511ng/m^3 0.7mg/m^3 771ng/m^3 2.4mg/m^3 1969ng/m^3 0.6mg/m^3 302ng/m^3 3.1mg/m^3		(0.1-4.9mg/m^3) (33-74614ng/m^3) (0.3-5.5mg/m^3) (33-2539ng/m^3) (1.2-8.8mg/m^3) (1289-53275ng/m^3) (0.3-14.2mg/m^3) (261-44200ng/m^3) (0.1-3.7mg/m^3) (33-3812ng/m^3)	

				Rye-bread production site	Dough maker Oven Staff Dough maker Oven Staff		15 21 15 7 4 5 5	Wheat Antigen Exposure Total Dust Exposure Wheat Antigen Exposure Total Dust Exposure Wheat Antigen Exposure Total Dust Exposure Wheat Antigen Exposure Total Dust Exposure Wheat Antigen Exposure Total Dust Exposure Wheat Antigen Exposure Total Dust Exposure Wheat Antigen Exposure Total Dust Exposure Wheat Antigen Exposure	5104ng/m^3 0.7mg/m^3 128ng/m^3 0.9mg/m^3 364ng/m^3 0.4mg/m^3 36ng/m^3		(0.1-37.7mg/m^3) (33-252407ng/m^3) (0.9-37.7mg/m^3) (1597-252407ng/m^3) (0.1-5.1mg/m^3) (33-28079ng/m^3) (0.4-7.4mg/m^3) (33-12024ng/m^3) (0.1-3.2mg/m^3) (33-2600ng/m^3)	

											(0.9-8.9mg/m^3) (1425-11468ng/m^3) (0.4-1.3mg/m^3) (55-413ng/m^3) (0.4-1.9mg/m^3) (98-972ng/m^3) (0.3-0.6mg/m^3) (33-51ng/m^3)	
Hur (2007)	2006	IOM inhalable dust sampler; SKC Inc.	P	Industrial Bakery	Group 3 (mixing, weighing, sieving) Group 2 (foaming, baking, decorating) Group 1 (non-		37 28 22	Wheat Dust Wheat Dust Wheat Dust		3.04mg/m^3 1.16mg/m^3 0.01mg/m^3	(0.07-11.27 mg/m^3) (0.02-5.97 mg/m^3)	

					production areas)						(0.00-0.35 mg/m^3)	
Kolopp-Sarda (1994)			P	Industrial Bakery			10	Total dust		4.9mg/m^3 (9.1)		
Lauriere (2008)		Bravo sampling pump (Tecora, Milan, Italy) set to a flow rate of 10 L/min using 25-mm cellulose ester membranes	P A	Industrial Bakery	Dough Making Dough Making area Dough Resting area Baking area		1 1 1 1 1 1 1 1 1	Total Air Particulate Total Air Particulate Total Air Particulate Total Air Particulate Total Air Particulate Total Air Particulate Total Air Particulate Total Air Particulate Total Air Particulate		5.0mg/m^3 5.1mg/m^3 2.3mg/m^3 1.4mg/m^3 1.6mg/m^3 10.0mg/m^3 4.6mg/m^3 0.8mg/m^3 0.4mg/m^3		Paper focuses on Protein Analyses of collected dust
Lillienberg (1994)		IOM inhalable dust sampler with open	P	5 Bakeries	Dough Mixing		6	Flour Dust (IOM) Flour Dust		7.5mg/m^3 (5.4) 3.6mg/m^3		

		faced, 37 mm filter Millipore 2 L/min		Job Categories	Bread forming (line) Bread forming (manual) Oven control Packing **Total** Mixing		6 10 3 3 29 249 minutes sampling time 369	(Millipore) Flour Dust (IOM) Flour Dust (Millipore) Flour Dust (IOM) Flour Dust (Millipore) Flour Dust (IOM) Flour Dust (Millipore) Flour Dust (IOM) Flour Dust (Millipore) Flour Dust (IOM) Flour Dust (Millipore) Inspirable Thoracic (ACGIH) Respirable		(2.5) 8.0mg/m^3 (6.7) 4.3mg/m^3 (4.8) 2.5mg/m^3 (0.8) 1.4mg/m^3 (0.4) 3.2mg/m^3 (1.7) 1.4mg/m^3 (0.3) 1.0mg/m^3 (0.4) 0.6mg/m^3 (0.2) 4.5mg/m^3 (4.7) 2.3mg/m^3 (2.7)		

					Forming General Oven		minutes 308 minutes 367 minutes	(BMRC) Inspirable Thoracic (ACGIH) Respirable (BMRC) Inspirable Thoracic (ACGIH) Respirable (BMRC) Inspirable Thoracic (ACGIH) Respirable (BMRC)		14.1mg/m^3 26% 9% 4.1mg/m^3 32% 15% 5.2mg/m^3 17% 8% 2.9mg/m^3 76% 45%		
Meijster (2007)		PAS6 head 2 L/min	P	Traditional Bakeries Industrial Bakeries			200 171 169 381 346	Inhalable dust Wheat allergens fungal alpha amylase Inhalable dust Wheat allergens	1.5mg/m^3 (2.7) 7.4µg/m^3 (8.3) 0.8ng/m^3 (6.5) 1.0mg/m^3 (3.5) 3.6µg/m^3 (10)		(0.2-318mg/m^3) (0.1-5365µg/m^3) (0.1-115ng/m^3)	Contains variance values for individual tasks and bakery type as well

							344	fungal alpha amylase	0.4ng/m^3 (6.0)		(0.2-292mg/m^3) (0.1-7571µg/m^3) (0.1-910ng/m^3)	
Meijster (2008)		PAS6 head 2 L/min	P	Bakeries	Breadbaker Pastry baker Dough Maker All baker Storage worker		30 4 16 8 1	Inhalable Dust Inhalable Dust Inhalable Dust Inhalable Dust Inhalable Dust		4.49mg/m^3 0.49mg/m^3 1.80mg/m^3 2.02mg/m^3 2.32mg/m^3	Max: 371mg/m^3 Max: 117mg/m^3 Max: 203mg/m^3 Max: 400mg/m^3 Max: 400mg/m^3	
Mounier-Geyssant (2007)	2003-2005	Harvard Chempass sampler connected to a portable BGI pump	P From the results Notes and results	Bakeries	Baker apprentice ($PM_{2.5}$)		17 21	Flour Dust ($PM_{2.5}$) summer winter average		0.50mg/m^3 (0.37) 0.71mg/m^3 (0.37) 0.61mg/m^3	(0.17-1.52) (0.19-1.42)	($PM_{2.5}$): 2.5µm particulate (PM_{10}): 10µm particulate

		1.8 L/min	table		Pastry apprentice($PM_{2.5}$) Baker apprentice (PM_{10}) Pastry apprentice(PM_{10})		4 13 15 20 3 13	Flour Dust ($PM_{2.5}$) summer winter average Flour Dust (PM_{10}) summer winter average Flour Dust (PM_{10}) summer winter average		(0.38) 0.29mg/m^3 (0.06) 0.35mg/m^3 (0.17) 0.32mg/m^3 (0.15) 0.63mg/m^3 (0.36) 1.10mg/m^3 (0.83) 0.87mg/m^3 (0.70) 0.47mg/m^3 (0.13) 0.44mg/m^3 (0.16) 0.46mg/m^3 (0.15)	(0.22-0.36) (0.20-0.70) (0.17-1.73) (0.28-4.04) (0.33-0.58) (0.22-0.82)	
Musk (1989)		Casella and three piece samplers	P	Large Bakery	Office, transport, and		1	Total Dust	0.18 mg/m^3		--	Ranking 0

		2 L/min			vehicle-workshop staff			sampling				
							2		0.01 mg/m^3		(0.00-0.08)	1
					Despatch, tray washing, nursing, and canteen staff			Total Dust sampling				
							23		0.34 mg/m^3		(0.00-3.65)	2
					Slicers, wrappers, and packers			Total Dust sampling				
							0		--		--	3
					Bakery manager, quality control staff			--				
							5		0.24 mg/m^3		(0.01-0.99)	4
					Production foremen, security staff			Total Dust sampling				
							1		2.97 mg/m^3		--	5
							16[3]*		1.73 mg/m^3			6
					Bakery maintenance staff			Total Dust sampling			(0.00-37.57)	
					Staff attending ovens or in cooking areas		12[2]	Total Dust sampling	2.13 mg/m^3		(0.01-	7

											16.80)	
					Bakery cleaning staff, doughmakers (main bread bakery)		10[1]	Total Dust sampling	2.69 mg/m^3			8
											(0.59-14.10)	
					Doughmakers (confectionery bakery), mixers (hot platebakery)		2[1]	Total Dust sampling	11.00mg/m^3			9
											(9.97-12.05)	
					Staff preparing ingredients in confectionery bakery		7[2]	Total Dust sampling	6.59 mg/m^3			10
					Flour room staff, scone production staff		79[9]	Total Dust sampling	--		(1.84-13.03)	Ranking was based on perceived dustiness
					Total						--	*Numbers in square parentheses refer to samples with levels above 10mg/m^3

												The exposure limit was 10mg/m^3
Nieuwen huijsen (1994)		Seven hole Casella Teflon filter 2 L/min	P	3 British Bakeries (200-450 employees)	Total		352	Total dust Flour aeroallergen			(0.4-6.4mg/m^3) (45.5-252.0µg/m^3)	
					Conf/dough brake		9	Total dust Flour aeroallergen	6.4mg/m^3 (1.8) 208.5µg/m^3 (3.0)	7.5mg/m^3 387.0µg/m^3	(2.87-15.30) (36.10-1912.70)	
					Dispense/mixi ng		24	Total dust Flour aeroallergen	5.0mg/m^3 (2.5) 228.7µg/m^3 (2.4)	9.0mg/m^3 310.7µg/m^3	(1.42-86.02) (25.96-842.97)	
					Roll production		32	Total dust Flour aeroallergen	2.4mg/m^3 (2.5) 215.3µg/m^3 (1.8)	3.6mg/m^3 259.9µg/m^3	(0.35-21.05) (71.14-1015.35)	
					Hygiene Inside		36	Total dust Flour aeroallergen	1.7mg/m^3 (2.6) 148.6µg/m^3 (3.8)	2.6mg/m^3 408.2µg/m^3	(0.20-12.91)	
					Conf/flour involved		26	Total dust Flour aeroallergen	1.6mg/m^3 (2.0) 252.0µg/m^3 (2.2)	2.1mg/m^3 326.5µg/m^3		

							22	Total dust	1.0mg/m³ (2.2)	1.5mg/m³	(15.40-4506.26)	
								Flour aeroallergen	121.8µg/m³ (2.3)	170.5µg/m³		
					Maintenance		45	Total dust	0.9mg/m³ (2.9)	1.6mg/m³	(0.49-6.22)	
								Flour aeroallergen	176.6µg/m³ (2.3)	241.1µg/m³	(62.70-1156.98)	
					Bread production		24	Total dust	0.8mg/m³ (2.2)	1.2mg/m³	(0.39-7.36)	
								Flour aeroallergen	100.9µg/m³ (2.3)	141.3µg/m³	(43.57-586.91)	
					Roll wrapping		3	Total dust	0.8mg/m³ (1.8)	1.0mg/m³	(0.06-15.98)	
								Flour aeroallergen	96.0µg/m³ (5.7)	200.7µg/m³	(43.91-744.29)	
					Quality control		33	Total dust	0.7mg/m³ (2.5)	1.1mg/m³	(0.18-6.17)	
								Flour aeroallergen	80.2µg/m³ (1.9)	101.7µg/m³	(29.14-512.28)	
					Conf/no flour involved		28	Total dust	0.7mg/m³ (2.5)	1.0mg/m³	(0.48-1.62)	
								Flour aeroallergen	72.8µg/m³ (2.2)	99.1µg/m³	(14.85-456.84)	
					Hygiene		5	Total dust	0.7mg/m³ (2.5)	0.9mg/m³		
								Flour aeroallergen	169.8µg/m³ (2.2)	213.7µg/m³		
					Outside		34	Total dust	0.5mg/m³ (1.8)	0.6mg/m³		

					Miscellaneous			Flour aeroallergen	64.5µg/m^3 (2.0)	88.5µg/m^3	(0.18-4.91)	
							31	Total dust	0.4mg/m^3 (1.7)	0.5mg/m^3	(38.02-382.25)	
					Despatch			Flour aeroallergen	45.5µg/m^3 (2.0)	57.3µg/m^3		
											(0.18-4.23)	
								Total dust				
					Bread Wrapping			Flour aeroallergen			(15.22-525.21)	
											(0.21-1.94)	
					Total						(74.44-468.43)	
											(0.13-1.98)	
											(23.95-459.99)	
											(0.21-1.78)	
											(7.68-257.45)	
											(0.4-6.4mg/m^3)	
											(45.5-252.0µg/	

											m³)	
Nieuwen huijsen (1995)		Seven hole Casella	P	Industrial Bakery	Tipping/weighing/sifting/bag disposal/mixing		32	Total dust sampling	7.3mg/m³ (3.6)	13.5	(0.3-53.5)	Task group
		Teflon filter					32	Flour aeroallergen	269.8µg/m³ (3.4)	481.7	(13.6-2301.3)	A- Tipping
		2 L/min										
				4 task groups	Dispense/mix, floor		7	Total dust sampling	8.3mg/m³ (3.4)	13.7	(1.3-33.2)	B1- Cleaning
				13 tasks			7	Flour aeroallergen	415.9µg/m³ (4.0)	956.5	(75.6-3657.7)	
					Production floor		18	Total dust sampling	1.4mg/m³ (3.3)	2.3	(0.1-8.4)	B2
							18	Flour aeroallergen	18.6µg/m³ (3.2)	29.3	(2.5-69.0)	
					Flour silo		4	Total dust sampling	23.4mg/m³ (2.3)	29.1	(7.6-54.4)	B3
							4	Flour aeroallergen	654.5µg/m³ (2.2)	831.8	(313.3-1862.9)	
					Bread machinery		8		1.8mg/m³ (3.4)	5.0	(0.7-31.3)	B4
							8		20.7µg/m³ (5.4)	110.4	(4.3-756.4)	
					Roll machinery		5	Total dust sampling	5.3mg/m³ (2.1)	6.5	(1.9-11.46)	B5
							5	Flour aeroallergen	107.9µmg/m³(2.7	156.7	(33.0-374.2)	
							4	Total dust sampling	1.8mg/m³ (1.6)	2.0		B6
							4	Flour aeroallergen	29.7µg/m³ (1.2)	30.0		

					Confectionery machinery		5	Total dust sampling	42.9mg/m^3 (3.8)	99.8	(1.2-3.6)	B7
							5	Flour aeroallergen	1138.5µmg/m^3(2.1)	1293.8	(24.4-33.6)	
					Bins		--	Total dust sampling	40* mg/m^3)	--	(10.7-387.8)	B8
								Flour aeroallergen	464.1*µg/m^3	--	(679.2-1908.3)	
					Breakdown/blockages		9	Total dust sampling	9.0mg/m^3 (2.3)	11.8	--	C1-Flour dusting
							9	Flour aeroallergen	185.5µg/m^3 (1.7)	214.5	--	
					Bread production		17	Total dust sampling	8.8mg/m^3 (3.5)	18.1	(2.2-25.0)	C2
							17	Flour aeroallergen	163.1µg/m^3 (2.9)	301.8	(85.7-523.1)	
					Roll production		19	Total dust sampling	4.2mg/m^3 (2.5)	6.2	(1.3-80.7)	C3
							19	Flour aeroallergen	118.5µg/m^3 (3.0)	192.4	(36.1-1933.2)	
					Dough brake		--	Total dust sampling	--	tstm 10*	(0.9-21.1)	D- Bag disposal
								Flour aeroallergen	139.8*µg/m^3	--	(7.0-684.2)	
					Bag disposal			Total dust				tstm = too short to measure *assigned

								sampling Flour aeroallergen			-- --	values
Nieuwen huijsen (1999)		Seven hole Casella Teflon filter 2 L/min	P	3 British Bakeries (200-450 employees)	Dispense/Mixing							
					Site 7		3	fungal alpha amylase	39.7ng/m^3 (2.2)	47.3		
					Site 8		6		1.4ng/m^3 (16.8)	22.7		
					Site 9		13		6.0ng/m^3 (6.0)	24.9		
					Bread Production							
					Site 7		23	fungal alpha amylase	0.4ng/m^3 (5.4)	1.5		
					Site 8		11		1.3ng/m^3 (3.5)	2.5		
					Site 9		10		5.8ng/m^3 (17.9)	61.4		
					Bread Wrapping							
					Site 7		21	fungal alpha amylase	0.1ng/m^3 (1.3)	0.1		
					Site 8		0		-	-		
					Site 9		8		0.1ng/m^3 (1.6)	0.1		
					Roll Production							
					Site 7		11	fungal alpha amylase	1.0ng/m^3 (5.3)	2.5		
					Site 8		15		0.1ng/m^3 (1.9)	0.1		
							6		4.2ng/m^3 (7.4)	12.5		

					Site 9								
							12		0.2ng/m^3 (3.6)	0.6			
					Roll Wrapping		5		0.1ng/m^3 (1.4)	0.1			
							7	fungal alpha amylase	0.1ng/m^3 (1.2)	0.1			
					Site 7								
					Site 8								
					Site 9								
							0		-	-			
							8		0.1ng/m^3 (2.6)	0.2			
					Dough Break								
							1		-	5.2			
					Site 7			fungal alpha amylase					
					Site 8								
					Site 9								
							0		-	-			
							15		0.2ng/m^3 (8.4)	0.3			
					Confectionary or flour		8		0.3ng/m^3 (4.0)	1.0			
					Site 7			fungal alpha amylase					
					Site 8								
					Site 9		0		-	-			
							12		0.1ng/m^3 (1.7)	0.1			
					Confectionary no flour		21		0.1ng/m^3 (4.0)	1.2			
					Site 7			fungal alpha amylase					
					Site 8								
							9		0.1ng/m^3 (1.8)	0.2			
					Site 9								

							6		$0.1 ng/m^3$ (1.4)	0.1		
					Despatch		19		$0.1 ng/m^3$ (1.4)	0.1		
					Site 7							
					Site 8			fungal alpha amylase				
					Site 9		14		$1.5 ng/m^3$ (4.3)	3.2		
							9		$0.4 ng/m^3$ (5.9)	1.3		
					Hygiene Inside		11		$0.4 ng/m^3$ (5.1)	1.6		
					Site 7							
					Site 8		13	fungal alpha amylase	$0.5 ng/m^3$ (6.9)	2.1		
					Site 9							
							13		$0.2 ng/m^3$ (3.7)	0.7		
							2		$0.7 ng/m^3$ (2.3)	0.8		
					Hygiene Outside							
					Site 7							
					Site 8		7	fungal alpha amylase	$0.2 ng/m^3$ (2.9)	0.4		
					Site 9		4		$0.1 ng/m^3$ (2.6)	0.1		
							11		$0.2 ng/m^3$ (4.4)	0.7		
					Maintenance							
					Site 7							
					Site 8		0		-	-		
					Site 9		0	fungal alpha amylase	-	-		
							2		$0.1 ng/m^3$ (1.1)	0.1		
					Quality							

					Control Site 7 Site 8 Site 9 Miscellaneous Site 7 Site 8 Site 9		0 0 5	fungal alpha amylase fungal alpha amylase	- - 0.9ng/m^3 (3.3)	- - 1.5		
Page (2010)		IOM sampler Teflon filter 2 L/min	P & A	Large Bakery	High exposure* Low Exposure*		60(P) + 6 (A) 23(P) + 13(A)	Inhalable Flour Dust fungal alpha amylase Wheat Inhalable Flour Dust fungal alpha amylase Wheat	3.01mg/m^3 2.10ng/m^3 12.6µg/m^3 0.235mg/m^3 0.122ng/m^3 0.433µg/m^3		(Trace-65mg/m^3) (0.095-11000ng/m^3) (0.18-900µg/m^3) (0-14mg/m^3) (0.019-1.2ng/m^3) (0.14-3.6µg/m^3)	*high exposure defined as activities prior to the oven *low exposure defined as activities from oven to shipping and office work
Roberge		IOM and Closed	P		Dough mixer/weighin		11	Total Dust			4.9 (<0.03-	Daily Average total dust

(2006)		Cassettes 2 L/min			g Dough moulding 1.Dough mixer(367min) 1.Table(368min) 2.Dough mixer(302min) 2.Table(349min) 2.Moulder(36		13	Inhalable fraction Total Dust Inhalable fraction Total Dust Inhalable fraction Total Dust Inhalable fraction Total Dust Inhalable fraction Total Dust Inhalable fraction Total Dust Inhalable fraction Total Dust Inhalable fraction		4.6mg/m^3 5.7mg/m^3 1.5mg/m^3 2.4mg/m^3 4.9mg/m^3 8.0mg/m^3 2.7mg/m^3 4.7mg/m^3 0.9mg/m^3 1.2mg/m^3 7.5mg/m^3 14mg/m^3	17) 8.0 (0.2-19) 2.4 (<0.03-8.7) 3.8 (0.2-9.2)	Exposure Values(averages time spent at each station for an 8 hour workshift) 1: 3.5 1: 1.2 2: 3.6 2: 2.0 2.:0.6 3: 4.6 3: 1.5 3: 2.2 4: 0.6 4: - 5: 3.5 5: - 6: 5.6 6: - 7: - 7: - 8: 1.2 8: 1.9 9: 4.4

					1min)							9: -
								Total Dust		2.2mg/m^3		10: 7.5
								Inhalable fraction		4.1mg/m^3		10: -
					3.Dough mixer(278min)							11: 1.8
								Total Dust		3.1mg/m^3		11: -
								Inhalable fraction		5.9mg/m^3		
					3.table(334min)			Total Dust		1.5mg/m^3		Also contains data on amount of flour used vs. the total dust concentration
								Inhalable fraction		2.0mg/m^3		
								Total Dust		0.1mg/m^3		
					3.Table(331min)			Inhalable fraction		0.5mg/m^3		
								Total Dust		7.7mg/m^3		
					4.Dough mixer(171min)			Inhalable fraction		11mg/m^3		
								Total Dust		8.7mg/m^3		
								Inhalable fraction		9.2mg/m^3		
					4.Table (174min)			Total Dust		9.1mg/m^3		
								Inhalable fraction		14mg/m^3		
					5.Dough							

					mixer(77min)			Total Dust		2.4mg/m^3		
								Inhalable fraction		3.7mg/m^3		
					5.Table(127min)			Total Dust		<0.03mg/m^3		
								Inhalable fraction		0.2mg/m^3		
					6.Dough mixer(260min)			Total Dust		<0.03mg/m^3		
								Inhalable fraction		0.2mg/m^3		
								Total Dust		2.1mg/m^3		
					6.Table(143min)			Inhalable fraction		2.4mg/m^3		
								Total Dust		2.4mg/m^3		
								Inhalable fraction		3.5mg/m^3		
					7.Dough mixer(260min)			Total Dust		11mg/m^3		
								Inhalable fraction		18mg/m^3		
					7.Table(143min)			Total Dust		0.1mg/m^3		
								Inhalable fraction		0.4mg/m^3		
								Total Dust		16mg/m^3		
					8.Dough Mixer(258min							

					)			Inhalable fraction		19mg/m^3		
								Total Dust		3.6mg/m^3		
					8.Table(384min)			Inhalable fraction		5.2mg/m^3		
								Total Dust		0.8mg/m^3		
								Inhalable fraction		1.4mg/m^3		
					9.Dough mixer(195min)			Total Dust		3.9mg/m^3		
								Inhalable fraction		6.9mg/m^3		
					9.Table(197min)		11	Total Dust	3.0 (6.0)	6.0mg/m^3 (5.0)		
							11	Inhalable fraction	4.9 (4.2)	8.6mg/m^3 (6.9)	4.9mg/m^3(0.03-16.5)	
					10.Dough mixer(185min)		11	Respirable fraction	0.1 (2.5)	0.1mg/m^3 (0.1)	8.0mg/m^3 (0.2-19)	
							11	Total Dust	1.1 (6.2)			
					10.Table(160min)		11	Inhalable fraction	2.2 (3.7)	2.5mg/m^3 (2.5)	0.1mg/m^3 (0.03-0.5)	
					11.Dough mixer(159min		11	Respirable fraction	0.1 (2.2)	3.7mg/m^3 (2.8)	2.4mg/m^3	

					) 11.Dough mixer(186min) All Dough Mixer All Table					$0.1mg/m^3$ (0.1)	(0.03-8.7) $3.7mg/m^3$ (0.2-9.2) $0.1mg/m^3$ (0.03-0.3)	
Tagiyeva (2012)		Wipe Sampling $100cm^2$	Area Wipe Sampli ng	Bakery (16 workers) Bakery (35 workers)	Worktop Floor Beneath Mixer Worktop			Wheat Flour Antigen Fungal Alpha Amylase Wheat Flour Antigen Fungal Alpha Amylase		2.97 ng/cm^2 0.03 ng/cm^2 6.46 ng/cm^2 1.94 ng/cm^2 293.08 ng/cm^2		Study focuses on the level of WFA and FAA levels being brought home from work on the bakery employees by taking vaccum samples and wipe samples

								Wheat Flour Antigen		0.32 ng/cm^2		
				Bakery (22 workers)	Floor Beneath Mixer			Fungal Alpha Amylase		1449.15 ng/cm^2		
								Wheat Flour Antigen		8.32 ng/cm^2		
					Worktop			Fungal Alpha Amylase		309.91 ng/cm^2		
								Wheat Flour Antigen		0.08 ng/cm^2		
				Bakery (2 workers)	Floor Beneath Mixer			Fungal Alpha Amylase		1308.25 ng/cm^2		
								Wheat Flour Antigen		0.95 ng/cm^2		
					Worktop			Fungal Alpha Amylase		1.67 ng/cm^2		
				Bakery (1 worker)				Wheat Flour Antigen		0.0015 ng/cm^2		
					Floor Beneath Mixer			Fungal Alpha Amylase		1.14 ng/cm^2		
								Wheat Flour Antigen		0.01 ng/cm^2		
					Worktop			Fungal Alpha Amylase		4.89 ng/cm^2		
								Wheat Flour Antigen		0.0015 ng/cm^2		
					Floor Beneath			Fungal Alpha				

					Mixer			Amylase Wheat Flour Antigen Fungal Alpha Amylase Wheat Flour Antigen Fungal Alpha Amylase		5.50 ng/cm^2 0.01 ng/cm^2		
Thorpe (2013)		Respicon Inhalable	A	Bakery	Background Excess flour brushed with extractor on Excess flour brushed with extractor off Mixing Machine Dough	Pita Bread	1	Inhalable dust fraction		0.98mg/m 2.94 mg/m^3 12.15 mg/m^3 8.31 mg/m^3 5.59 mg/m^3		*All Peaks caused by flour being sprinkled over pita dough Only 1 measurement taken for each number Focus of the paper is on the comparison of sampling devices

		DataRam 1	A		transfer Dough cut/weighed Flour Sifter Brushed clean Floor Swept Total Duration Average Background Excess flour brushed with extractor on Excess flour brushed with extractor off Mixing Machine Dough transfer			Total Dust		1.20 mg/m^3 4.53 mg/m^3 1.32 mg/m^3 2.26 mg/m^3 0.083 mg/m^3 0.103 mg/m^3 0.589 mg/m^3 0.358 mg/m^3 0.289 mg/m^3 0.202 mg/m^3		

		PDM inhalable	A		Dough cut/weighed Flour Sifter Brushed clean Floor Swept Total Duration Average Background Excess flour brushed with extractor on Excess flour brushed with extractor off Mixing Machine Dough transfer			Inhalable dust fraction		0.186 mg/m^3 0.107 mg/m^3 0.136 mg/m^3 2.20 mg/m^3 4.53 mg/m^3 14.03 mg/m^3 13.80 mg/m^3 15.99 mg/m^3 2.63 mg/m^3 12.59 mg/m^3 4.72 mg/m^3		

					Dough cut/weighed							
		DataRam 2	A		Flour Sifter Brushed clean Total Duration Average Background Excess flour brushed with extractor on Excess flour brushed with extractor off Mixing Machine Dough transfer			Total Dust		0.066 mg/m^3 0.109 mg/m^3 0.484 mg/m^3 0.347 mg/m^3 0.366 mg/m^3 0.188 mg/m^3 0.200 mg/m^3 0.137 mg/m^3		
		Respicon Inhalable	P		Dough cut/weighed Flour Sifter			Inhalable Dust Fraction		0.41 mg/m^3 0.81 mg/m^3 3.24 mg/m^3		

		DataRam 1	P		Brushed clean Total Duration Average Background Unknown Source *Peak1 Peak2 Peak3 Peak4 Peak5 Peak6 Peak7 Peak8 Peak9 Peak10 Sifter Hopper Filling Flour Tray set down Total Duration Average			Total Dust		2.65 mg/m^3 2.90 mg/m^3 2.62 mg/m^3 2.52 mg/m^3 3.10 mg/m^3 3.19 mg/m^3 3.17 mg/m^3 2.17 mg/m^3 2.40 mg/m^3 2.04 mg/m^3 7.27 mg/m^3 1.45 mg/m^3 0.508 mg/m^3 0.473 mg/m^3 0.165 mg/m^3 0.165 mg/m^3 0.308 mg/m^3 0.217 mg/m^3 0.234 mg/m^3 0.245 mg/m^3		

		PDM DataRam IOM Respicon DataRam IOM PDM Respicon	A		Background Unknown Source *Peak1 Peak2 Peak3 Peak4 Peak5 Peak6 Peak7 Peak8 Peak9 Peak10 Sifter Hopper Filling Flour Tray set down Total Duration Average Average Average			Total Total Total Respirable Thoracic Inhalable Total Total Inhalable Inhalable		0.306 mg/m^3 0.256 mg/m^3 0.197 mg/m^3 0.224 mg/m^3 0.810 mg/m^3 0.616 mg/m^3 0.433 mg/m^3 2.64 mg/m^3 0.14 mg/m^3 3.57 mg/m^3 0.1 mg/m^3 0.31 mg/m^3 2.26 mg/m^3 0.14 mg/m^3 2.32 mg/m^3 0.74 mg/m^3 0.97 mg/m^3		

					Average Average Average Average Average Average							
van tongeren (2009)	1985-2003		P & A	Industry	Bakery		1148	Inhalable flour dust	3.2mg/m^3 (3.9)	7.8mg/m^3	(0.0-571.9)	
				Occupations	Bakery workers		283	Inhalable flour dust	3.5mg/m^3 (3.6)	7.9mg/m^3	(0.0-213.0)	
					Cleaners		67	Inhalable flour dust	6.9mg/m^3 (5.8)	42.4mg/m^3	(0.1-1148.7)	
					Dough shapers/dusters		143	Inhalable flour dust	4.5mg/m^3 (3.4)	8.5mg/m^3	(0.2-70.1)	
					Millers		131	Inhalable flour dust	3.3mg/m^3 (4.3)	8.2mg/m^3	(0.0-112.6)	
					Mixers/weigh		662	Inhalable flour dust	3.4mg/m^3 (4.3)	9.2mg/m^3	(0.00-	

					ers		75	Inhalable flour dust	2.2mg/m^3 (3.3)	4.0mg/m^3	571.9)	
					Oven operators		90	Inhalable flour dust	1.6mg/m^3 (3.6)	3.4mg/m^3	(0.0-26.8)	
					Packers/slicers			Inhalable flour dust			(0.0-29.1)	
Vanhanen (1996)		Millipore Cassette 2 L/min	P & A	4 Bakeries	Dough making P		7	Total Dust		8.4mg/m^3	(3.0-18.8)	<dl -- below the detection limit
							7	Alpha-Amylase		2.3µg/m^3	(<0.2-6.6)	
							--	Cellulase CBH 1		--	--	Detection limit-- 0.1mg/m^3
							--	Xylanase pI 9.0		--	--	for total dust
					A		9	Total Dust		2.5mg/m^3	(0.7-8.4)	For alpha amylase-- 0.1µg/sample
							9	Alpha-Amylase		1.5µg/m^3	(0.04-4.3)	
							8	Cellulase CBH 1		<dl	--	
							8	Xylanase pI 9.0		65ng/m^3	(2-200)	Fungal alpha-amylase and proteases.
					Bread making P		10	Total Dust		3.2mg/m^3	(1.2-5.5)	
							10	Alpha-Amylase		0.1µg/m^3	(<0.4	
							--	Cellulase CBH 1		--	--	
							--	Xylanase pI 9.0		--	--	

							11	Total Dust		1.1mg/m^3	(0.1-2.9)	
					A		11	Alpha-Amylase		0.3µg/m^3	(<0.02-2.0)	
							1	Cellulase CBH 1		<dl	--	
							1	Xylanase pI 9.0		2ng/m^3	(2-200)	
					Packing		1	Total Dust		0.1mg/m^3	--	
					A		1	Alpha-Amylase		<0.01µg/m^3	--	
							1	Cellulase CBH 1		<dl	--	
							1	Xylanase pI 9.0		2ng/m^3	--	
				Crispbread factory	Crispbread factory		10	Total Dust		3.1mg/m^3	(1.0-9.4)	
					P		10	Alpha-Amylase		0.1µg/m^3	(0.7	
							--	Cellulase CBH 1		--	--	
							--	Xylanase pI 9.0		--	--	
							6	Total Dust		0.8mg/m^3	(0.2-2.1)	
					A		6	Alpha-Amylase		0.03µg/m^3	(<0.02-	

							4	Cellulase CBH 1		85ng/m^3	0.09)	
							4	Xylanase pI 9.0		22ng/m^3	(25-160)	
											(7-40)	
Stuurman (2007)	2005	Pas-6 Sampling head	P	13 Dutch Industrial Bakeries	Bread Baker		20	B(1→3) Glucan	1.48µg/m3 (2.84)	2.57 µg/m3	(0.44-12.11)	
							20	Inhalable Dust	1.98mg/m3 (2.31)	2.67 mg/m3	(0.29-7.43)	
		Teflon filter (Millipore 1.0 µm)					19	Wheat Allergens	14.97µg/m3 (3.02)	24.26 µg/m3	(1.35-81.06)	
					Pastry Baker		9	B(1→3) Glucan	1.33µg/m3 (3.13)	2.87 µg/m3		
							10	Inhalable Dust	1.62mg/m3 (2.62)	2.40 mg/m3		
		2 L/min flow rate					9	Wheat Allergens	7.05µg/m3 (4.87)	21.94 µg/m3	(0.46-16.16)	
					Dough Maker		62	B(1→3) Glucan	1.37µg/m3 (3.23)	3.81 µg/m3	(0.40-8.27)	
							68	Inhalable Dust	1.85mg/m3 (3.35)	4.21 mg/m3	(0.61-131.89)	
							64	Wheat Allergens	17.42µg/m3 (3.96)	56.60 µg/m3		
					Wrapper		30	B(1→3) Glucan	0.55µg/m3 (1.55)	0.62 µg/m3	(0.39-90.66)	
							31	Inhalable Dust	0.37mg/m3 (1.97)	0.45 mg/m3	(0.13-82.40)	
							30	Wheat Allergens	0.53µg/m3 (3.09)	1.09 µg/m3	(0.42-1833.18)	
					Cleaner		7	B(1→3) Glucan	0.72µg/m3 (1.38)	0.76 µg/m3		
							7	Inhalable Dust	0.47mg/m3 (1.49)	0.51 mg/m3	(0.38-1.75)	
							7	Wheat Allergens	1.03µg/m3 (1.47)	1.10 µg/m3	(0.12-1.21)	

											(0.07-6.60)	
					Boss/foreman		16	B(1→3) Glucan	1.05µg/m3 (2.95)	2.08 µg/m3	(0.44-1.29)	
							17	Inhalable Dust	0.85mg/m3 (3.28)	2.05 mg/m3	(0.22-0.98)	
							17	Wheat Allergens	4.30µg/m3 (6.36)	17.61 µg/m3	(0.63-1.66)	
					Storage Worker		6	B(1→3) Glucan	0.98µg/m3 (4.79)	4.40 µg/m3	(0.39-14.11)	
							6	Inhalable Dust	1.10mg/m3 (6.33)	6.50 mg/m3	(0.14-18.17)	
							6	Wheat Allergens	3.82µg/m3 (16.27)	159.54 µg/m3	(0.13-150.75)	
					Maintenance Worker		11	B(1→3) Glucan	1.11µg/m3 (3.20)	2.28 µg/m3	(0.47-23.83)	
							12	Inhalable Dust	1.01mg/m3 (3.94)	2.48 mg/m3	(0.16-35.69)	
							12	Wheat Allergens	3.05µg/m3 (6.89)	13.21 µg/m3	(0.40-949.39)	
					Oven Operator		14	B(1→3) Glucan	0.84µg/m3 (2.60)	1.41 µg/m3	(0.42-10.86)	
							15	Inhalable Dust	0.92mg/m3 (2.23)	1.19 mg/m3	(0.16-10.77)	
							15	Wheat Allergens	5.80µg/m3 (2.87)	8.84 µg/m3	(0.29-	

											60.56) (0.40-6.46) (0.20-3.29) (0.79-26.74)	
Storaas (2007)	2004	Gelman Total Dust Sampler 25mm Teflon filter (Millipore 1 µm) 2 L/min flow rate	211 P & 24 A	6 Bakeries	Dough making Bread Forming Confectionay Oven Work Packing Administratio n Packers, oven		107	Total Dust	3.14 mg/m3 1.51 mg/m3 1.35 mg/m3 0.54 mg/m3 0.29 mg/m3 0.06 mg/m3		(0.93-16.56) (0.26-9.15) (0.41-5.35) (0.17-1.87) (0.02-1.81) (0-0.26)	Exposures were reported clumped into categories as the study focused on the incidence of rhinitis versus exposure

					workers, administration Mainly confectionary workers and bread formers Mainly dough makers Mainly dough makers		33 24 19				(<1.0 mg/m3) (1.0-1.9 mg/m3) (2.0-3.9 mg/m3) (>3.9 mg/m3)	
Droste (2005)	1997-1999	Gillair 5 PAS 6 head Teflon filter (Millipore 1.0 µm) 2L/min flow rate	P	Traditional and Industrial Bakeries	Low Exposure jobs* Medium Exposure Jobs*		31 32 32 55 56 55 102	Inhalable Dust Wheat Allergen Fungal Alpha Amylase Inhalable Dust Wheat Allergen Fungal Alpha Amylase	0.53mg/m3(1.14**) 2.81 ng/m3 (1.15**) 0.07 pg/m3 (1.16**) 1.05 mg/m3 (1.15**) 8.13 ng/m3 (1.23**) 0.27 pg/m3			*Low Exposure Jobs: industrial packers *Medium Exposure Jobs: Industrial bakers, traditional pastry bakers *High Exposure jobs: traditional bread bakers, traditional bread+pastry

					High Exposure Jobs*		104 96	Inhalable Dust Wheat Allergen Fungal Alpha Amylase	(1.31**) 2.09 mg/m3 (1.07**) 16.34 ng/m3 (1.14**) 0.40 pg/m3 (1.20**)			bakers **Standard error of the means rather than normal standard deviation
Peretz (2005)	August 2000 – July 2001	PAS6 Head 2 L/min Flow rate	P	Traditional and Industrial Bakeries	Traditional Bakeries (All Tasks) Industrialized Bakeries (All Tasks)		80 65 91 83	Inhalable Dust Wheat Allergens Inhalable Dust Wheat Allergens	1.71mg/m3 (2.99) 8.63µg EQ/m3 (7.45) 1.03mg/m3 (3.72) 2.14µg EQ/m3(14.07)			EQ – equivalent (in comparison with an arbitrary wheat allergen mixture standard
Smith (2004)		UKAEA Head Gelman GF(A) 25 mm Filter	P	Bakery	Sieving Without LEV Sieving With LEV Sieving Without LEV Weighing Without LEV Weighing With LEV Mixing	Bread	13 9 13 6 14 76 42	Total Inhalable Dust		15.8 mg/m3 8.7 mg/m3 15.0mg/m3 7.8 mg/m3 2.7 mg/m3 4.5 mg/m3 4.9 mg/m3	15.0 (5.8-28.5) 5.7 (2.1-21.2) 15.8 (5.8-28.5) 11.0 (4.2-45.7) 2.0 (0.3-8.0) 3.0 (0.3-	LEV: Local Exhaust Ventilation

					Without LEV Bread Plant ALL Cake Mixing Room	Cake	37			11.1 mg/m3	21.7) 1.9 (0.1-49.9) 4.4 (1.0-139.0)	
Heederik (2001)	1991-1993	Teflon 1.0 µm PAS-6 Head 2 L/min	P	Bakery	1.Low Exposure 2.Medium-Low Exposure 3.Medium Exposure 4.Medium-High Exposure			Wheat Allergen Total Dust Wheat Allergen Total Dust Wheat Allergen Total Dust Wheat Allergen Total Dust		0.7 µg/m3/yr (0.5) 1.5 mg/m3/yr (0.8) 5.3 µg/m3/yr (3.0) 5.4 mg/m3/yr (1.7) 22.4 µg/m3/yr (8.0) 12.0 mg/m3/yr (3.0) 70.6 µg/m3/yr (2.1)		Grouped workers into categories based on level of exposure but did not disclose tasks Original data from Houba 1998 Exposures are on a per year basis

					5.High Exposure			Wheat Allergen Total Dust		29.3 mg/m3/yr (8.2) 224 µg/m3/yr (109) 81.9mg/m3/yr (39.3)		
Elms (2001)	1998	IOM Head GF/A 1.6mm Millipore filter 2 L/min flow rate	P	Bakery	Mixer Bakery 1 Mixer Bakery 2 Mixer Bakery 3 Dough Cutter and Mixer Bakery 4 Dough Cutter and Mixer Bakery 2		4 1 4 1 4 1 4 1 4 1 4	Fungal alpha Amylase Inhalable Dust Fungal alpha Amylase Inhalable Dust Fungal alpha Amylase Inhalable Dust Fungal alpha Amylase Inhalable Dust Fungal alpha Amylase		104.5 ng/m3 7.9 mg/m3 9.6 ng/m3 12.3 mg/m3 17.1 ng/m3 7.5 mg/m3 2.8 ng/m3 13.5 mg/m3 0 ng/m3 0.9 mg/m3 6 ng/m3		

							1	Inhalable Dust		5.1 mg/m3		
					End of line bakery 1							
							4	Fungal alpha Amylase		12.7 ng/m3		
							1	Inhalable Dust		0 mg/m3		
					Pastries Bakery 3		4			17.6 ng/m3		
							1	Fungal alpha Amylase		3.5 mg/m3		
								Inhalable Dust				
					Pastries bakery 3		1			16.7 ng/m3		
								Fungal alpha Amylase		0.5 mg/m3		
										7.9 mg/m3		
								Inhalable Dust				
					Flour Mixer (mixing room)		1			0 ng/m3		
								Fungal alpha Amylase		0.4 mg/m3		
								Total Inhalable Protein		10.4 mg/m3		
					Flour Mixer (bread products)			Inhalable Dust				
							1			2.7 ng/m3		
										0.6 mg/m3		
								Fungal alpha Amylase		36.7 mg/m3		
								Total Inhalable Protein				
							1			18.3 ng/m3		
								Inhalable Dust		4.1 mg/m3		

								Fungal alpha Amylase		21.4 mg/m3		
							1	Total Inhalable Protein		26.5 ng/m3		
								Inhalable Dust		1.7 mg/m3		
										12.3 mg/m3		
								Fungal alpha Amylase				
							1			8.7 ng/m3		
								Total Inhalable Protein		1.2 mg/m3		
								Inhalable Dust		12.2 mg/m3		
							1	Fungal alpha Amylase		3 ng/m3		
										0.9 mg/m3		
								Total Inhalable Protein		7.5 mg/m3		
								Inhalable Dust				
							1			10.9 ng/m3		
								Fungal alpha Amylase		1.4 mg/m3		
										2.2 mg/m3		
					Dough mixer/cutter			Total Inhalable Protein				
							1	Inhalable Dust		0 ng/m3		
										3.3 mg/m3		
										68.1 mg/m3		
								Fungal alpha Amylase				
								Total Inhalable				

					Packer		1 1 1 1 1 1	Protein Inhalable Dust Fungal alpha Amylase Total Inhalable Protein Inhalable Dust Fungal alpha Amylase Total Inhalable Protein Inhalable Dust Fungal alpha Amylase Total Inhalable Protein Inhalable Dust Fungal alpha Amylase Total Inhalable Protein Inhalable Dust		0 ng/m3 0.1 mg/m3 9 mg/m3 19.2 ng/m3 1 mg/m3 13.5 mg/m3 4 ng/m3 1.6 mg/m3 3.1 mg/m3 2.2 ng/m3 0.8 mg/m3 1.3 mg/m3 0 ng/m3 0 mg/m3 1.2 mg/m3 0 ng/m3 2.9 mg/m3		

										39.8 mg/m3		
							1	Fungal alpha Amylase Total Inhalable Protein Inhalable Dust		0 ng/m3 0.3 mg/m3 3 mg/m3		
							1	Fungal alpha Amylase Total Inhalable Protein Inhalable Dust		0 ng/m3 0.4 mg/m3 3.8 mg/m3		
					Loader		1	Fungal alpha Amylase Total Inhalable Protein Inhalable Dust		29.8 ng/m3 0.2 mg/m3 0.8 mg/m3		
							1	Fungal alpha Amylase Total Inhalable Protein Inhalable Dust		0 ng/m3 1 mg/m3 3.6 mg/m3		
							1	Fungal alpha Amylase		10.9 ng/m3 0.5 mg/m3 7.8 mg/m3		

							1	Total Inhalable Protein Inhalable Dust		0 ng/m3 0.1 mg/m3 2.3 mg/m3		
					Confectionary and Pastries		1	Fungal alpha Amylase Total Inhalable Protein Inhalable Dust		0 ng/m3 0.2 mg/m3 3.5 mg/m3		
					Ovens		1	Fungal alpha Amylase Total Inhalable Protein Inhalable Dust		0 ng/m3 0.8 mg/m3 5.2 mg/m3		
					End of the line		1	Fungal alpha Amylase Total Inhalable Protein Inhalable Dust		0.2 ng/m3 0.2 mg/m3 2.8 mg/m3		
							1	Fungal alpha Amylase Total Inhalable Protein Inhalable Dust		4.6 ng/m3 0.7 mg/m3 20.4 mg/m3		
							1			0 ng/m3 1.1 mg/m3		

								Fungal alpha Amylase Total Inhalable Protein Inhalable Dust Fungal alpha Amylase Total Inhalable Protein Inhalable Dust Fungal alpha Amylase Total Inhalable Protein Inhalable Dust Fungal alpha Amylase Total Inhalable Protein Inhalable Dust Fungal alpha Amylase		18.6 mg/m3		

								Total Inhalable Protein Inhalable Dust Fungal alpha Amylase Total Inhalable Protein Inhalable Dust				
Lillienberg (2000)		PAS-6 25mm Teflon filter 2 L/min	P	Bakery	All tasks combined		80 80 80 80	Fungal Alpha Amylase Fungal Alpha Amylase Fungal Alpha Amylase Fungal Alpha Amylase	1.46 ng/m3 (8) 0.81 ng/m3 (9) 1.54 ng/m3 (6) 4.70 ng/m3 (5)	12.51 ng/m3 11.31 ng/m3 8.62 ng/m3 25.91 ng/m3	(0.19-192.44) (0.12-214.83) (0.28-207.03) (1.09-614.63)	Paper compares three laboratories analyzing the same samples as well as polyclonal vs monoclonal and breaks down totals between three countries
Jeffrey (1999)	1990-1991	UKAEA or Casella cyclone head 25mm GFA filter	P	Bakery	All Tasks Combined Category A*		144 87 57	Total Inhalable Dust Total Respirable Dust Total Inhalable Dust	2.8 mg/m3 (3.3) 0.17 mg/m3 (0.28) 4.9 mg/m3 (2.3) 1.0 mg/m3 (2.7)	6.7 mg/m3 (5.3) 1.5 mg/m3	(0.1-23.7) (0.01-3.6) (0.6-23.7) (0.1-5.5)	*Category A: dough brake/roll machine, general cleaning/bag collection, weighing and mixing, dividing and moulding, cake mixing *Category B:

					Category B*			Total Inhalable Dust		(1.5)		Hot plate, lidding, filling, pie shell making, sugar confectionery, proving and finishing/packing/glazing/shop office
Smith (1998)	1990-1996		P	19 bread Bakeries 3 cake bakeries	Sieving with LEV Sieving without LEV Weighing with LEV Weighing without LEV Doughmaking without LEV Sieving without LEV Weighing without LEV Mixing without LEV	Bread Cake	27 35 22 26 80 12 8 24	Total Dust	8.2 mg/m3 (13.3) 11.4 mg/m3 (73.1) 2.7 mg/m3 (10.3) 8.2 (mg/m3 146.7) 3.3 mg/m3 (19.5) 35.7 mg/m3 (26) 19.2 mg/m3 (20.7) 3.8 mg/m3 (4.2)		10.1 (0.9-52.6) 9.2 (0.9-349.5) 2.8 (0.2-51.0) 7.0 (1.0-770.0) 3.2 (0.1-142.2) 30.6 (15.9-90) 14.6 (7.4-68.5) 3.9 (0.5-	Similar to Smith (2004) data, using same dataset with different numbers?

											16.3)	
Brisman (1998)	1993	IOM sampler 2 L/min	P	Bakery	Bread Production	Bread	6	Inhalable dust			(1.0-3.8 mg/m3)	
					Dough Maker		1 1			2.2 mg/m3 2.7 mg/m3		
					Line Operator		1			1.0 mg/m3		
					Packer		2			0.3 mg/m3		
			A		Flour Adding, Bread Forming, Packing		3				(1.6-1.9 mg/m3)	
Houba (1996-2)	1992-1993	Teflon 1.0 µm PAS-6 Head 2 L/min	P	Bakery	High*	Crispbread	27	Fungal alpha amylase	18.1 ng/m3 (4.3)	39.4 ng/m3	(0.2-221.8)	*High: doughmakers in crispbread factory *Medium: doughmakers and all around staff from wheat bread production, bread and mixed bakers from small bakeries *Low: non production
					Medium*	Mixed	43		1.3 ng/m3 (3.8)	3.4 ng/m3	(0.2-33.1)	
					Low*	Mixed	7		0.7 ng/m3 (4.0)	1.9 ng/m3	(0.2-8.8)	
					Indistinct*	Crispbread	15		6.1 ng/m3 (8.2)	25.1 ng/m3	(0.2-150.2)	

												workers handling amylase occasionally *Indistinct: All around workers from crispbread factory
Houba (1997-2) Expanded from Houba 1996-2		PAS-6 Head Teflon 1.0 µm 2 L/min	P	Large Industrial Bakery	Dough Maker All around staff Oven Staff Slicers, packer, transport Production managers	Wheat Bread Pastry Crispbakes Rye Bread Wheat Bread Pastry Crispbakes	32 32 27 7 35 4 26 77 119 20 27	Fungal alpha amylase	0.8 ng/m3 (5.14) <LOD 18.1 ng/m3 (4.56) 0.2 ng/m3 (1.48) 0.2 ng/m3 (2.35) <LOD 1.3 ng/m3 (11.02) 0.2 ng/m3 (1.45) 0.2 ng/m3 (1.44) <LOD 0.2 ng/m3 (1.33)			LOD: 250 pg/m3

				Small traditional bakery	Maintenance/cleaner		31		0.3 ng/m3 (3.09)			
							54		0.2 ng/m3 (1.81)			
					Bread Baker	Bread						
							16		<LOD			
				Large Industrial Bakery	Mixed Baker	Mixed						
					Pastry cook	Pastry			0.24 mg/m3			
								Total Dust	1.2 ng/m3			
					Dough Making	Wheat Bread		Fungal Alpha amylase	1.45 mg/m3			
									229.3 ng/m3			
								Total Dust	0.50 mg/m3			
					Dough Making			Fungal Alpha amylase	3.4 ng/m3			
				Small bakery		Crispbakes		Total Dust	0.76 mg/m3			
								Fungal Alpha amylase	17.2 ng/m3			
								Total Dust	1.13 mg/m3			
								Fungal Alpha amylase	4.5 ng/m3			
									1.03 mg/m3			
								Total Dust	0.3 ng/m3			
					Dough			Fungal Alpha				

					Making	Mixed		amylase Total Dust Fungal Alpha amylase Total Dust Fungal Alpha amylase	2.39 mg/m3 59.1 ng/m3			
Houba (1997)		Teflon 1.0 µm PAS-6 Head 2 L/min	P	Bakeries Large Industrial Bakery	ALL Dough Makers	Bread Confecti onary Crispbak es Rye Bread	571 449 507 37 32 40 25 40 15 7 4	Inhalable Flour Dust Wheat Allergen Fungal alpha amylase Inhalable Flour Dust Wheat Allergen Inhalable Flour Dust Wheat Allergen Inhalable Flour Dust Wheat Allergen Inhalable Flour	1.0 mg/m3 (2.5bw)(2.0ww) 684ng/m3 (6.5bw)(3.1ww) 0.3 ng/m3 (3.1bw)(2.4ww) 4.5 mg/m3(2.1 bw)(1.7 ww) 16511ng/m3(2.7b w)(2.3ww) 2.2 mg/m3(1.5 bw)(1.8 ww) 1969 ng/m3(2.8 bw)(2.4 ww) 2.8 mg/m3(1.3 bw)(1.5 ww) 5104 ng/m3(1.0	2.0 mg/m3 5360 ng/m3 3.3 ng/m3 6.8 mg/m3 35068 ng/m3 2.8 mg/m3 3571 ng/m3 3.2 mg/m3 5853 ng/m3 1.0 mg/m3 503 ng/m3		BW: between workers WW: within worker LOD: 0.25 ng/m3

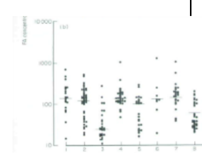
					All-round Staff		37	Dust	bw)(2.1 ww)	1.4 mg/m3		
						Bread	35	Wheat Allergen	0.9 mg/m3	4377 ng/m3		
							4		364 ng/m3	7.5 mg/m3		
						Confectionary	4	Inhalable Flour Dust		18505 ng/m3		
							29	Wheat Allergen	0.9 mg/m3(2.0 bw)(2.3 ww)	1.3 mg/m3		
							16			2305 ng/m3		
						Crispbakes		Inhalable Flour Dust	997 ng/m3(3.3 bw)(4.1 ww)			
							34	Wheat Allergen	1.2 mg/m3	1.0 mg/m3		
					Oven Staff							
							30	Inhalable Flour Dust	2487 ng/m3	3653 ng/m3		
						Bread	21	Wheat Allergen	1.1 mg/m3(1.2 bw)(1.8 ww)	0.9 mg/m3		
							21			720 ng/m3		
									876 ng/m3(1.0 bw)(5.4 ww)			
						Confectionary	24			0.8 mg/m3		
								Inhalable Flour Dust				
							15			152 ng/m3		
							5	Wheat Allergen	0.7 mg/m3(2.1 bw)(2.0 ww)	0.4 mg/m3		
						Crispbakes						
							5	Inhalable Flour Dust		37 ng/m3		
									771 ng/m3(6.4 bw)(2.6 ww)			
								Wheat Allergen				
						Rye Bread	66		0.6 mg/m3(1.0 bw)(2.4 ww)	0.5 mg/m3		
					Slicer, packer, transport			Inhalable Flour Dust				
							56			173 ng/m3		
									302 ng/m3(1.6 bw)(4.6 ww)			
							26	Wheat Allergen		0.5 mg/m3		
							22	Inhalable Flour Dust	0.7 mg/m3(1.4 bw)(1.4 ww)	102 ng/m3		
						Bread						
							22			0.8 mg/m3		
								Wheat Allergen	128 ng/m3(1.5 bw)(1.6 ww)			
							17			599 ng/m3		
						Confecti						

						onary	17	Inhalable Flour Dust	0.4 mg/m3	0.5 mg/m3		
							13	Wheat Allergen	36 ng/m3	40 ng/m3		
						Crispbakes		Inhalable Flour Dust				
							13		0.3 mg/m3(1.6 bw)(2.3 ww)	1.3 mg/m3		
					Production Manger		13	Wheat Allergen		7745 ng/m3		
						Rye Bread	3	Inhalable Flour Dust	74 ng/m3(2.2 bw)(2.3 ww)	0.5 mg/m3		
							3	Wheat Allergen	0.4 mg/m3(1.6 bw)(2.1 ww)	79 ng/m3		
							4	Inhalable Flour Dust	62 ng/m3(1.7 bw)(2.1 ww)	0.7 mg/m3		
						Bread	1			304 ng/m3		
								Wheat Allergen	0.8 mg/m3(1.0 bw)(1.3 ww)			
						Confectionary	27			0.9 mg/m3		
							20	Inhalable Flour Dust	150 ng/m3(1.0 bw)(4.4 ww)	528 ng/m3		
				Small traditional bakery	Maintenance /Cleaning							
						Crispbake		Wheat Allergen	0.5 mg/m3(1.2 bw)(1.6 ww)			
							36			3.8 mg/m3		
								Inhalable Flour Dust	38 ng/m3(1.0 bw)(1.4 ww)			
							31			8687 ng/m3		
					Baker		57	Wheat Allergen		2.7 mg/m3		
						ALL	55	Inhalable Flour Dust	0.7 mg/m3(1.0 bw)(3.7 ww)	5298 ng/m3		
					Baker		22			1.0 mg/m3		
								Wheat Allergen	859 ng/m3(2.4 bw)(7.2 ww)			
				Large Industrial bakery			16			1183 ng/m3		
					Cook	Bread			0.5 mg/m3			
							32	Inhalable Flour Dust	60 ng/m3	3.2 ng/m3		
						Mixed	32	Wheat Allergen	0.6 mg/m3	<LOD		

				Small traditional bakery	Dough Maker All-round staff All other jobs Baker Baker Cook	Pastry Bread Confectionary Crispbake Rye bread Bread Confectionary Crispbake All Bread Mixed	27 7 35 4 26 243 31 54 16	Inhalable Flour Dust Wheat allergen Inhalable Flour Dust Wheat allergen Inhalable Flour Dust Wheat allergen Fungal Alpha amylase Fungal Alpha amylase Fungal Alpha amylase Fungal Alpha amylase Fungal Alpha amylase Fungal Alpha amylase Fungal Alpha amylase Fungal Alpha	304 ng/m3 0.7 mg/m3 1.0 bw)(2.1 ww) 242 ng/m3(1.3 bw)(3.8 ww) 3.3 mg/m3(1.6 bw)(1.3 ww) 5989 ng/m3(2.0 bw)(1.7 ww) 2.0 mg/m3(1.9 bw)(1.8 ww) 2729 ng/m3(2.1 bw)(2.3 ww) 0.7 mg/m3(1.0 bw)(2.3 ww) 614 ng/m3(2.4 bw)(3.4 ww) 0.8 ng/m3(4.6 bw)(2.0 ww) <LOD 18.1 ng/m3(2.6bw)(3.3 ww) 0.2 ng/m3	39.4 ng/m3 0.2 ng/m3 0.6 ng/m3 <LOD 14.5 ng/m3 0.2 ng/m3 0.8 ng/m3 0.3 ng/m3 <LOD		

						Pastry		amylase Fungal Alpha amylase Fungal Alpha amylase Fungal Alpha amylase	0.2 ng/m3 (2.1 bw)(1.5 ww) <LOD 1.3 ng/m3 (3.1 bw)(8.5 ww) 0.2 ng/m3 (1.0 bw)(1.4 ww) 0.3 ng/m3 (2.4 bw)(2.1 ww) 0.2 ng/m3 (1.0 bw)(1.9 ww) <LOD			
Houba (1998)	1991-1993	Teflon 1.0 µm PAS-6 Head 2 L/min	P	Bakeries	Low* Intermediate* High*		151 120 178	Wheat Flour Allergens Total Dust Wheat Flour Allergens Total Dust Wheat Flour Allergens Total Dust	0.1 µg/m3 (3.1) 0.46 mg/m3 0.7 µg/m3 (6.4) 0.78 mg/m3 3.8 µg/m3 (4.4) 2.37 mg/m3	0.2 µg/m3 3.5 µg/m3 11.0 µg/m3	(0.03-7.7) (0.03-74.6) (0.03-252.4)	*Low: Other workers *Intermediate: All-round staff, oven staff, production mangers *High: Dough makers and all small traditional bakery

												workers
Nieuwen huijsen (1995-2) - Follow up data to 1994		Seven Hole Head (Casella) PTFE filter 1.2 µm pore, 25mm diameter 2 L/min	P	Bakeries	Dispense/mixing		37	Total Dust	3.8 mg/m3 (1.7)		(0.66-15.69)	Rest of data focuses on within and between worker variation
					Production	Bread	22		1.4 mg/m3 (2.1)		(0.39-6.54)	
					Wrapping	Bread	32		0.4 mg/m3 (1.4)		(0.15-1.62)	
					Production	Rolls	30		1.4 mg/m3 (2.5)		(0.15-7.27)	
					Wrapping	Rolls	17		0.4 mg/m3 (1.9)		(0.15-3.19)	
					Confectionery (dough brake)		8		6.1 mg/m3 (1.6)		(2.18-12.00)	
					Confectionery (flour involved)		43		2.2 mg/m3 (2.6)		(0.06-28.46)	
					Confectionery (no flour involved)		23		0.7 mg/m3 (2.5)		(0.20-9.10)	
					Despatch		22		0.3 mg/m3 (1.4)		(0.12-0.56)	
					Hygiene Inside		43		1.2 mg/m3 (2.3)			

											(0.03-15.87)	
Sandiford (1994)*		Eight stage Sierra Marple cascade impactor 2 L/min flow rate Glycerol coated mylar membranes	P	Bakery	Dough Brake Roll Production			Total Dust Flour Aeroallergen Total Dust Flour Aeroallergen	12.0mg/ml 315.7 µg/ml 1.9mg/ml 18.6 µg/ml			*Exposure levels reported in per ml concentrations rather than the standard per cubic meter
Sandiford (1994-2)		Cassela AFC123 pump 2 L/min PTFE Filter	P	Bakery	Production Confectionary	Bread Rolls		Airborne Flour Proteins	228.7 µg/m3 252.0 µg/m3 * 			*Places the exposure data into a chart from which data can be extrapolated but not accurately
Domanska (1994)	1993	AS-50 aspirator Cellulose membrane 0.8 µm pore	A	Bakery	Kneading Trough	Bread and rolls	1 1 1 1	Total Dust concentration		27.5 mg/m3 16.3 mg/m3 11.6 mg/m3 6.1 mg/m3		*Large volume sampling over a short period of time

		30 min sampling time *50 L/min			Dough Dividing machine		1 1 1 1			2.1 mg/m3 1.9 mg/m3 2.5 mg/m3 2.0 mg/m3		
Brisman (1991)		Cellulose acetate filter (0.8 µm pore) 2 L/min	P A	Bakery	Packing Mixing		1 1 2 1 1	Total Dust Total Dust Fungal alpha amylase Total Dust Total Dust		6.7 mg/m3 10 mg/m3 0.03 mg/m3 2.8 mg/m3 2.3 mg/m3		
Elms (2003)	1999	IOM sampling head Glasss fiber filter (1.6mm Millipore) 2L/min	P	Bakeries Small 1-20 workers	All All		96 96 27 27	Inhalable Dust Fungal alpha amylase Inhalable Dust Fungal alpha amylase			5.6 mg/m3 (bld-36.8) 1.9 ng/m3 (bld-1370) 7.4 mg/m3 (bld-27.8)	bld: Below limit of detection Inhalable Dust limit of detection: 0.02 mg/m3 Fungal alpha amylase limit of detection: 0.42ng/m3 *Includes

				Medium 20-100 workers Large 100+ workers All Bakeries	All All Mixer Weigher		28 28 41 41 29 29 13	Inhalable Dust Fungal alpha amylase Inhalable Dust Fungal alpha amylase Inhalable Dust Fungal alpha amylase Inhalable Dust			1.7 ng/m3 (bld-173) 4 mg/m3 (bld-25.9) 1.4 ng/m3 (bld-12.1) 6.4 mg/m3 (bld-36.8) 4.22 ng/m3 (bld-1370) 7.6 ng/m3 (1.0-36.8) 3.2 ng/m3 (bld-123.7)	bakers and millers	

							13					
					Packer		9	Fungal alpha amylase			11.4 mg/m3 (2.4-26.3)	
							9	Inhalable Dust			29.1 ng/m3 (bld-1370)	
					Baker		21	Fungal alpha amylase			0.8 mg/m3 (bld-2.2)	
							21	Inhalable Dust			1.4 ng/m3 (bld-2.1)	
					Confectionery		5	Fungal alpha amylase			6.3 mg/m3 (bld-27.8)	
							5	Inhalable Dust			1.6 ng/m3 (bld-185)	
					Pastries		3	Fungal alpha			4 mg/m3	

								amylase			(0.6-8.2)	
							3				Bld	
								Inhalable Dust			Bld	
					Ovens		8				11.2 mg/m3	
								Fungal alpha amylase			(2.5-13.3)	
							8				1.1 ng/m3	
								Inhalable Dust			(bld-1.5)	
					Miscellaneous		11				2.1 mg/m3	
								Fungal alpha amylase			(bld-18.0)	
							11				1.5 ng/m3	
								Inhalable Dust			(bld-3.2)	
					*Handles Flour Improver		43				1.9 mg/m3	
								Fungal alpha amylase			(bld-23.1)	
							43					
											1.4 ng/m3	

					*Does not Handle Flour Improver		69 69	Inhalable Dust Fungal alpha amylase Inhalable Dust Fungal alpha amylase			(bld-24.6) 7.9 mg/m3 (bld-36.8) 5.3 ng/m3 (bld-1370) 4.8 mg/m3 (bld-25.0) 1.4 ng/m3 (bld-24.6)	
Cullinan (1994)			p	Bakery	All workers		104 90 90 83 62 83	Dust Flour Aeroallergen Dust Flour Aeroallergen Dust Flour Aeroallergen			<1 mg/m3 <100.9 µg/m3 1-5mg/m3 101-215.3 µg/m3 >5mg/m3	Workers divided into groups based on exposure levels. Data also used in Nieuwenhuijsen (1994)

											>227.6 µg/m3	
Hartmann (1986) - Extracted from Brisman 2002 paper				Bakery	All workers		133 139 42	Total Dust			GM Range 0.2-1.8 µg/m3 1.0-4.4 µg/m3 3.2-19.8 µg/m3	
Masalin (1988) - Extracted from Baatjies 2013 literature review				Bakery	All workers		29	Total Dust			0.1-8.8 µg/m3	
Jauhiainen (1993)		3 piece cassettes		Bakery	Making of Dough Making of Bread		13 13	Total Dust	4.6 mg/m3 (3.6) 2.3 mg/m3 (0.9)		0.9-14.7 mg/m3 1.5-3.4 mg/m3	

Appendix II: List of Papers selected for reference papers selected for extraction.

Number	List of Papers selected for extraction
1	Baatjies R, Meijster T, Lopata A, Sander I, Raulf-Heimsoth M, Heederik D, Jeebhay M. Exposure to flour dust in South African supermarket bakeries: modeling of baseline measurements of an intervention study. Ann Occup Hyg. 2010 Apr;54(3):309-18
2	Baatjies R, Meijster T, Heederik D, Sander I, Jeebhay MF. Effectiveness of interventions to reduce flour dust exposures in supermarket bakeries in South Africa. Occup Environ Med. 2014 Dec; 71(12):811-8.
3	Bogdanovic J, Koets M, Sander I, Wouters I, Meijster T, Heederik D, van Amerongen A, Doekes G. Rapid detection of fungal alpha-amylase in the work environment with a lateral flow immunoassay. J Allergy Clin Immunol. 2006 Nov; 118(5):1157-63.
4	Bohadana AB, Massin N, Wild P, Kolopp MN, Toamain JP. Respiratory symptoms and airway responsiveness in apparently healthy workers exposed to flour dust. Eur Respir J. 1994 Jun; 7(6):1070-6.
5	Brant A, Berriman J, Sharp C, Welch J, Zekveld C, Nieuwenhuijsen M, Elms J, Newman-Taylor A, Cullinan P. The changing distribution of occupational asthma: a survey of supermarket bakery workers. Eur Respir J. 2005 Feb; 25(2):303-8.
6	Brisman J, Belin L. Clinical and immunological responses to occupational exposure to alpha-amylase in the baking industry. Br J Ind Med. 1991 Sep; 48(9):604-8.
7	Brisman J, Torén K, Lillienberg L, Karlsson G, Ahlstedt S. Nasal symptoms and indices of nasal inflammation in flour-dust-exposed bakers. Int Arch Occup Environ Health. 1998 Nov; 71(8):525-32.
8	Bulat P, Myny K, Braeckman L, van Sprundel M, Kusters E, Doekes G, Pössel K, Droste J, Vanhoorne M. Exposure to inhalable dust, wheat flour and alpha-amylase allergens in industrial and traditional bakeries. Ann Occup Hyg. 2004 Jan;48(1):57-63.
9	Burdorf A, Lillienberg L, Brisman J. Characterization of exposure to inhalable flour dust in Swedish bakeries. Ann Occup Hyg. 1994 Feb; 38(1):67-78.

10	Burstyn I, Teschke K, Kennedy SM., Exposure Levels and determinants of inhalable dust exposure in bakeries, Ann Occup Hyg., Dec;41(6):609-24. (1997)
11	Burstyn I, Teschke K, Bartlett K, Kennedy SM. Determinants of wheat antigen and fungal alpha-amylase exposure in bakeries. Am Ind Hyg Assoc J. 1998 May; 59(5):313-20.
12	Cullinan P, Lowson D, Nieuwenhuijsen MJ, Sandiford C, Tee RD, Venables KM, McDonald JC, Newman Taylor AJ. Work related symptoms, sensitization, and estimated exposure in workers not previously exposed to flour. Occup Environ Med. 1994 Sep; 51(9):579-83.
13	Domańska A, Stroszejn-Mrowca G. Endotoxin in the occupational environment of bakers: method of detection. Int J Occup Med Environ Health. 1994;(2):125-34.
14	Droste J, Vermeire P, Van Sprundel M, Bulat P, Braeckman L, Myny K, Vanhoorne M. Occupational exposure among bakery workers: impact on the occurrence of work-related symptoms as compared with allergic characteristics. J Occup Environ Med. 2005 May;47(5):458-65.
15	Elms J, Denniss S, Smith M, Evans PG, Wiley K, Griffin P, Curran AD. Development and validation of a monoclonal based immunoassay for the measurement of fungal alpha-amylase: focus on peak exposures. Ann Occup Hyg. 2001 Mar; 45(2):89-95.
16	Elms J, Beckett P, Griffin P, Evans P, Sams C, Roff M, Curran AD. Job categories and their effect on exposure to fungal alpha-amylase and inhalable dust in the U.K. baking industry. AIHA J (Fairfax, Va). 2003 Jul-Aug; 64(4):467-71.
17	Elms J, Robinson E, Rahman S, Garrod A. Exposure to flour dust in UK bakeries: current use of control measures. Ann Occup Hyg. 2005 Jan; 49(1):85-91.
18	Golder Associates for Alberta Jobs, S. T. Evaluation of worker exposure to flour dust in commercial baking facilities in Alberta. Edmonton: Golder Associates, Report (2014) Number 13-1324-0189.
19	Hartmann AL. "Berufsallergien bei Bäckern - Epidemiologie; Diagnose, Therapie und Prophylaxe; Versicherungsrecht." München-Deisenhofen, Germany: Dustri-Verlag Dr. Karl Feistle, 1986. –table extracted, but unable to access article in german.

20	Heederik D, Houba R. An exploratory quantitative risk assessment for high molecular weight sensitizers: wheat flour. Ann Occup Hyg. 2001 Apr; 45(3):175-85.
21	Houba R, Van Run P, Heederik D, Doekes G. Wheat antigen exposure assessment for epidemiological studies in bakeries using personal dust sampling and inhibition ELISA. Clin Exp Allergy. 1996 Feb; 26(2):154-63.
22	Houba R, Heederik DJ, Doekes G, van Run PE. Exposure-sensitization relationship for alpha-amylase allergens in the baking industry. Am J Respir Crit Care Med. 1996 Jul;154(1):130-6.
23	Houba R, Heederik D, Kromhout H. Grouping strategies for exposure to inhalable dust, wheat allergens and alpha-amylase allergens in bakeries. Ann Occup Hyg. 1997 Jun;41(3):287-96.
24	Houba R, van Run P, Doekes G, Heederik D, Spithoven J. Airborne levels of alpha-amylase allergens in bakeries. J Allergy Clin Immunol. 1997 Mar; 99(3):286-92.
25	Houba R, Heederik D, Doekes G. Wheat sensitization and work-related symptoms in the baking industry are preventable. An epidemiologic study. Am J Respir Crit Care Med. 1998 Nov; 158(5 Pt 1):1499-503.
26	Hur GY, Koh DH, Kim HA, Park HJ, Ye YM, Kim KS, Park HS. Prevalence of work-related symptoms and serum-specific antibodies to wheat flour in exposed workers in the bakery industry. Respir Med. 2008 Apr; 102(4):548-55.
27	Jauhiainen, A., Louhelainen, K. and Linnainmaa (1993) Exposure to dust and alpha-amylase in bakeries. Applied Occupational and Environmental Hygiene, vol 8, 721-725.
28	Jeffrey P, Griffin P, Gibson M, Curran AD. Small bakeries--a cross-sectional study of respiratory symptoms, sensitization and dust exposure. Occup Med (Lond). 1999 May; 49(4):237-41.
29	Kolopp-Sarda MN, Massin N, Gobert B, Wild P, Moulin JJ, Béné MC, Faure GC. Humoral immune responses of workers occupationally exposed to wheat flour. Am J Ind Med. 1994 Nov; 26(5):671-9.
30	Laurière M, Gorner P, Bouchez-Mahiout I, Wrobel R, Breton C, Fabriès JF, Choudat D. Physical and biochemical properties of airborne flour particles involved in occupational asthma. Ann Occup Hyg. 2008 Nov; 52(8):727-37.

31	Lillienberg L, Brisman J (1994): Flour dust in bakeries: A comparison between methods. Ann Occup Hyg 38(Suppl 1):571–575.
32	Lillienberg L, Baur X, Doekes G, Belin L, Raulf-Heimsoth M, Sander I, Ståhl A, Thissen J, Heederik D. Comparison of four methods to assess fungal alpha-amylase in flour dust. Ann Occup Hyg. 2000 Sep;4 4(6):427-33.
33	Masalin, K E., Degereth, R K And Murtomaa, H.T (1988) Airborne sugar and flour dust in the Finnish confectionery industry. Appl. md. Hyg 3, 231 -235.
34	Meijster T, Tielemans E, de Pater N, Heederik D. Modelling exposure in flour processing sectors in the Netherlands: a baseline measurement in the context of an intervention program. Ann Occup Hyg. 2007 Apr; 51(3):293-304.
35	Meijster, T.; Tielemans, E.; Schinkel, J.; Heederik, D., Evaluation of Peak Exposures in the Dutch Flour Processing Industry: Implications for Intervention Strategies, Ann. Occup. Hyg., Vol. 52, No. 7, pp. 587-596 (2008)
36	Mounier-Geyssant E, Barthélemy JF, Mouchot L, Paris C, Zmirou-Navier D. Exposure of bakery and pastry apprentices to airborne flour dust using PM2.5 and PM10 personal samplers. BMC Public Health. 2007 Nov 1; 7:311.
37	Musk AW, Venables KM, Crook B, Nunn AJ, Hawkins R, Crook GD, Graneek BJ, Tee RD, Farrer N, Johnson DA, et al. Respiratory symptoms, lung function, and sensitization to flour in a British bakery. Br J Ind Med. 1989 Sep; 46(9):636-42.
38	Nieuwenhuijsen MJ, Sandiford CP, Lowson D, Tee RD, Venables KM, McDonald JC, Newman Taylor AJ. Dust and flour aeroallergen exposure in flour mills and bakeries. Occup Environ Med. 1994 Sep; 51(9):584-8.
39	Nieuwenhuijsen MJ, Lowson D, Venables KM, Newman Taylor AJ. Flour dust exposure variability in flour mills and bakeries. Ann Occup Hyg. 1995 Jun; 39(3):299-305.
40	Nieuwenhuijsen MJ, Sandiford CP, Lowson D, Tee RD, Venables KM, Newman Taylor AJ. Peak exposure concentrations of dust and flour aeroallergen in flour mills and bakeries. Ann Occup Hyg. 1995 Apr; 39(2):193-201.
41	Nieuwenhuijsen MJ, Heederik D, Doekes G, Venables KM, Newman Taylor AJ. Exposure-response relations of alpha-amylase sensitization in British bakeries and flour mills. Occup Environ Med. 1999 Mar; 56(3):197-201.

42	Page EH, Dowell CH, Mueller CA, Biagini RE, Heederik D. Exposure to flour dust and sensitization among bakery employees. Am J Ind Med. 2010 Dec; 53(12):1225-32.
43	Peretz C, de Pater N, de Monchy J, Oostenbrink J, Heederik D. Assessment of exposure to wheat flour and the shape of its relationship with specific sensitization. Scand J Work Environ Health. 2005 Feb; 31(1):65-74.
44	Roberge, B.; Aubin, S.; Cloutier, Y.:, Characterization of Dusts in Traditional Bakeries, IRSST Studies and Research Projects, Report R-760 (2012)
45	Sandiford CP, Nieuwenhuijsen MJ, Tee RD, Taylor AJ. Determination of the size of airborne flour particles. Allergy. 1994 Dec; 49(10):891-3.
46	Sandiford CP, Nieuwenhuijsen MJ, Tee RD, Taylor AJ. Measurement of airborne proteins involved in Bakers' asthma. Clin Exp Allergy. 1994 May; 24(5):450-6.
47	Smith TA, Smith PW. Respiratory symptoms and sensitization in bread and cake bakers. Occup Med (Lond). 1998 Jul; 48(5):321-8.
48	Smith TA. Preventing baker's asthma: an alternative strategy. Occup Med (Lond). 2004 Jan; 54(1):21-7.
49	Storaas T, Ardal L, Van Do T, Florvaag E, Steinsvåg SK, Irgens A, Aasen TB, Greiff L. Nasal indices of eosinophilic and exudative inflammation in bakery-workers. Clin Physiol Funct Imaging. 2007 Jan; 27(1):23-9.
50	Stuurman B, Meijster T, Heederik D, Doekes G. Inhalable beta (1->3) glucans as a non-allergenic exposure factor in Dutch bakeries. Occup Environ Med. 2008 Jan; 65(1):68-70.
51	Tagiyeva N, Anua SM, Semple S, Dick F, Devereux G. The 'take home' burden of workplace sensitizers: flour contamination in bakers' families. Environ Int. 2012 Oct 1; 46:44-9.
52	Thorpe A, Walsh PT. Direct-reading inhalable dust monitoring--an assessment of current measurement methods. Ann Occup Hyg. 2013 Aug; 57(7):824-41.
53	Van Tongeren M, Galea KS, Ticker J, While D, Kromhout H, Cherrie JW. J Environ Monit. 2009 Aug; 11(8):1492-7.

54	Vanhanen M, Tuomi T, Hokkanen H, Tupasela O, Tuomainen A, Holmberg PC, Leisola M, Nordman H. Enzyme exposure and enzyme sensitization in the baking industry. Occup Environ Med. 1996 Oct; 53(10):670-676.
55	Beritić-Stahuljak D, Valić F, Cigula M, Butković D. Simultaneous exposure to airborne flour particles and thermal load as cause of respiratory impairment. Int Arch Occup Environ Health. 1976 Jul 5;37(3):193-203. PMID: 977140

Appendix III: Job titles used in published papers and their reclassification.

Pre-Oven	Post-Oven	Pre & Post Oven
Baker (1,2,5,8,16,17,18,21,23,24,34,35,50)	Packer/Shipper (3)	Overall (1,2)
General Baker (4)	Packing (6,18,31,49,54)	All Tasks (3,18,28,29,32,55)
Special Baker (4)	Packer (7,9,15,16)	Total (5,9, 10,21,31,38)
Bakery Assistant (5)	Packaging (8,18)	Flour adding, bread forming, packing (7)
Production (7,8,18, 38,39,40,41,45,46)	industrial packers (14)	Mixed Task (9)
industrial bakers, traditional pastry bakers (14)	end of the line (15)	All (10,11,12,16,17,23,43,53)
traditional bread bakers, traditional bread + pastry bakers (14)	loader (15)	Miscellaneous (16,38,41)
pre-oven worker (18)	other (packer, driver, admin, counter hand) (17)	all workers (19,22,33)
cook (23)	shipper (18)	all-round staff (21,23,24)
mixed baker (24)	slicer (18)	All-round staff, oven staff, production mangers (25)
dough brake/roll machine, general cleaning/bag collection, weighing and mixing, dividing and moulding, cake mixing (28)	slicer/packer/transport (21,23,24)	general (31)
baking area (30)	slicer, wrapper, packer (37)	bread plant all (48)
baker apprentice (36)	wrapping (38,40,41,50)	average (52)
production floor (39)	despatch (38,40,41)	crispbread factory(54)
Weighing & Mixing (3)	Packers, oven workers, administration (49)	
Mixing (6,18,31)	packer/slicer (53)	
Dough Maker (7,9,21,22,23,24,35,49,50)	Counter hand (1,2)	
Dough Making (8,24,30,49,54)	Despatch, tray washing, nursing, and canteen staff (37)	
equipment: horizontal mixer (10,11)	Office, transport, and vehicle-workshop staff (37)	
equipment: vertical mixer (10,11)	administration (49)	
Dough Mixer/cutter (15)	other workers (25)	
flour mixer (15)	all other jobs (23)	
mixer (15,16,18)	front counter (18)	

Weigher (16)	Foaming, Baking, decorating (26)	
mixer/siever/weigher (17,26)		
mixing & packing (18)		
weighing (18)		
Dough makers and all small traditional bakery workers (25)		
making of dough (27)		
dough mixing (31)		
Bakery cleaning staff, dough makers (main bread bakery) (37)		
Flour room staff, scone production staff (37)		
dispense/mixing (38,40,41)		
bag disposal (39)		
dispense/mix, floor (39)		
flour silo (39)		
Tipping/weighing/sifting/bag disposal/mixing (39)		
dough mixer (44)		
dough mixer/weighing (44)		
Doughmaking without LEV (47,48)		
Mixing without LEV (47,48)		
Sieving with LEV (47,48)		
Sieving without LEV (47,48)		
Weighing with LEV (47,48)		
Weighing without LEV (47,48)		
flour sifter brushed clean (52)		
flour tray set down (52)		
mixing machine (52)		
mixer/Weigher (53)		
Frozen Dough Handler (4,)		
Work Table (8)		
Former (9,31)		
equipment: dough-brake (10,11)		
equipment: flour to prevent adhesion (10,11)		
equipment: reversible sheeter +/- manual (10,11)		
equipment: use of divider oil (10,11)		
dough dividing machine (13)		

kneading trough (13)		
Divider (18)		
proofer (18) roller (18)		
making of bread (27)		
bread forming (31,49)		
dough resting (30)		
bread machinery (39)		
bread production (39)		
dough brake (39,41,45)		
roll machinery (39)		
Table (44), Moulder (44)		
dough moulding (44)		
excess flour brushed off (52)		
dough transfer (52)		
dough cut/weighed (52)		
peak caused by flour being brushed off(52)		
dough shaper/duster (53)		
bread making (54)		
Croissant Maker (4)		
Pastry Production (8)		
Staff preparing ingredients in confectionery bakery (37)		
conf/dough brake (38)		
conf/flour involved (38,40,41)		
conf/no flour (38,40,41)		
confectionery machinery(39)		
confectionery (dough brake)(40)		
Cake Mixing Room (48)		
Dough makers (confectionery bakery), mixers, (hot plate bakery) (37)		
Pastry baker (35,50)		
pastry apprentice (36)		
equipment: automated (10)		
Oven Staff (3,21,23,24)		
Oven Handler (4)		
Oven Worker (9,49,50,53)		
ovens (15,16,31)		
Staff attending ovens or in cooking areas (37)		

Appendix IV. Job titles and their reclassification under the major job/tasks in bakery

Baker/Oven worker	Confectioner	Weighing & Mixing	Dough Former	Other Production Related Tasks	All Production tasks	Packers/Shippers	Front Counter & Other	Cleaners, Maintenance
Baker (1,2,5,8,16,17,18,21,23,24,34,35,50)	Confectioner (1,2,5,16,21)	Weighing & Mixing (3)	Frozen Dough Handler (4)	Manager (1,2,5	Overall (1,2	Packer/Shipper (3,	Packers, oven workers, administration (49	Cleaner (17,18,50
General Baker (4)	Croissant Maker (4)	Mixing (6,18,31)	Work Table (8)	Supervisor (1,2,53	All Tasks (3,18,28,29,32,55	Packing (6,18,31,49,54	Office, transport, and vehicle-workshop staff (37	maintenance (18,50
Special Baker (4)	Pastry Production (8)	Dough Maker (7,9,21,22,23,24,35,49,50)	Former (9,31)	Oven Staff (3,21,23,24)	Total (5,9, 10,21,31,38)	Packer (7,9,15,16)	other (packer, driver, admin, counterhand) (17) all other jobs (23)	others(maintenance, QA/QC, floaters, cleaners, shipper) (18)
Bakery Assistant (5)	Confectionery (9,46,49)	Dough Making (8,24,30,49, 54)	equipment: dough-brake (10,11)	Oven Handler (4)	Flour adding, bread forming, packing (7)	Packaging (8,18)	other workers (25)	maintenance/cleaners (21,23,24)
Production (7,8,18, 38,39,40,	Confectionery and Pastries	equipment: horizontal mixer	equipment: flour to prevent	Line Operator (7)	Mixed Task (9)	industrial packers (14)	front counter (18)	

41,45,46)	(15)	(10,11)	adhesion (10,11)					
industrial bakers, traditional pastry bakers (14)	Pastries (15,16)	equipment: vertical mixer (10,11)	equipment: reversible sheeter +/- manual (10,11)	Oven Worker (9,49,50,53)	All (10,11,12, 16,17,23,43,53)	end of the line (15)	Counterhand (1,2)	bakery maintenance staff (37)
traditional bread bakers, tradition bread+pastry bakers (14)	Pastry cook (24)	Dough Mixer/cutter (15)	equipment: use of divider oil (10,11)	equipment: automated (10)	Miscellaneous (16,38,41)	loader (15)	Non-Production Tasks (3,22,26)	
pre-oven worker (18)	foaming. Baking, decorating (26)	flour mixer (15)	dough dividing machine (13)	ovens (15,16,31)	all workers (19,22,33)	shipper (18)		hygiene inside (38,40,41)
cook (23)	Hot plate, lidding, filling, pie shell making, sugar confectionery, proving and finishing/packing/glazing/shop	mixer (15,16,18)	kneading trough (13)	production managers (21,23,24)	all-round staff (21,23,24)	slicer (18)		hygiene outside (38,41)

	office (28)							
mixed baker (24)	Pastry baker (35,50)	Weigher (16)	Divider (18)	bakery manager, quality control staff (37)	All-round staff, oven staff, production mangers (25)	slicer/packer/transport (21,23,24)		maintenance (38,41)
dough brake/roll machine, general cleaning/ bag collection, weighing and mixing, dividing and moulding, cake mixing (28)	pastry apprentice (36)	mixer/siever /weigher (17,26)	proofer (18)	Production foremen, security staff (37)	general (31)	slicer, wrapper, packer (37)		bins (39)
baking area (30)	Doughmakers (confectionery bakery), mixers, (hot	mixing & packing (18)	roller(18)	Staff attending ovens or in cooking areas (37)	bread plant all (48)	wrapping (38,40,41, 50)		floor swept (52)

	platebakery) (37)							
baker apprentice (36)	Staff preparing ingredients in confectionery bakery (37)	weighing (18)	making of bread (27)	quality control (38,41)	average (52)	despatch (38,40,41)		breakdown/ blockages (39)
production floor (39)	conf/dough brake (38)	Dough makers and all small traditional bakery workers (25)	bread forming (31,49)	boss/foreman (50)	crispbread factory(54)	packer/slicer (53)		
	conf/flour involved (38,40,41)	making of dough (27)	dough resting (30)	quality assurance (18)		storage worker (35,50)		
	conf/no flour (38,40,41)	dough mixing (31)	bread machinery (39)					
	confectionery machinery(39)	Bakery cleaning staff, doughmakers (mainbread bakery) (37)	bread production (39)					
	confectionery (dough brake)(40)	Flour room staff, scone production staff (37)	dough brake (39,41,45)					

	Cake Mixing Room (48)	dispense/mixing (38,40,41)	roll machinery (39)					
	Mainly confectionary workers and bread formers (49)	bag disposal (39) dispense/mix, floor (39)	table(44) moulder (44)					
		flour silo (39)	dough moulding (44)					
		Tipping/weighing/sifting/bag disposal/mixing (39)	excess flour burshed off (52)					
		dough mixer (44)	dough transfer (52)					
		dough mixer/weighing (44)	dough cut/wieghed (52)					
		Doughmaking without LEV (47,48)	peak caused by flour being brushed off(52)					
		Mixing without LEV	dough shaper/duster (53)					

		(47,48)						
		Sieving with LEV (47,48)	bread making (54)					
		Sieving without LEV (47,48)						
		Weighing with LEV (47,48)						
		Weighing without LEV (47,48)						
		flour sifter brushed clean (52)						
		flour tray set down (52)						
		mixing machine (52)						
		mixer/weigher (53)						

Appendix V: Table showing the products and the papers that published them.

Bread	**Confectionery**	**Mixed**
Bagels (10,11)	Puff Pastry (10,11)	Mixed (3,10,11,18,20,21,22,23,24,25,26,28,37,38,39,40,41,49,53)
Bread (1,2,5,6,7,8,9,10,11,15,16,21,23,24,27,29,30,31,32,35,36,37,38,39,40,41,47,48,49,50,54,55)	Pastry (1,2,8,9,15,16,21,23,24,35,36,50)	Bread & pastry (1,2,8,9,14,15,16,17,34,35)
Bread & Buns (42)	Confectionery (21,23,38,39,40,41)	Buns, scones, rolls, pastries (37)
Bread (multiple types) (44)	Cinnamon Buns (10,11)	
Bread and rolls (13,46)	Cakes and Pastry (10,11)	
Pita Bread (18,52)	Cake (47,48)	
Wheat Bread (21,24)	Scones (37)	
Pizza, pita, tortilla (10,11)	Crumpets (10,11)	
Rolls (38,39,40,41,45)	Croissant (4,10,11)	
Rye bread (21,23,24)	Baklava (18)	
Crispbread (21,22,23,24,54)		

Appendix VI. Various tables showing stages in the development of the final JEM.

Table I: Geometric means of total dust by Job tasks and product.

This first table calculated total dust geometric mean not inhalable dust.

Total dust Geometric Mean (mg/m^3)	Job/Tasks	Bread Products (mg/m^3)	Non-Bread Products (mg/m^3)	Bread & Non-Bread Products(total mg/m^3)
Production Based Tasks	Baker	1.51	0.90	1.48
	Confectioner	-	0.87	1.35
	Weigher & Mixer	3.46	3.91	3.21
	Dough Former	1.78	6.26	3.94
	Other Pdn[5] Tasks	0.7	0.6	1.23
	All Pdn Tasks	0.88	1.79	1.42
Non Production Based Tasks	Packer/Shipper	0.41	0.40	0.59
	Front Counter & Other	0.72	0.50	1.19
	Cleaner/Maintenance	2.13	-	5.25

[5] Pdn- Production

Table II: Geometric means of wheat allergen by Job tasks and product

Wheat Allergen Geometric Mean(μg/m^3)	Job/Tasks	Bread Products (μg/m^3)	Non-Bread Products (μg/m^3)	Bread & Non-Bread Products (μg/m^3)
Production Based Tasks	Baker	18.46	1.48	1.98
	Confectioner	-	13.30	0.61
	Weigher & Mixer	11.34	16.94	10.95
	Dough Former	39.06	208.5	33.71
	Other Pdn Tasks	0.48	0.30	0.55
	All Pdn Tasks	3.39	46.19	1.91
Non Production Based Tasks	Packer/Shipper	0.90	0.06	0.24
	Front Counter & Other	2.02	0.06	1.19
	Cleaner/Maintenance	-	-	980.34

Table III: Geometric means of fungal amylase by Job tasks and product

Fungal amylase Geometric Mean(ng/m^3)	Job/Tasks	Bread Products (ng/m^3)	Non-Bread Products (ng/m^3)	Bread & Non-Bread Products (ng/m^3)
Production Based Tasks	Baker	0.43	0.12	0.14
	Confectioner	-	0.22	-
	Weigher & Mixer	3.57	0.80	0.49
	Dough Former	-	-	1.49
	Other Pdn Tasks	-	-	0.35
	All Pdn Tasks	1.35	11.87	0.91
Non Production Based Tasks	Packer/Shipper	0.12	-	0.05
	Front Counter & Other	-	-	0.23
	Cleaner/Maintenance	-	-	-

Table IV: Arithmetic means of total dust by Job tasks and product

Total dust Arithmetic Mean (mg/m³)	Job/Tasks	Bread Products (mg/m³)	Non-Bread Products (mg/m³)	Bread & Non-Bread Products (mg/m³)
Production Based Tasks	Baker	2.40	1.30	2.38
	Confectioner	-	0.86	-
	Weigher & Mixer	5.67	6.79	8.05
	Dough Former	3.06	0.83	9.22
	Other Pdn Tasks	1.11	-	3.79
	All Pdn Tasks	3.97	7.35	4.51
Non Production Based Tasks	Packer/Shipper	0.88	0.02	3.14
	Front Counter & Other	1.66	0.17	4.22
	Cleaner/Maintenance	0.71	-	19.96

Table V. Arithmetic means of wheat allergen by Job tasks and product

Wheat Allergen Arithmetic Mean (µg/m^3)	Job/Tasks	Bread Products (µg/m^3)	Non-Bread Products (µg/m^3)	Bread & Non-Bread Products (µg/m^3)
Production Based Tasks	Baker	71.93	8.66	11.22
	Confectioner	-	69.03	41.43
	Weigher & Mixer	42.04	3.57	522.45
	Dough Former	128.21	387	192.40
	Other Pdn Tasks	3.76	0.72	-
	All Pdn Tasks	3.87	18.51	22.57
Non Production Based Tasks	Packer/Shipper	34.9	0.1	88.50
	Front Counter & Other	0.20	-	0.0
	Cleaner/Maintenance	-	-	1293.8

Table VI: Arithmetic means of fungal amylase by Job tasks and product

Fungal amylase Arithmetic Mean (ng/m³)	**Job/Tasks**	**Bread Products (ng/m³)**	**Non-Bread Products (ng/m³)**	**Bread & Non-Bread Products (ng/m³)**
Production Based Tasks	Baker	3.90	-	0.005
	Confectioner	-	1.60	-
	Weigher & Mixer	233.50	-	26.89
	Dough Former	204.70	-	1.37
	Other Pdn Tasks	-	-	-
	All Pdn Tasks	16.07	-	27.61
Non Production Based Tasks	Packer/Shipper	0.21	-	1.60
	Front Counter & Other	12.4	-	0.22
	Cleaner/Maintenance	-	-	-

Papers that published results for both GM and AM. (20 PAPERS)

Table VII. Geometric means of Inhalable dust by Job tasks and products

Inhalable dust Geometric Mean (mg/m^3)	Job/Tasks	Bread Products (mg/m^3)	Confectionery Products (mg/m^3)	Mixed Products (mg/m^3)
Production Based Tasks	Baker	2.16	0.91	1.63
	Confectioner		1.05	0.67
	Weigher & Mixer	2.72	2.20	3.63
	Dough Former	2.47	6.40	4.94
	Other Pdn Tasks	0.97	0.59	1.22
	All Pdn Tasks	1.06	1.90	2.37
Non Production Based Tasks	Packer/Shipper	0.43	0.40	1.10
	Front Counter & Other	0.80	-	2.24
	Cleaner/Maintenance	-	-	1.80

Table VIII. Geometric means of wheat allergen by Job tasks and products with 20 papers

Wheat Allergen Geometric Mean (μg/m³)	Job/Tasks	Bread Products (μg/m³)	Confectionery Products (μg/m³)	Mixed Products (μg/m³)
Production Based Tasks	Baker	67.85	4.18	10.19
	Confectioner	-	120.78	-
	Weigher & Mixer	14.53	1.17	10.63
	Dough Former	39.06	208.5	118.5
	Other Pdn Tasks	5.80	0.49	4.51
	All Pdn Tasks	0.96	2.49	0.87
Non Production Based Tasks	Packer/Shipper	1.30	0.06	64.5
	Front Counter & Other	2.90	-	1.31
	Cleaner/Maintenance	-	-	1.30

Table IX. Geometric means of fungal alpha-amylase by Job tasks and products (20 Papers)

Fungal amylase Geometric Mean (ng/m^3)	Job/Tasks	Bread Products (ng/m^3)	Confectionery Products (ng/m^3)	Mixed Products (ng/m^3)
Production Based Tasks	Baker	0.48	0.12	0.16
	Confectioner	-	0.14	-
	Weigher & Mixer	3.33	-	1.33
	Dough Former	18.10	-	2.7
	Other Pdn Tasks	-	-	0.11
	All Pdn Tasks	1.05	-	0.27
Non Production Based Tasks	Packer/Shipper	0.12	-	0.10
	Front Counter & Other	-	-	0.28
	Cleaner/Maintenance	-	-	-

Table X. Arithmetic means of Inhalable dust by Job tasks and products (20 Papers)

Inhalable dust Arithmetic Mean (mg/m^3)	Job/Tasks	Bread Products (mg/m^3)	Confectionery Products (mg/m^3)	Mixed Products (mg/m^3)
Production Based Tasks	Baker	4.23	1.44	2.15
	Confectioner		1.63	0.88
	Weigher & Mixer	4.91	2.80	9.72
	Dough Former	4.81	7.50	11.88
	Other Pdn Tasks	0.99	0.70	2.89
	All Pdn Tasks	1.53	7.09	7.18
Non Production Based Tasks	Packer/Shipper	1.42	0.50	2.50
	Front Counter & Other	1.68	-	4.51
	Cleaner/Maintenance	-	-	*16.35

Table XI. Arithmetic means of wheat allergen by Job tasks and products (20 Papers)

Wheat Allergen Arithmetic Mean (μg/m^3)	Job Tasks	Bread Products (μg/m^3)	Confectionery Products (μg/m^3)	Mixed Products (μg/m^3)
Production Based Tasks	Baker	174.51	8.25	18.37
	Confectioner	-	202.41	-
	Weigher & Mixer	41.30	3.57	184.70
	Dough Former	133.55	387.00	192.4
	Other Pdn Tasks	8.84	2.96	7.70
	All Pdn Tasks	3.35	18.51	11.91
Non Production Based Tasks	Packer/Shipper	52.14	0.10	88.5
	Front Counter & Other	10.64	-	64.39
	Cleaner/Maintenance	-	-	259.18

Table XII. Arithmetic means of fungal alpha-amylase by Job tasks and products (20 Papers)

Fungal amylase Arithmetic Mean (ng/m^3)	Job/Tasks	Bread Products (ng/m^3)	Confectionery Products (ng/m^3)	Mixed Products (ng/m^3)
Production Based Tasks	Baker	7.77	0.29	0.35
	Confectioner	-	0.13	-
	Weigher & Mixer	21.30	-	30.37
	Dough Former	39.4	-	2.7
	Other Pdn Tasks	-	-	0.12
	All Pdn Tasks	11.78	-	0.70
Non Production Based Tasks	Packer/Shipper	0.20	-	0.13
	Front Counter & Other	-	-	0.88
	Cleaner/Maintenance	-	-	-

Geometric means and Arithmetic means for all extracted data. No conversion factor applied.

Table XIII. Geometric means of Inhalable dust by Job tasks and products

Inhalable dust Geometric Mean (mg/m³)	Job/Tasks	Bread Products (mg/m³)	Confectionery Products (mg/m³)	Mixed Products (mg/m³)
Production Based Tasks	Baker	1.46 (509)[6]	1.14 (613)	1.78 (93)
	Confectioner		0.82 (259)	
	Weigher & Mixer	2.95 (197)	2.20 (40)	3.73 (805)
	Dough Former	2.63 (86)	6.28 (17)	4.86 (204)
	Other	0.75 (88)	0.60 (21)	2.21 (92)
	All	1.38 (95)	2.29 (199)	1.69 (2958)
Non Production Based Tasks	Packer/Shipper	0.43 (246)	0.42 (35)	0.95 (146)
	Front Counter & Other	0.76 (53)	0.50 (3)	1.52 (683)
	Cleaner/Maintenance	0.75 (1)	-	1.33 (32)

[6] Numbers in brackets represent number of samples

Table XIV. Geometric means of wheat allergen by Job tasks and products

Inhalable dust Geometric Mean (mg/m^3)	Job/Tasks	Bread Products (mg/m^3)	Confectionery Products (mg/m^3)	Mixed Products (mg/m^3)
Production Based Tasks	Baker	1.46 (509)	1.14 (613)	1.78 (93)
	Confectioner		0.82 (259)	
	Weigher & Mixer	2.95 (197)	2.20 (40)	3.73 (805)
	Dough Former	2.63 (86)	6.28 (17)	4.86 (204)
	Other	0.75 (88)	0.60 (21)	2.21 (92)
	All	1.38 (95)	2.29 (199)	1.69 (2958)
Non Production Based Tasks	Packer/Shipper	0.43 (246)	0.42 (35)	0.95 (146)
	Front Counter & Other	0.76 (50)	0.50 (3)	1.52 (683)
	Cleaner/Maintenance	-	-	*1.3 (25)

Table XV. Geometric means of fungal alpha-amylase by Job tasks and products

Fungal amylase Geometric Mean (ng/m^3)	Job/Tasks	Bread Products (ng/m^3)	Confectionery Products (ng/m^3)	Mixed Products (ng/m^3)
Production Based Tasks	Baker	0.28 (219)	0.48 (529)	0.20 (54)
	Confectioner	-	0.13 (94)	- -
	Weigher & Mixer	4.41 (93)	0.18 (32)	3.10 (55)
	Dough Former	- -	- -	3.99 (50)
	Other	- -	- -	4.10 (17)
	All	1.34 (185)	2.59 (63)	0.41 (946)
Non Production Based Tasks	Packer/Shipper	0.12 (53)	- -	0.10 (34)
	Front Counter & Other	- -	- -	0.21 (397)
	Cleaner/Maintenance	- -	- -	- -

Table XVI. Arithmetic means of Inhalable dust by Job tasks and products

Inhalable dust Arithmetic Mean (mg/m³)	Job/Tasks	Bread Products (mg/m³)	Confectionery Products (mg/m³)	Mixed Products (mg/m³)
Production Based Tasks	Baker	2.90 (490)	1.46 (44)	2.55 (106)
	Confectioner	0.54 (21)	1.00 (193)	- -
	Weigher & Mixer	5.20 (211)	2.51 (56)	9.39 (749)
	Dough Former	3.72 (98)	7.50 (9)	9.89 (190)
	Other	1.01 (88)	0.9 (21)	4.04 (92)
	All	4.51 (95)	4.92 (199)	4.72 (2,814)
Non Production Based Tasks	Packer/Shipper	0.79 (197)	0.58 (36)	2.62 (125)
	Front Counter & Other	1.66 (50)	0.50 (3)	4.33 (647)
	Cleaner/Maintenance	- -	- -	- -

Table XVII. Arithmetic means of wheat allergen by Job tasks and products

Wheat Allergen Arithmetic Mean (µg/m³)	Job/Tasks	Bread Products (µg/m³)	Confectionery Products (µg/m³)	Mixed Products (µg/m³)
Production Based Tasks	Baker	71.93 (450)	8.66 (25)	11.22 (73)
	Confectioner	-	69.03 (185)	-
	Weigher & Mixer	42.04 (115)	3.57 (25)	142.25 (245)
	Dough Former	128.21 (13)	387 (9)	192.40 (19)
	Other	3.76 (65)	0.72 (21)	-
	All	3.73 (51)	18.51 (4)	22.57 (1347)
Non Production Based Tasks	Packer/Shipper	34.9 (177)	0.10 (22)	88.50 (34)
	Front Counter & Other	11.30 (53)	0.79 (3)	51.94 (434)
	Cleaner/Maintenance	- -	- -	1293.8 (5)

Table XVIII. Arithmetic means of fungal alpha-amylase by Job tasks and products

Wheat Allergen Arithmetic Mean (μg/m³)	Job/Tasks	Bread Products (μg/m³)	Confectionery Products (μg/m³)	Mixed Products (μg/m³)
Production Based Tasks	Baker	71.93 (450)	8.66 (25)	11.22 (73)
	Confectioner	-	69.03 (185)	-
	Weigher & Mixer	42.04 (115)	3.57 (25)	142.25 (245)
	Dough Former	128.21 (13)	387 (9)	192.40 (19)
	Other	3.76 (65)	0.72 (21)	-
	All	3.73 (51)	18.51 (4)	22.57 (1347)
Non Production Based Tasks	Packer/Shipper	34.9 (177)	0.10 (22)	88.50 (34)
	Front Counter & Other	11.30 (50)	0.79 (3)	51.94 (434)
	Cleaner/Maintenance	- -	- -	1293.8 (5)

Appendix VII. Questionnaire

Please see below.

UNIVERSITY OF ALBERTA

Division of Preventive Medicine
Department of Medicine
Faculty of Medicine and Dentistry

Please write patient ID number or attach sticker here.

Name of Interviewer: ____

PLACE OF INTERVIEW: ____

DATE OF INTERVIEW: _______________________________________

TIME INTERVIEW STARTED: __________________________________

TIME INTERVIEW ENDED: ___________________________________

☐ Cohort   Height (cm):______________________

☐ Cross-sectional   Weight (kg):______________________

Date:____________________ ID number: Please write patient ID number or attach sticker here

Section 1 - Personal Details

1. Can I please confirm your personal details?

1.1 How old are you now? ______ Date of Birth DD / MMM / YY

1.2 What is your gender? ☐ M ☐ F

1.3 Marital status single/separated/widowed/divorced ☐ 1

married or living as married ☐ 2

Section 2 - Education

2. I would now like to ask some questions about your education.

2.1 Did you attend high school? Yes ☐ 1 No ☐ 2

If no, go to question 2.2

If yes,

2.1.1 was it in North America? Yes ☐ 1 No ☐ 2

2.1.1.1 **If yes,** what was the highest grade completed? ________

2.1.1.2 **If no,** how old were you when you left secondary education?________

2.2 Have you ever completed an apprenticeship or formal trade training as a baker or cook?

Yes ☐ 1 No ☐ 2

3. Health

3.1 Are you in good health now? Yes ☐ 1 No ☐ 2

If yes, go to question 3.2

If no,

3.1.1 What health problems do you have?

____

3.2 Are you taking any tablets or using any other medications (including inhalers) now?

Include both those prescribed by a doctor and those bought without prescription.

Yes ☐ 1 No ☐ 2

If no, go to section on the next page: **CHEST SYMPTOMS IN LAST 12 MONTHS**

If yes, please give details

What tablets or other medications are you using?	**How often do you take/use it?**	**For what condition or symptoms are you taking this medication?**
3.2.1		
3.2.2		
3.2.3		
3.2.4		

CHEST SYMPTOMS IN LAST 12 MONTHS		
1. At any time in the last 12 months have you had wheezing or whistling in your chest	No □	Yes □
2. At any time in the last 12 months have you woken up with a feeling of tightness in your chest first thing in the morning?	No □	Yes □
3. At any time in the last 12 months have you had an attack of shortness of breath that came on when you were not doing anything strenuous?	No □	Yes □
4. At any time in the last 12 months have you been woken at night by an attack of shortness of breath?	No □	Yes □
5. Have you been woken by an attack of coughing at any time in the last 12 months	No □	Yes □
If you answered NO to questions 1-5 please go to section on ASTHMA		
6. Thinking about your chest symptoms as a whole in the last 12 months, what happened to them when you were away from work for a week or longer?	Improved Same Worse N/A	□ □ □ □
7. Thinking about your chest symptoms as a whole in the last 12 months, what happened to them on working days compared with non-working days	Improved Same Worse N/A	□ □ □ □
8. Have these symptoms been brought on by doing any particular task or activity If Yes, which tasks or activities? ____________________ ____________________ ____________________	No □	Yes □

Asthma	
1. Have you ever had asthma?	No □ Yes □
If NO go to section on RHINITIS	
2. Was this confirmed by a doctor?	No □ Yes □
3. How old were you when you had your first attack of asthma?	___________years
4. Have you had an attack of asthma in the last 12 months?	No □ Yes □
5. Have you ever been told by a doctor that you have had asthma caused by or related to your work?	No □ Yes □
6. Please indicate which of these best describes your asthma: □ You had childhood asthma which went away and now you are asymptomatic □ You had childhood asthma which went away for several years, but is now back again □ You had childhood asthma which you still have at this age. □ You have adult onset asthma □ Others, please specify____	
7. Thinking about your asthma as a whole in the last 12 months, what happened to it when you were away from work for a week or longer?	Improved □ Same □ Worse □ N/A □
8. Thinking about your asthma as a whole in the last 12 months, what happened to it on working days compared with non-working days	Improved □ Same □ Worse □ N/A □
9. Have these symptoms been brought on by doing any particular task or activity If Yes, which tasks or activities? ______________________________ ______________________________ ______________________________	No □ Yes □

Hay fever/Rhinitis		
1. Do you have any nasal allergies or symptoms, including hay fever?	No □	Yes □
2. Have you ever had a problem with sneezing, or a blocked nose (rhinitis) when you did not have a cold or the flu?	No □	Yes
3. Have you had an attack of sneezing, or a or a blocked nose (rhinitis) when you did not have a cold or the flu in the last 12 months?	No □	Yes □
4. How old were you when you had your first attack of rhinitis or hay fever?	___________years	
5. Has this problem been accompanied by itchy or watery eyes	No □	Yes □
6. Have you ever been told by a doctor that you have had rhinitis caused by or related to your work?	No □	Yes □
6. Thinking about your hay fever/rhinitis as a whole in the last 12 months, what happened to it when you were away from work for a week or longer?	Improved Same Worse N/A	□ □ □ □
7. Thinking about your hay fever/rhinitis as a whole in the last 12 months, what happened to it on working days compared with non-working days	Improved Same Worse N/A	□ □ □ □
8. Have these symptoms been brought on by doing any particular task or activity If Yes, which tasks or activities? ____________________ ____________________ ____________________	No □	Yes □

Section 4 Smoking

4.1 Have you ever smoked at least one cigarette a day for as long as a year?

Yes ☐ 1

If no, go to question 4.5

If yes,

No ☐ 2

4.2 At what age did you start smoking at least one cigarette a day? _____ years

4.3 Do you currently smoke at least one cigarette a day?

Yes ☐ 1

If yes, go to 4.4

No ☐ 2

If no,

4.3.1 How old were you when you last smoked at least one cigarette a day? _____ years

4.4 How many cigarettes a day do/did you usually smoke? ____ per day

Section 5 Occupational information

5.1 Please fill the following table regarding all your occupations, starting with your current job and working backwards in time.

No	Occupation	Industry	Start date (Month/Year)	End date (Month/Year)
1.				
2.				
3.				
4.				
5.				
6				

When did you first start working with flour/bakery ingredients? MMM/YY____________________

5.2 Are you currently working with flour/bakery ingredients? Yes ☐ No ☐

If No, a. What date did you stop? ____

b. Why did you stop? ____

For each of the jobs above please complete the supplementary exposure questionnaire.

5.3 Before you started college or work in the jobs listed Yes ☐ No ☐
above did you regularly (once a week or more) take part in baking or other activities using flour?

If yes,

5.3.1 What did you do (please describe)?

____

5.3.2 In what years did you do this? Started _________ Stopped ______________

5.3.4 For how many hours per week did you do this _______ hours

Section 6 Family History

1. Indicate any of the blood relatives that whoever had any of the following:

	Parents	Grand parents	Brother/Sister	Children
Hay fever/ Allergic Rhinitis				
Eczema (Skin Allergies)				
Asthma				
Itchy or watery eyes (Allergic Conjunctivitis)				
Other Allergies				

2. Please list any additional allergies that you yourself may have:

____
____
____

Please write patient ID number or attach sticker here.

Supplementary exposure questionnaire

Section 7 - supplementary exposure questionnaire.

Job number ___

7.1 What is/was your job title:_____________________________________

7.2 What type of work do you do? Please describe the tasks you carry out/carried out on a usual day.

____

____

____

7.3 Duration of work per week under the same job title:

Less than 10 h/week ☐ 10-20 h/week ☐ 20-30 h/week ☐ 30-40h/week ☐ 40< h/week ☐

If this was a baking trade please complete questions 7.4 -7.6

7.4 Were you a production worker?

Yes ☐ No ☐

If yes:
What were your main products:

Bread or bread products ☐ Confectionery ☐ Mixed ☐

7.5 Which of the tasks below are/were you involved with in this job?. For each describe what products are/were you making, how much of your time at work you spend/spent doing these tasks, and your use of personal protective equipment?

Type of work undertaken (Production)	**Product(s)**	**Approximate number of hours per work day doing this task**	**Use of mask or respirator**	**Other protective equipment**
Baker Yes ☐ No ☐			Simple particulate (e.g. N95) ☐ Half face with filters ☐ PAPR/supplied air ☐ Other ☐ Please specify (________________)	Gloves ☐ Earplugs ☐ Local exhaust ventilation/ extraction ☐
Confectioner Yes ☐ No ☐			Simple particulate (e.g. N95) ☐ Half face with filters ☐ PAPR/supplied air ☐ Other ☐ Please specify (________________)	Gloves ☐ Earplugs ☐ Local exhaust ventilation/ extraction ☐

Type of work undertaken (Production)	Products(s)	Approximate number of hours per work day doing this task	Use of mask or respirator	Other protective measures
Weighing and mixing Yes ☐ No ☐			Simple particulate (e.g. N95) ☐ Half face with filters ☐ PAPR/supplied air ☐ Other ☐ Please specify (_________________)	Gloves ☐ Earplugs ☐ Local exhaust ventilation/ extraction ☐
Dough former Yes ☐ No ☐			Simple particulate (e.g. N95) ☐ Half face with filters ☐ PAPR/supplied air ☐ Other ☐ Please specify (_________________)	Gloves ☐ Earplugs ☐ Local exhaust ventilation/ extraction ☐
Other production based tasks (please specify) _________________ Yes ☐ No ☐			Simple particulate (e.g. N95) ☐ Half face with filters ☐ PAPR/supplied air ☐ Other ☐ Please specify (_________________)	Gloves ☐ Earplugs ☐ Local exhaust ventilation/ extraction ☐
All of above tasks Yes ☐ No ☐			Simple particulate (e.g. N95) ☐ Half face with filters ☐ PAPR/supplied air ☐ Other ☐ Please specify (_________________)	Gloves ☐ Earplugs ☐ Local exhaust ventilation/ extraction ☐

Type of work undertaken (Non-production)	Products(s)	Approximate number of hours per work day doing this task	Use of mask or respirator	Other protective measures
Packer/shipper Yes ☐ No ☐			Simple particulate (e.g. N95) ☐ Half face with filters ☐ PAPR/supplied air ☐ Other ☐ Please specify (_________________)	Gloves ☐ Earplugs ☐ Local exhaust ventilation/ Extraction ☐
Front counter/sales Yes ☐ No ☐			Simple particulate (e.g. N95) ☐ Half face with filters ☐ PAPR/supplied air ☐ Other ☐ Please specify (_________________)	Gloves ☐ Earplugs ☐ Local exhaust ventilation/ extraction ☐
Cleaner/maintenance Yes ☐ No ☐			Simple particulate (e.g. N95) ☐ Half face with filters ☐ PAPR/supplied air ☐ Other ☐ Please specify (_________________)	Gloves ☐ Earplugs ☐ Local exhaust ventilation/ Extraction ☐

7.6 Does/did this job involve work in the food processing industry? Yes ☐ No ☐
(must be completed for current job)

7.5.1 If yes, which of the following ingredients did you work with?

Flour Yes ☐ No ☐

Types of flour used:

Wheat ☐	Rye ☐	Barley ☐	Triticale ☐
Millet ☐	Maize ☐	Soya ☐	Other ☐ (please specify) ______________________

Flour improvers Yes ☐ No ☐

Yeast Yes ☐ No ☐

Spices and herbs Yes ☐ No ☐

(please specify ___________________________________)

Flavourings other than spices and herbs Yes ☐ No ☐

(please specify ___________________________________)

Colouring agents Yes ☐ No ☐

(please specify ___________________________________)

Resins or gums Yes ☐ No ☐

(please specify ___________________________________)