

Determination of the size of airborne flour particles

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Air sampling was done in a UK bakery and a flour mill with an eight-stage cascade impactor to determine the size of airborne flour particles. The concentration of captured material was determined by a competitive inhibition radioimmunoassay. Comparison of the different sites revealed that 8.79% and 52.14% of the particles in the bakery dough-brake and roll-production areas had a diameter $\leq 6.0 \mu\text{m}$, respectively, and 19.7% of the particles in the flour mill packing area were of this size. We conclude 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 bronchial airways and alveoli.

Key words: airborne; flour; particles; size.

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Baker's asthma is an allergic occupational lung disease that occurs in millers, bakers (4), and others involved in the use of cereal flour such as animal feed workers (8). The disease is caused by inhaled airborne flour and is usually associated with the development of IgE antibodies against water- and salt-soluble cereal proteins (7). It may also be caused by fungal α -amylase derived from *Aspergillus oryzae* (1), which is a widely used additive. To determine the size of allergen-bearing particles in the air of the working environment, we sampled particle size in a large bakery and a mill typical of those in the UK.

Material and methods

Sampling sites

Sampling was done in the dough-brake (where dough is mechanically kneaded) and roll-production (where flour is both mechanically and hand dispensed) areas of a large bakery. Samples were obtained from the packing area of a mill where flour is transferred under gravity from flour silos into bags before distribution.

Particle sizing

For determination of the size of flour particles generated in the sampling sites, workers in the above areas wore eight-stage Sierra Marple personal cascade impactor air samplers (Anderson Instruments,

distributed by Schieffer Instruments Ltd, Oxon, UK), run at a standard flow rate of 2 l per min for 8 h (9). Five samples were taken at each site. The sampled material was captured on glycerol (Sigma Chemical Co, Dorset, UK)-coated mylar membranes, which were subsequently weighed and analysed for protein content.

Elution of filters

Captured material was eluted from the filters by the method of Gordon et al. (3). The membranes were shaken for 2 h in 6 ml 0.1 M NH_4HCO_3 (pH 7.0) 0.5% v/v Tween 20. Filter eluates were freeze-dried and reconstituted in 400 μl PBS 0.1% BSA (Sigma Chemical Co) and stored at -20°C .

Measurement of airborne flour

The concentration of flour protein in the filter eluates was determined by a competitive inhibition radioimmunoassay using purified polyclonal rabbit IgG antibodies against water- and salt-soluble wheat flour proteins, as reported previously (6). The identity of the proteins recognized by the rabbit antibodies used in the immunoassay was determined by Western blotting and shown to have mol. masses similar to those of human allergens. The assay has been standardized against a number of wheat flours

and found to have no cross-reactivity with noncereal agents such as fungal α -amylase.

Method of competitive inhibition radioimmunoassay

Briefly, a standard curve was constructed with concentrations of flour protein ranging from 1000 to 0.122 $\mu\text{g/ml}$ applied to the microwell plate. The filter eluates were applied to the plates, and purified polyclonal rabbit antibodies were added simultaneously. The plates were incubated overnight, washed, labelled with ^{125}I -protein-A (Amersham International, Amersham, UK), and incubated for a further 16 h before counting on a Packard model 5005 gamma-counter (Packard Ltd, Hampshire, UK). The concentration of airborne flour (FA) was read from the standard curve and calculated by the following equation:

$$\text{FA } (\mu\text{g/ml}) = \frac{[\text{flour}] (\mu\text{g/ml}) \times \text{reconstituted volume (ml)}}{\text{volume of air sampled (m}^3\text{)}}$$

where the flour concentration [flour] was interpolated from the standard curve. The assay detection limit was between 200 and 1 $\mu\text{g/ml}$.

Results

Figs. 1–3 show the percentage distribution of the airborne dust and flour proteins on airborne particles of different aerodynamic diameter obtained from samples taken in the dough-brake and roll-production areas of a bakery and the packing area of a mill. The levels of flour protein carried by airborne particles of different diameter are shown in Fig. 4. Table 1 gives the geometric mean total dust and total airborne protein levels detected in the three

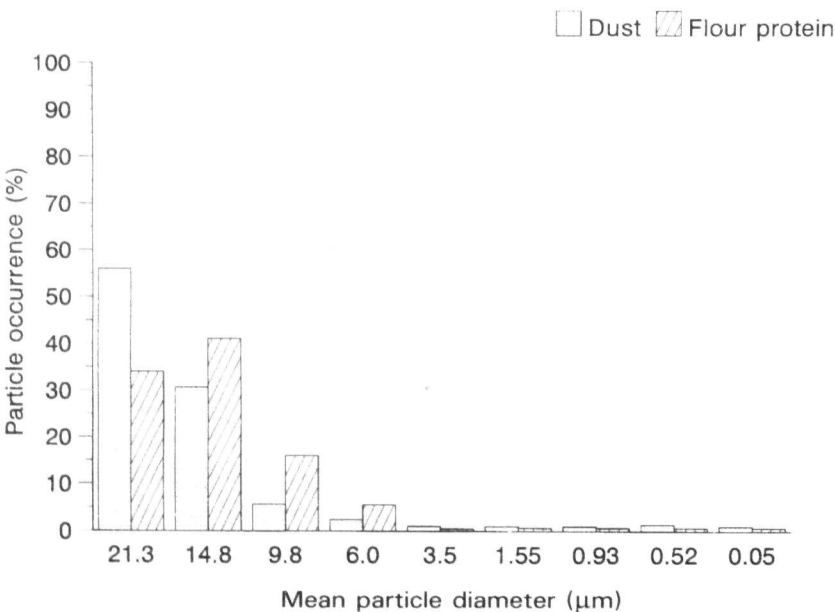


Fig. 1. Distribution of dust and flour protein loads on airborne particles in bakery dough-brake area.

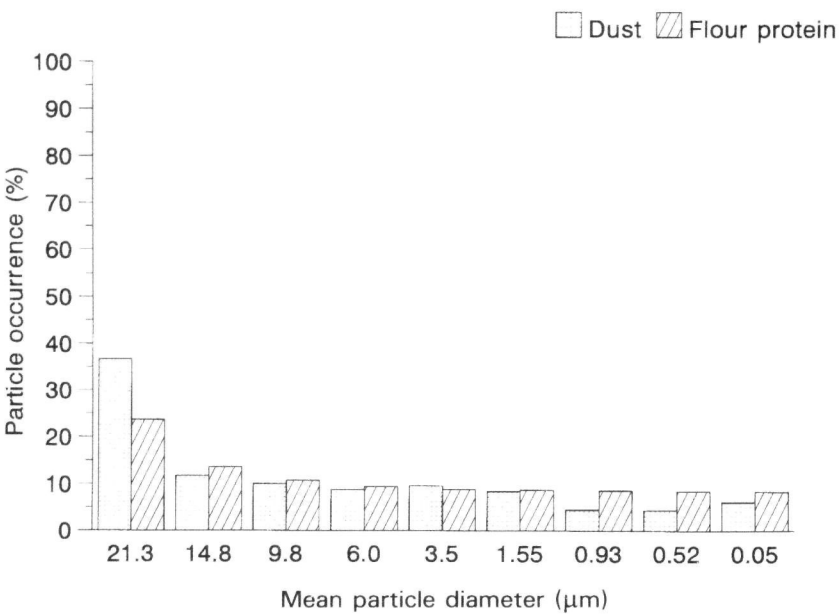


Fig. 2. Distribution of dust and flour protein loads on airborne particles in bakery roll-production area.

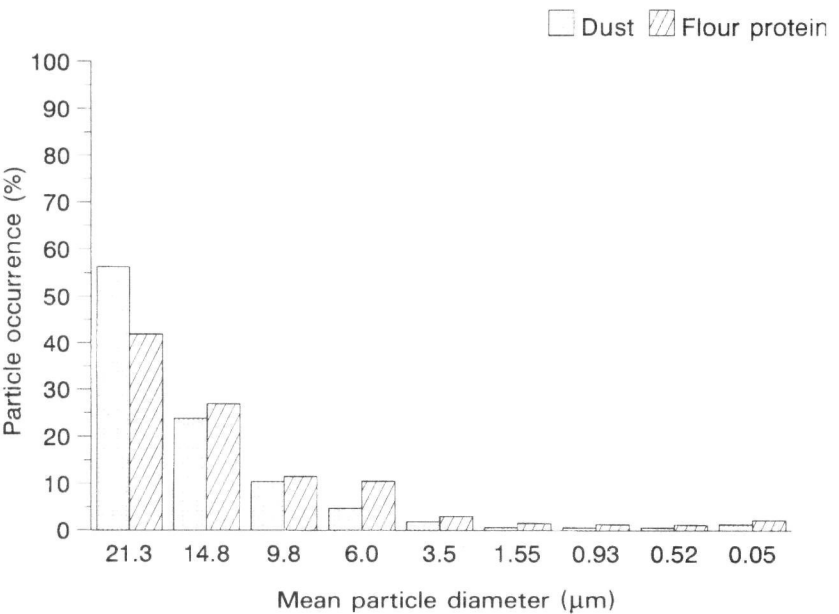


Fig. 3. Distribution of dust and flour protein loads on airborne particles in flour mill packing area.

sites. The samples obtained from the dough-brake and packing areas had the highest concentrations of dust and flour, while the roll-production area had a high concentration of airborne dust and a low concentration of flour proteins.

Discussion

The data we have obtained with an assay that specifically measures airborne flour shows that in the dough-brake area 75% of the airborne flour proteins are borne on particles of 21.3–14.8 μm diameter and that 16% of the proteins are borne on particles of 9.8 μm diameter. The airborne flour proteins were distributed uniformly across particles of different size in the less dusty roll-production area even though flour was manually handled in this area. The packing area in the mill showed a size distribution of particles like that of the dough-brake area, with

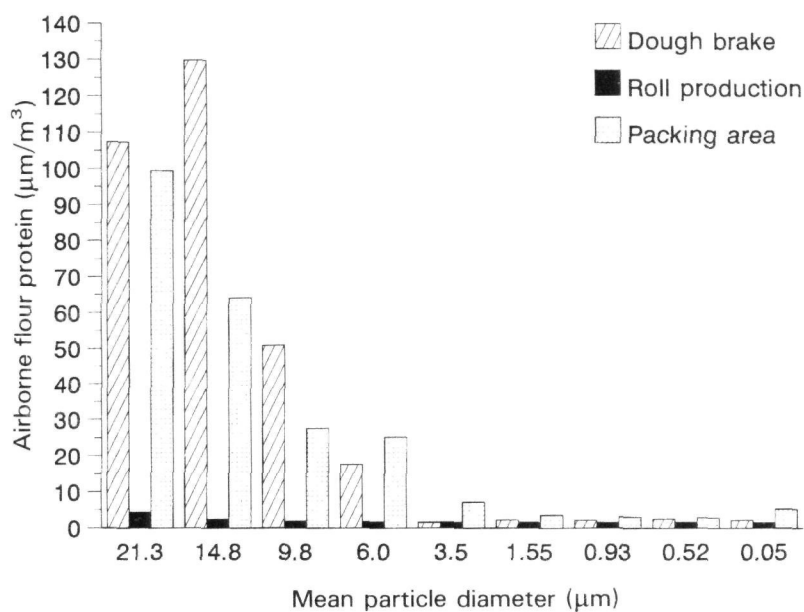


Fig. 4. Level of airborne flour protein detected on particles on different sizes in dough-brake, roll-production, and mill packing areas.

Table 1. Geometric mean levels of total dust and total aeroallergen levels in two areas of UK bakery and mill packing station

Sampling area	Geometric mean total dust (mg/ml)	Geometric mean total flour aeroallergen (µg/ml)
Dough brake	12.0	315.7
Roll production	1.9	18.6
Packing	15.3	237.1

68.8% of the airborne protein detected on particles of 21.3–14.8 µm diameter. Comparison of the different areas showed that 8.79%, 52.14%, and 19.7% of the airborne flour proteins were borne on particles ≤6.0 µm diameter in the dough-brake, roll-production, and mill-packing areas, respectively.

These results are similar to those obtained in other studies which have examined the size distribution of aeroallergen particles. Findlay et al. examined the size of cat allergen particles with an eight-stage Anderson sampler and found that 70.2–85.7% of the allergen was borne on particles of ≥10 µm, 17.26–14.2% on particles of 9.0–10 µm, and 12.5–0.1% on particles ≤9.0 µm in diameter (2). This group concluded that approximately 5% of cat-allergen-bearing particles were of an aerodynamic

diameter likely to allow them to be deposited in the alveolar and tracheobronchial tree. A recent study of Wood et al. found that 15% of cat allergen was borne on particles ≤4.0 µm diameter (9). Using a Casella cascade impactor, Platts-Mills et al. found that 27.8% of rat urinary allergen in animal husbandry areas was borne on particles of 5–0.3 µm diameter and that 4.5% of *Der p I* was found on particles of a similar size distribution (5).

If the observations we have made are typical of bakeries and flour mills, they suggest that most of the allergen-carrying particles inhaled by flour-exposed workers are likely to be deposited in their nasal passages and upper airways, and that in dusty areas a smaller proportion, of 8–20%, is deposited in the bronchial airways and alveoli. These results also suggest that in some areas of a bakery, such as the roll-production unit, approximately 50% of the flour particles to which workers are exposed are ≤3.5 µm in diameter.

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