Ann. occup. Hyg., Vol. 46, No. 4, pp. 395–400, 2002

Published by Oxford University Press
DOI: 10.1093/annhyg/mef045

Exposure to Cooking Fumes in Restaurant Kitchens in Norway

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Received 3 August 2001; in final form 17 December 2001

Objectives: The purpose of this study was to assess exposure to fat aerosols and aldehydes in kitchens and to study the variations in exposure between different types of kitchen.

Methods: Measurements were made in four hotel kitchens, two hamburger chain restaurants, 10 à la carte restaurants and three small local restaurants serving mostly fried food. The measurements were performed as personal measurements and each person carried two sampling devices connected to pumps. One pump was connected to a filter cassette with a 37 mm glassfibre filter and the other to a sampling device for aldehydes. The measurements were repeated on 3 days in each kitchen. Variables which could influence the level of exposure were recorded by the occupational hygienist.

Results: The level of fat aerosols varied between the different types of kitchen. The highest measured level of fat aerosol was 6.6 mg/m^3, in a small local restaurant. The arithmetic mean for all the kitchens was 0.62 mg/m^3. The highest level of the sum of the aldehydes was 186 μg/m^3 (0.186 mg/m^3), while the arithmetic mean was 69 μg/m^3.

Conclusions: The exposure to fat aerosols was modest, but could be up to 50% of the Norwegian threshold limit value (TLV) for nuisance dust (10 mg/m^3). Fat aerosols from frying will, however, contain a mixture of heat- and water-treated fat from the meat which is being fried, hydrolysed vegetable fat and other degradation products, such as fatty acids, other organic acids and aldehydes. As a consequence of this, cooking fumes should be regarded as harmful to the lungs. The levels of formaldehyde, acetaldehyde and acrolein were well below the TLVs.

Keywords: aldehydes; fat aerosols; frying; kitchens

INTRODUCTION

Food is prepared under high temperatures when grilled or fried. Harmful degradation products may be formed during such processes (Kiel, 1986; Kiel and Andersen, 1988; Vainiotalo and Matveinen, 1993). The most important chemical processes during the high temperature treatment of food are the degradation of sugars, pyrolysis of proteins and amino acids and the degradation of fats. Aldehydes, such as formaldehyde, acetaldehyde and acrolein, may be generated in these processes (Vainiotalo and Matveinen, 1993; Zhong *et al.*, 1999). Acrolein and formaldehyde can produce local irritation in the airways when inhaled (Ghilarducci and Tjeerdema, 1995; Ross *et al.*, 1995; Costa and Amdur, 1996). During frying at high temperatures, fats will enter the atmosphere as aerosols, formed both from splashing and volatilization. When inhaled, fat aerosols are irritating to the lung tissue and inhalation of high concentrations can produce lipid pneumonia (Oldenburger *et al.*, 1972; Kennedy *et al.*, 1981). The lung-damaging potential of aerosols from vegetable and animal fats is supposed to be dependent on the content of free fatty acids in the fat (Spickard and Hirschmann, 1994).

Several mutagenic and carcinogenic compounds have been identified in cooking fumes (Kiel, 1986; Kiel and Andersen, 1988; Vainiotalo and Matveinen, 1993) and previous investigations have also shown that cooks may have an increased risk of lung cancer (Coggon *et al.*, 1986; Lund, 1986). Based on early Norwegian statistics, there have also been indications of an increased mortality from respiratory diseases, such as asthma and emphysema, in employees in hotels and restaurants (Borgan and Kristoffersen, 1986). This could well be a result of the occupational

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inhalation of irritants. The levels of fat aerosols and aldehydes produced during frying have earlier been measured by stationary sampling near the source (Vainiotalo and Matveinen, 1993). The purpose of this study was to assess exposure to fat aerosols and aldehydes in kitchens and to study the variation of exposure between different types of kitchen.

MATERIALS AND METHODS

By collaboration with the local Labour Inspectorate we were able to perform measurements in 19 kitchens in restaurants and fast food outlets which were selected from the local telephone directory.

These kitchens consisted of four hotel kitchens, two hamburger chain restaurants, 10 à la carte restaurants with grills and three small, local restaurants serving mostly fried food. All 19 kitchens had devices for deep frying equipped with ventilation hoods. The temperature of the oil ranged from 160 to 190°C. These deep frying devices were used for potato frying during all measurements except in one hotel kitchen (no. 2). The oils used during frying were vegetable oils, such as soya, palm and sunflower oil, in all the kitchens. The four hotel kitchens mainly used cabinets for frying and boiling and they produced mostly boiled or cold food for lunch. Meat, eggs and potatoes were fried for a short time during most of the measurements. All four hotel kitchens had effective ventilation hoods above all cooking tops and frying cabinets.

The two hamburger chain kitchens were local units of international enterprises and were equipped with modern, effective ventilation hoods above the frying unit or the closed frying devices. The foods prepared were hamburgers and deep fried potatoes.

All of the 10 à la carte restaurants had ventilation hoods above the cooking and frying top and the grill. In most kitchens these exhaust systems were able to take care of the main part of the cooking fumes produced. Also, the cook worked outside the ventilation hood in the majority of these kitchens. In some of these kitchens the exhaust system was, however, not effective enough. In these kitchens cooking fumes filled the whole working area of the cooks. During all measurements meat was prepared and during six measurements fish were also fried.

The three, small, local restaurants mostly produced fried food (meat and deep fried potatoes) for the restaurant and the 'take away' service. These three restaurants had insufficient exhaust systems compared with the other restaurant kitchens. In these three kitchens the ventilation hood filled a large part of the kitchen and thus the cooks were working inside or under the hood, so the cooking fumes often reached their breathing zones.

The measurements were performed as personal measurements and each person carried two sampling devices connected to two pumps. One pump was connected to a filter cassette with a 37 mm glassfibre filter (Nuclepore AAA) with a flow rate of 2 l/min and sampling time of 1.5–2.5 h. Another pump was connected to a sampling device for aldehydes. The device contained silica impregnated with 2,4-dinitrophenyl hydrazine, and the pump had a flow rate of 1.5 l/min and a sampling time of 1.5–2.5 h. The measurements were repeated for 3 days in 16 of the kitchens, for 2 days in two kitchens and for 6 days in one kitchen, as aerosol production was supposed to differ in the daytime and in the evening. It was not always possible to take measurements on the same person each day as the workers had greatly varying work shifts. The measurements were taken at different times of the day, with most being taken in the afternoon and evening, and some late at night. The time of the day when the measurements were performed was recorded and used as a possible explanatory variable in a multivariate regression model for the determined exposure levels. Other possible explanatory variables which were recorded during the measurements were: the number of persons involved with frying during the measurements; that part of the sampling time involving frying (%); whether the kitchen was open to public areas with smoking (yes/no). Six à la carte restaurants were open to a public area with smoking, the others were not.

Analysis

The filters with trapped fat aerosols were extracted with 5 ml of 1,1,2-trichloro-1,2,2-trifluoroethane and the oil concentration was determined using FT-IR (Perkin Elmer model 1605, wavenumber range 2928–2930, 4 scans/sample, 1 cm cell path length). External standards (sunflower oil) for quantification were prepared at three concentrations. The different samples showed the same absorbance in the C-H region.

The aldehydes react with 2,4-dinitrophenylhydrazin (DNPH) to form the corresponding stable hydrazone derivatives. In this study commercial samplers from Waters were used (Waters SEP-PAK DNPH-silica cartridge). The cartridge consists of 55–105 μm chromatographic grade silica coated with DNPH. The DNPH derivatives were eluted with HPLC grade acetonitrile. The eluate was injected onto a C18 reverse phase column. Separation of derivatives of C1–C3 aldehydes was performed isocratically (60% acetonitrile/40% water). A UV detector, operating at 360 nm was used (ISO, 2001). The detected aldehydes were formaldehyde, acetaldehyde and acrolein.

Statistical analysis of the data was performed by means of SPSS 10.0 for Windows. The influence of possible explanatory variables on the measured levels of fat aerosols and aldehydes was examined by stepwise linear regression analysis. The level of statistical significance was set to $P < 0.05$ for entering a variable and to $P > 0.1$ for removing a variable. The explanatory value of each model was assessed through the coefficient of determination (adjusted r^2). The natural logarithm of the measurement values was used as the dependent variable, since this transformation produces a multiplicative effect for each of the variables, and the results from the measurements were log-normally distributed.

Tests for statistical differences between the means were done using one-way ANOVA with *post hoc* multiple comparison (Tukey HSD).

RESULTS

The results of the measurements in the kitchens are given in Table 1. The parameters registered during sampling are given for all kitchens in Table 2, together with the arithmetic mean and SD for fat aerosols in each kitchen. The non-detectable values were substituted by $L/\sqrt{2}$ (where L is the detection limit) (Hornung and Reed, 1990). Both the level of fat aerosols and the sum of aldehydes were highest in the three small local restaurants. The lowest exposure levels to fat aerosols and aldehydes were in the hamburger chains. The levels of fat aerosols and the sum of aldehydes were statistically different for the three small local restaurants when compared with the other types of kitchen. The variation within each type of kitchen was great. For instance, the lowest and highest levels of fat aerosols in the three small local restaurants were 0.5 and 6.6 mg/m^3 and the lowest and highest measured levels for the sum of aldehydes were 73 and 186 μg/m^3, respectively. The highest levels of formaldehyde (60 μg/m^3) and

Table 1. Results of the personal measurements in the different kinds of kitchen given as arithmetic means (mean) with SD, geometric means, minimum and maximum, with the number of samples (*n*) for each kitchen type also given

Type of kitchen		Fat aerosol (mg/m^3)	Formaldehyde (μg/m^3)	Acetaldehyde (μg/m^3)	Acrolein (μg/m^3)	Sum of aldehydes (μg/m^3)
Hotel kitchen	Mean	0.3	11	29	11	51
	n	17	8	8	8	8
	SD	0.3	8	30	10	31
	Minimum	0.05	4	4	1	22
	Maximum	1.16	24	68	27	96
	Geometric mean	0.2	8	16	7	43
Hamburger chain	Mean	0.1	7	16	14	37
	n	11	3	3	3	3
	SD	0.1	0	5	9	14
	Minimum	0.05	7	12	4	23
	Maximum	0.4	7	22	22	51
	Geometric mean	0.1	7	16	11	35
Restaurants with grill	Mean	0.6	15	34	12	60
	n	41	24	24	24	24
	SD	0.8	11	24	11	34
	Minimum	0.05	2	3	1	8
	Maximum	3.6	60	93	32	145
	Geometric mean	0.3	12	26	7	51
Small local restaurants	Mean	1.9	14	102	3	119
	n	9	9	9	9	9
	SD	1.9	6	33	1	36
	Minimum	0.5	7	57	0	73
	Maximum	6.6	26	162	4	186
	Geometric mean	1.4	13	97	2	114
Total	Mean	0.6	14	46	10	69
	n	78	44	44	44	44
	SD	1.0	9	39	10	42
	Minimum	0.05	2	3	0	8
	Maximum	6.6	60	162	32	186
	Geometric mean	0.3	11	30	6	57

The levels of fat aerosol, sum of aldehydes and acetaldehyde are statistically significantly different between small local restaurants and the other types of kitchens.

Table 2. Fat aerosol measurements

Kitchen	Arithmetic mean fat aerosol ± SD (mg/m^3)	Time of measurements (samples)	No. of persons frying during sampling	Activity level	Percent of sampling time with frying (range)	No. of persons sampled/days/ total sample
In the four hotel kitchens[a]						
1	0.62 ± 0.56	7–12 p.m. (3)	1 person, 3 samples	<Medium, 1 sample		
				Medium, 1 sample	10–25	1/3/3
				>Medium, 1 sample		
2	0.25 ± 0.18	Before 4 p.m. (3)	No person was frying	<Medium, 3 samples	0	3/3/3
3	0.23 (0,13)	Before 4 p.m. (4)	1 person, 8 samples	<Medium, 7 samples	0–30	3/6/8
		4–7 p.m. (1)		Medium, 1 sample		
		7–12 p.m. (3)				
4	0.32 ± 0.24	Before 4 p.m. (2)	1 person, 2 samples	<Medium, 2 samples	0–30	1/2/2
In the two hamburger chain kitchens[b]						
1	0.11 ± 0.05	Before 4 p.m. (3)	2 persons, 2 samples	<Medium, 2 samples	25	2/3/5
		4–7 p.m. (2)	4 persons, 3 samples	Medium, 2 samples		
				>Medium, 1 sample		
2	0.15 ± 0.16	Before 4 p.m. (2)	2 persons, 6 samples	Low, 2 samples	25–100	2/3/6
		4–7 p.m. (2)		<Medium, 2 samples		
		After 12 p.m. (2)		High, 2 samples		
In the 10 à la carte restaurants[c]						
1	0.18 ± 0.11	4–7 p.m. (1)	1 person, 3 samples	Medium, 1 sample	25–50	1/3/3
		7–12 p.m. (2)		>Medium, 2 samples		
2	0.24 ± 0.12	7–12 p.m. (6)	1 person, 6 samples	<Medium, 2 samples	25–75	3/3/6
				>Medium, 2 samples		
3	2.48 ± 0.81	4–7 p.m. (1)	1 person, 4 samples	Medium, 1 sample	10–100	2/3/4
		7–12 p.m. (3)		>Medium, 2 samples		
				High, 1 sample		
4	0.83 ± 0.40	4–7 p.m. (1)	1 person, 3 samples	Medium, 3 samples	25–30	1/3/3
		7–12 p.m. (2)				
5	0.30 ± 0.14	Before 4 p.m. (1)	1 person, 2 samples	Medium, 1 samples	5–40	1/2/2
		4–7 p.m. (1)		>Medium, 1 sample		
6	0.11 ± 0.09	7–12 p.m. (3)	1 person, 3 samples	<Medium, 3 samples	50	1/3/3
7	0.52 ± 0.30	7–12 p.m. (5)	1 person, 5 samples	Low, 1 sample	5–30	3/3/5
				Medium, 4 samples		
8	0.08 ± 0.06	7–12 p.m. (6)	2 persons, 6 samples	<Medium, 2 samples	50	2/3/6
				Medium, 2 samples		
				>Medium, 2 samples		
9	0.43 ± 0.19	4–7 p.m. (6)	1 person, 6 samples	<Medium, 6 samples	25–30	3/3/6
10	1.22 ± 1.32	Before 4 p.m. (2)	1 person, 3 samples	<Medium, 3 samples	25–100	1/3/3
		4–7 p.m. (1)				
In the three small local restaurant kitchens[d]						
1	2.95 ± 3.20	Before 4 p.m. (2)	1 person, 3 samples	Low, 1 sample	40–80	1/3/3
		4–7 p.m. (1)		>Medium, 1 sample		
				High, 1 sample		
2	0.76 ± 0.27	Before 4 p.m. (2)	1 person, 3 samples	<Medium, 1 sample	30–50	1/3/3
		4–7 p.m. (1)		Medium, 1 sample		
				>Medium, 1 sample		
3	2.01 ± 0.68	Before 4 p.m. (3)	1 person, 3 samples	Medium, 3 samples	95	1/3/3

[a]Aldehyde measurements were performed in kitchens 1 (three samples) and 3 and 4 (one sample in each kitchen).
[b]Aldehyde measurements were performed in kitchens 1 (one sample) and 2 (two samples).
[c]Aldehyde measurements were performed in all kitchens exept 6 and 8. In kitchen 7 six aldehyde samples were taken; in the other kitchens three samples were taken.
[d]Aldehyde measurements were performed in all three kitchens (three samples in each).

Table 3. Multivariate regression models for natural logarithms of (a) level of fat aerosol, (b) sum of aldehydes, (c) level of formaldehyde, (d) level of acetaldehyde and (e) level of acrolein as a function of possible explanatory variables registered in the kitchens

Independent variable	Coefficient of determination (adjusted r^2)	Explanatory variables	Regression coeficient	SE	*P*
(a) Fat aerosol	0.127	No. of persons frying	–0.650	0.192	0.001
	0.253	Number of persons frying during sampling	–0.727	0.170	<0.001
		and part of sampling time with active frying	0.018	0.005	0.001
(b) Sum of aldehydes	0.244	Part of sampling time with active frying	0.012	0.003	<0.001
(c) Formaldehyde	0.158	Time when measurements were done	0.312	0.105	0.005
	0.251	Time when measurements were done	0.327	0.099	0.002
		and part of the sampling time with active frying	0.007	0.003	0.018
(d) Acetaldehyde	0.318	Part of sampling time with active frying	0.020	0.004	<0.001
(e) Acrolein	0.142	Kitchen open to public area with smoking	1.111	0.394	0.007

acrolein (32 μg/m^3) were measured in two different restaurants with grills. The arithmetic mean of fat aerosols from all the kitchens was 0.62 mg/m^3 and the arithmetic mean for the sum of the aldehydes was 69 μg/m^3.

Table 3 shows the results of the multiple regression analysis of the separate independent variables. The models explained between 14 and 32% of the variation in the exposure levels.

DISCUSSION

The results of these measurements show that working in some types of kitchen can entail exposure to fat aerosols of up to 6.6 mg/m^3 and to a sum of aldehydes of up 185 μg/m^3 (0.185 mg/m^3). However, the levels of fat aerosols and aldehydes varied to a great extent between and within the different kitchens.

The main causes of the differences in exposure levels to fat aerosols between the kitchens are, from our observations, that the different kitchens produce different types of food and have different kinds of ventilation hoods. Ventilation hoods which only covered the cooking and frying units and had sufficient exhaust systems seemed to give the lowest exposure levels to fat aerosols. The highest levels were seen in kitchens where the hoods covered the working area of the cooks and thus allowed the cook to work inside the edges of the hood. The levels of formaldehyde, acetaldehyde and acrolein were well below the Norwegian threshold limit values (TLV) (600 μg/m^3 for formaldehyde, 45000 μg/m^3 for acetaldehyde and 250 μg/m^3 for acrolein).

The multivariate regression analysis shows that a contributory factor to the measured levels of formaldehyde and acetaldehyde was frying, as the variable ‘part of the sampling time with active frying’ was a statistically significant explanatory variable for the variation in acetaldehyde concentration and ‘time of the day when measurements were done’ and ‘part of the sampling time with active frying’ were so for formaldehyde. None of the variables which included frying seemed to explain the variation in the level of acrolein. One source for acrolein seems to be smoking in the public areas outside the kitchens.

The multivariate regression analysis shows that when several persons share the workload of frying, the exposure to fat aerosols for each person decreases. We had expected that when the number of persons who worked with frying during sampling increased, more cooking fumes would be produced. The reason for the decrease in exposure may be that in a small restaurant kitchen with insufficient ventilation there will not be as many people frying at the same time as in big restaurants with efficient ventilation, where there are more people working. However, when the ‘part of the sampling time with active frying’ increases, the exposure level increases.

As there is no TLV for this kind of fat aerosols, the Norwegian TLV for nuisance dust of 10 mg/m^3 or the TLV (ACGIH) for vegetable oil mist of 10 mg/m^3 was used as a reference value. Fat aerosols from cooking fumes could, however, contain compounds which are specifically harmful to the lungs. Fats of animal origin are known to contain free fatty acids which can damage the lung, while vegetable oils are supposed to be harmless (Spickard and Hirschmann, 1994). The aerosols from frying, however, never consist of clean vegetable fat. The aerosols will always contain a mixture of heat- and water-treated fat from the meat which is being fried, hydrolysed vegetable fat and other degradation products, such as fatty acids, other organic acids and aldehydes (Alexander, 1981; Durak *et al.*, 1999). As a consequence of this, cooking fumes should be regarded as harmful to the lungs. Further investigations are needed to estimate what exposure levels can be regarded as safe in a work environment.

Acknowledgements—The grant sponsor was the Work Environment Fund of the Confederation of Norwegian Business and Industry.

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