Influence of ventilation system on aerosol and vapour concentration in the kitchen

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Abstract

During the experiments and under the experimental conditions, displacement ventilation with air outlets close to floor level were found to produce the lowest concentrations of hazardous substances and aerosols in the working areas of kitchen appliances when compared with mixed or displacement ventilation through ceiling outlets. Displacement ventilation with low-induction ceiling outlets achieved better results than mixed ventilation. Since the experimental setup had been selected specifically for its closeness to practical conditions, it can be expected that, arrangement of appliances and, consequently, any additional space requirement must be taken into account in practical scenarios.

Introduction

Personnel in industrial and commercial kitchens are particularly subject to a whole range of influences. Important influencing factors include the hazardous substances, thermal loads and moisture released during cooking, frying and grilling processes. Releases of heat and moisture in particular play a key role as regards the climatic influence on kitchen personnel.
These include substances which are damaging to health [1].
The resulting decomposition products are present in gas, vapour and aerosol form [2]. Even the water vapour has been found to contain substances with a chemically irritant effect [3].
To ensure a multidisciplinary approach to this problem, it is essential to deal jointly with the factors of climate and hazardous substances in the kitchen.

The influence of kitchen vapours

The table 1 shows the most important chemical compounds created during frying, baking and grilling.

Table1. Decomposition products occurring during food processing

Frying / baking / grilling – Pyrolysis / Maillard reaction
Acids- Hydrocarbons – Aldehydes/Ketones – Esters-Nitrogen compounds – CO/CO2 Nitrosamines - PAHs

Many of these compounds are formed through pyrolysis and the Maillard reaction. Pyrolysis is the decomposition of substances at high temperatures. The Maillard reaction is partly responsible for the browning of food through the application of heat in the frying process. This gives rise to organic acids such as formic acid and acetic acid, paraffin hydrocarbons such as nonene, aldehydes and ketones such as formaldehyde, acrolein, acetaldehyde, 2,4-decadienal, and complex nitrogen compounds from the proteins in the foodstuffs.

Under certain conditions, nitrosamines can also be generated e.g. when grilling cured meat. When char-grilling or heating foodstuffs at temperatures of over 250°C, polycyclic- aromatic hydrocarbons can be generated .Toxicologically relevant substances in kitchen vapours are those possessing chemically irritant, carcinogenic and mutagenic properties. The first group includes the short-chain aldehydes (acrolein tr-2-hexenal, 2,4-decadienal), some of which possess mutagenic properties.

The carcinogenic substances include nitrosamines and a number of polycyclic aromatic hydrocarbons such as benzo(a)pyrene. The limit values of individual substances and their total concentrations can be exceeded in some kitchens if the ventilation is inadequate. This can result in respiratory tract problems.

Results of measurements in kitchen

Kitchens have a number of emission sources. Tilt frying pans, deep fat fryers, grills and frying pans are just a few examples. The temperatures of the fat in the various appliances can be as high as 200°C. During grilling, even surface temperatures of up to 500°C are possible. Figure 1 shows the results of measurements conducted at various kitchen appliances.

Higher levels of PAHs have been measured when frying and charcoal grilling. The level of nitrosamines is increased when pans are cleaned by heating at temperatures higher than 300 °C. Values from a quarter to half of the limit value have been measured. The highest concentration of nitrosamines was measured when grilling. However, all individual values lie below their relevant limit values.

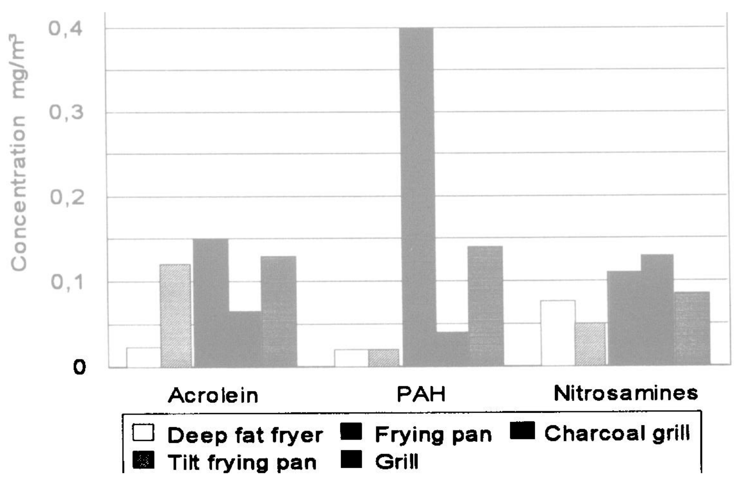

Figure 1: Health hazardous substances in kitchen atmospheres
PAH/Nitrosamines – Concentration µg/m³

The highly irritant chemical action of acrolein has been identified in all parts of the kitchen. Where kitchens have inadequate or poorly-designed ventilation, the hazardous substances are distributed throughout the room regardless of the physical state in which they occur.

The influence of ventilation systems

It has been proven that displacement ventilation has the effect of reducing both temperatures and hazardous substances in production bays [5].
It was therefore a logical move to examine the influence of ventilation systems on concentrations of hazardous substances and climate loading in kitchens.
Under close to practical conditions, the influence of various ventilation systems on the concentration of hazardous substances and climate loading in the working areas of kitchen appliances was examined. A more detailed account can be found in the FSA Report[4] .
The setup, implementation and results of the experiments are set out below.

Methods – Experimental setup

The experimental kitchen had an area of 23.75 m² and, with an average room height of 2.45 m, had a volume of 58.2 m³. The appliances were located under the left-hand half of a vented ceiling. A 5.4 kW grillplate (heated grill area 0.40 x 0.55 m²) and a 12-litre double deep fat fryer with an output of 12 kW were used for the experiments. The hazardous substances were released by applying a uniform coat of oil to the hot surface of the grillplate while simultaneously frying chips in the deep fat fryer under experimental conditions which were identical in each case, i.e. as reproducible as possible (oil quantity, weight of chips, surface temperature of the grillplate, temperature of fat in the deep fat fryer, working cycles, duration of experiment). After each experiment, the grillplate was cleaned thoroughly and the fat in the deep fat fryer exchanged.
The mixed ventilation was generated via 4 slotted outlets integrated into the ceiling (each 1500 x 150 mm²) . The displacement ventilation was produced by four low-induction air outlets integrated into the ceiling (each pair with dimensions 1200 x 500 mm² and 1200 x 220 mm²) and 4 cylindrical low-induction air outlets integrated into the corner areas of the floor. The volume of air supplied and extracted during the individual experiments can be seen in Table 2.
Carrying out the experiments:
The hazardous substances recorded at measuring points 4, 5 and 6 (Figure 2) at a measuring height of 1.65 m included the short-chain aldehydes formaldehyde, acrolein, trans-2-hexenal and capronaldehyde. At measuring point 7, the aerosols were collected at a measuring height of 1.65 m. The physical climatic parameters were measured at a height of 1.10 m at measuring point 3 in experiments 1, 2 and 3a

Table 2. Quantities of air supplied and extracted during experiments

Experiments	Ventilation system	Air supplied and Extracted (m³/h)	Air exchange n (1/h)
1	Mixed ventilation	1500	26
2	Displacement ventilation ,ceiling	1500	26
3a	Displacement ventilation , floor	1500	26
3b	Ditto	950	16
3c	Ditto	2000	34
4	Ditto and range hood	1050 680/hood + 370/ceiling	18

Results

Figure 3 shows the mean values for the aldehyde concentrations measured at measuring points 4, 5 and 6. They show a clear dependence on the ventilation system. The lowest concentrations were obtained for displacement ventilation with air outlets close to the floor or in combination with direct extraction at the sources of emission.

With direct extraction at a reduced level of 1050 m³/h, the results obtained were more or less as good as those recorded for displacement ventilation at a rate of 2000 m³/h. The same trends were identified for capronaldehyde and the other aldehydes, which were present in lower concentrations. Figure 4 shows the result of the aerosol concentration measurements. Here, too, there is a clear dependence on the ventilation system used.

Table 3 shows the results of the climatic measurements performed in experiments 1, 2 and 3a.

Table 3: Influence of ventilation systems on the room climate

1,6 met 0,7 clo	**Mixed ventilation**	**Displacement ventilation, ceiling**	**Displacement ventilation, floor**
Air temperature	21,1 °C	21,2 °C	20,0°C
Air velocity	0,13 m/s	0,05 m/s	0,05 m/s
Water vapour pressure	476 Pa	400 Pa	334 Pa
PMV	0,002	- 0,015	- 0,257

Discussion

The displacement ventilation with air supplied close to floor level resulted in the lowest measurements for air temperature, mean air velocity and water vapour pressure. Only the thermal sensation (PMV) shifted to lower values. This is understandable since the temperature in the kitchen was already comfortable during the experiments conducted with mixed and displacement ventilation via the ceiling outlets. If it is nevertheless assumed that, under real kitchen conditions, particularly in summer, the basic thermal load is higher than that encountered during the experimental conditions, the displacement ventilation will be well suited for ensuring comfortable climatic conditions .Under the experimental conditions, displacement ventilation with air outlets close to floor level were found to produce the lowest concentration of hazardous substances and aerosols in the working areas of kitchen appliances when compared with mixed or displacement ventilation through ceiling outlets .Of course, aspects relating to hygiene, the arrangement of appliances and, consequently, any additional space requirement must be taken into account.

Literature

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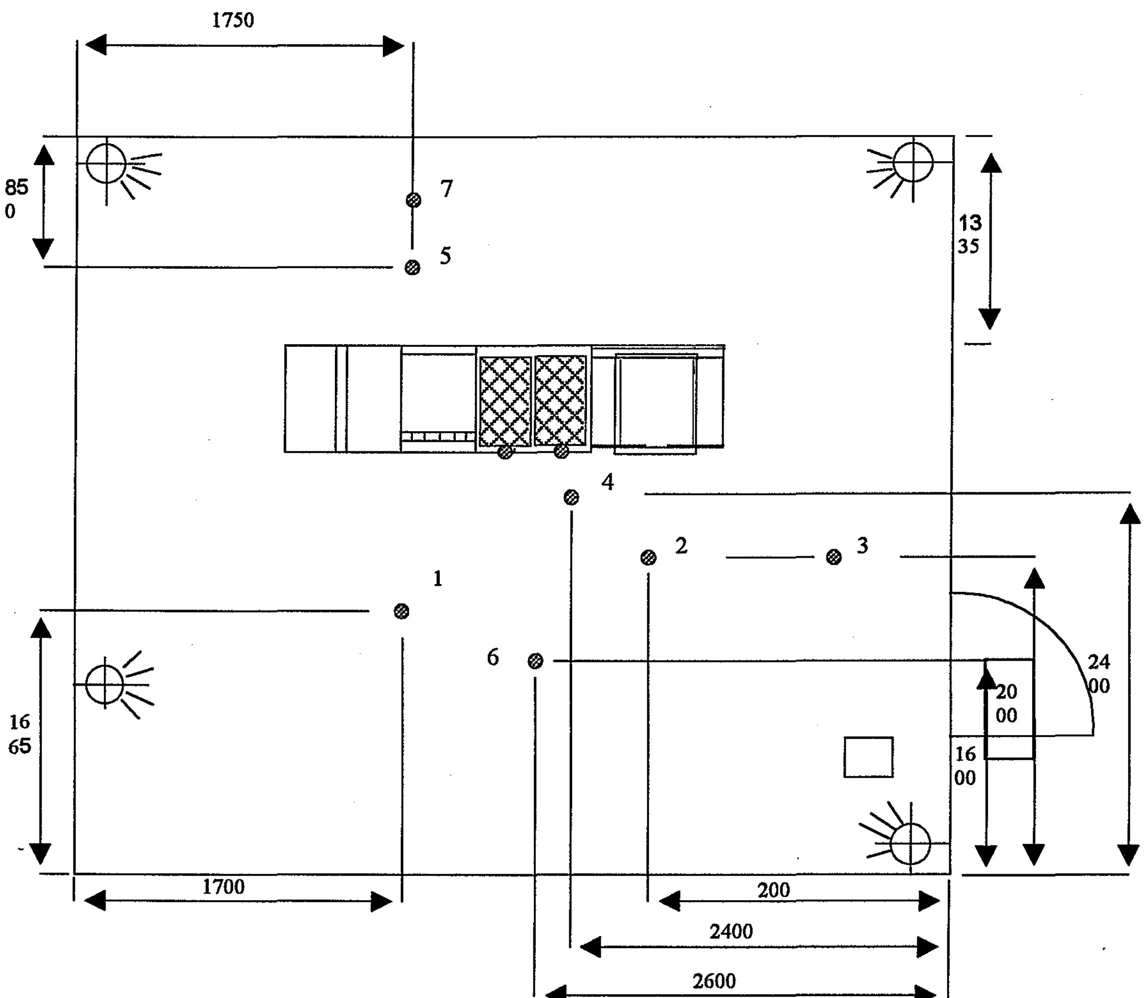
□ Figure 2. Floor plan and location of measuring points



Measuring points:

1. temperature
2. Velocity of the air
3. Climat measuring points:
4. Aldehydes
5. Aldehydes
6. Aldehydes
7. Aerosols, total dust, fine dust

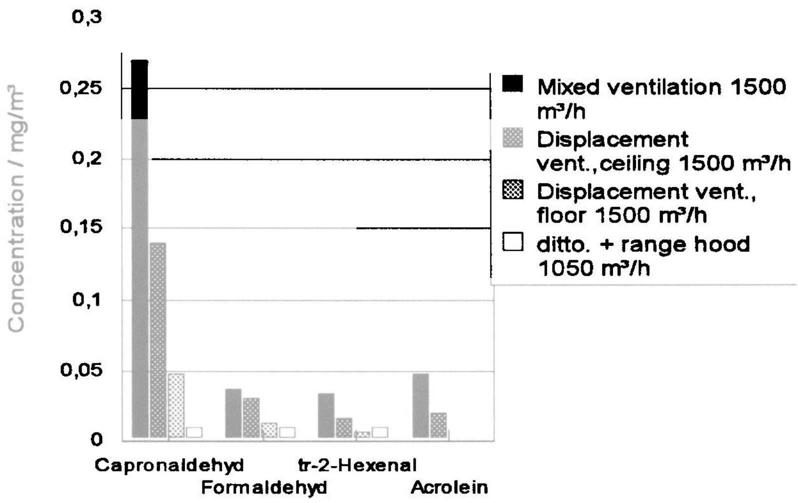


Figure 3 . Influence of ventilation systems on the concentration of various aldehydes

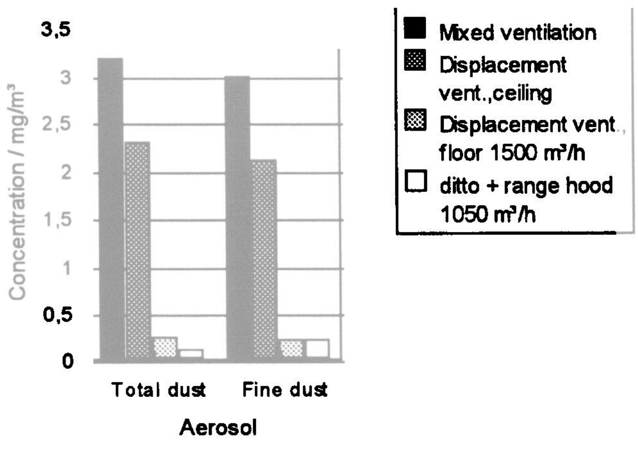


Figure 4. Influence of the ventilation system on the aerosol concentration