Assessment of olfactory function by Sniffin' sticks in bakery workers exposed to flour dust

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Abstract. – OBJECTIVE: This study used the Sniffin' Sticks test battery to evaluate olfactory function in employees of a bakery exposed to flour dust.

SUBJECTS AND METHODS: The study enrolled 43 individuals with exposure (i.e., to flour) plus 41 healthy volunteers as controls. Olfactory function was assessed in these subjects through the use of the Sniffin' Sticks test battery. The overall score was calculated by adding up the scores for each of the 12 separate odors. A score of 6 or less was deemed anosmia, from 7 to 10 hyposmia, and a score of 11 or 12 was taken to indicate no impairment of olfaction.

RESULTS: There was a statistically significant difference between the scores obtained in the exposure group (10.09±2.29) and the control group (10.73±2.07), the exposure group having a lower score ($p<0.05$). Within the exposure group, men and women did not score differently ($p>0.05$). Furthermore, in this group, the overall score did not correlate significantly with age, sex, length of employment, or use of tobacco or alcohol use ($p>0.05$). Using the scheme employed in this study, 9.3% of the exposed workers were anosmic, compared to 9.8% in the controls, whereas 34.9% of baker workers were hyposmic, compared to just 14.6% of the controls. Thus, our study shows that impairment of the ability to smell was present in 44.2% of individuals exposed occupationally to flour dust.

CONCLUSIONS: This study reveals that being exposed to flour dust reduces the ability to smell normally. In order to minimize the impact of being exposed, workplaces should ensure adequate ventilation and provide workers with protective facemasks.

Key Words:
Bakery workers, Flour dust, Sniffin sticks test, Olfactory impairment.

Introduction

Individuals employed in bakery-related occupations, such as those working in confectioneries, flour mills, food processing or in-store bakeries are exposed occupationally to flour dust on a daily basis and may thus undergo sensitization to allergens found in wheat flour. These allergens are of high molecular weight and may eventually trigger an allergic disorder, such as rhinitis, asthma, conjunctivitis, or allergic eczema. It has been demonstrated that, even if the individual is exposed only to a somewhat limited extent, the likelihood of becoming sensitized is still raised[1]. Confirmatory evidence for this comes from testing by skin prick or IgE (immunoglobulin E) quantification in bakery employees, which reveals that, amongst individuals showing respiratory symptoms, 60% react specifically through IgE to inhaled allergenic compounds found in flour[2,3].

Inhaled organic matter (IOM) samplers were utilized during a working period of 8 hours to calculate the exposure of 104 employees working as millers, sweepers, bakery mix operators, and miscellaneous operatives in 14 flour mills. The samples obtained indicate that exposure of above 0.5 $mg.m^{-3}$ occurred in 97.1% (n=101) of these individuals, and 67.3% were exposed to a level of at least 5 $mg.m^{-3}$ (n=66) and some 42.3% (n=44) of individuals encountered levels above 10 $mg.m^{-3}$. To set these values in context, IOM levels were also measured in a flour mill with a high level of automation and adhering to the most up-to-date standards. The levels recorded show the difficulty, even in an automated and very clean milling environment, of keeping dust concentrations in air less than 0.5 $mg.m^{-3}$, the threshold limit value. When IOM samplers have been compared with closed-

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face 37 mm cassettes, the IOM appears to perform better in capturing particles in the air of size 100 microns or less[4].

One study using a cross-sectional design looked at fractional exhaled nitric oxide levels (FeNO) in employees of in-store bakeries. The authors found a strong association between FeNO and levels of IgE specific for wheat antigens, symptoms of occupational rhinitis, and asthma. This association occurred regardless of tobacco use or history of allergic disorders[5]. However, whereas flour mites were considered an occupational allergen in bakery workers previously, this is no longer the case as bakery employees have been noted to be sensitized to a similar degree to the population at large[6].

Symptoms affecting the respiratory system arising due to prolonged exposure to flour dust may arise after a matter of months or may take tens of years to be noted. They may even lessen or disappear whilst an individual is employed handling flour[7]. Usually, occupational asthma develops only after symptoms of occupational allergic rhinitis have occurred. For our study, we assessed olfactory impairment in employees of bakeries by means of the Sniffin' Sticks test battery.

Subjects and Methods

This study was undertaken on employees of bakeries within the Antalya Province of Turkey, in adherence to the principles of the Declaration of Helsinki. The Ethical Committee Approval was granted by the University of Health Sciences (SBÜ) Antalya Training and Research Hospital Clinical Research Ethics Committee on 03.03.2022 by decree number 5/23.

Subjects

The exposure group (Group 1) was formed from 43 individuals with occupational exposure to flour dust working in the Antalya Province of Turkey. The mean length of occupational exposure was 8.41±8.55 (range: 1-30) years, whilst the mean age was 32.23±9.37 (range: 18-55) years. The control group was formed from 41 healthy volunteers who came to the Kumluca State Hospital. Their mean age was 36.14±12.00 (range: 18-58) years. Each participant in both groups provided verbal consent for their inclusion in the study.

The exclusion criteria were as follows: infection of the upper respiratory tract within the preceding 21 days, congenital abnormalities of olfaction or gustation, neoplasia, traumatic injury to the head, conditions affecting the nervous system (notably Alzheimer's or Parkinson's disease or epilepsy), and endocrinological disorders or metabolic disorders (specifically, diabetes mellitus).

Evaluation of Olfactory Function

The olfactory perception was assessed for each subject enrolled in the trial utilizing the Sniffin' Sticks odorous felt-tipped pens marketed as Sniffin' Sticks (Burghart GmbH, Wedel, Germany)[8-10]. The pens make up a panel of tests used to evaluate psychophysical aspects of olfactory perception. The test was administered as follows: the pen had its cap taken off and it was presented to the subject's nostril, being held 1-2 cm from the nose. The odors presented were all familiar smells. The subject needed to select which of four descriptors best fitted the odor presented. The pens were offered to the nostril no quicker than every 30 s so that nasal desensitization would not occur. It was left at the subject's discretion what length of time they felt necessary before selecting a descriptor. In reaching a final score, the examiners totaled the number of correctly applied descriptors[8-10].

The pens used for the evaluation each bore different odors, as follows: Orange (Pen 1), Leather (Pen 2), Cinnamon (Pen 3), Peppermint (Pen 4), Banana (Pen 5), Lemon (Pen 6), Licorice (Pen 7), Coffee (Pen 8), Cloves (Pen 9), Pineapple (Pen 10), Rose (Pen 11) and Fish (Pen 12).

The results were interpreted in the following manner: a score less than 6 was deemed anosmia, while a score falling in the range of 7-10 was interpreted as hyposmia. A score of 11 or more was deemed indicative of normal olfactory perception.

Statistical Analysis

This study utilized the SPSS for Windows 16.0 software (SPSS Inc., IBM Corp., Chicago, IL, USA) to perform the statistical comparisons and analysis. Statistical testing involved the Chi-square test, Mann-Whitney U test, Pearson correlation test and Spearman's rank correlation coefficient (rho).

The level of statistical significance was defined as a p-value less than 0.05.

Results

Within the exposure group (group 1), 79.1% (n=34) were men, while 20.9% (n=9) were women. Amongst the control subjects, 51.2% (n=21) were men and 48.4% (n=20) were women (p=0.007, χ^2=7.202). The age of participants in each group did not significantly differ (p=0.099).

There were 15 individuals who smoked in the exposure group, representing 53.6% of the sample. The corresponding rate amongst the controls was 31.7% (n=13) (p=0.758, χ^2=0.095).

The frequency of alcohol use in the exposure group was 14.0% (n=6), compared to 19.5% amongst the control subjects (n=8) (p=0.494, χ^2=0.467).

The results of testing with the Sniffin' Sticks battery are given in Table I, which lists the scores for each of the pens used. There was a significant difference between the scores obtained for pen 7, which the exposure group was less able to correctly identify (p<0.05). Overall, the score for the groups was also significantly different, with the exposure group having a lower olfactory perceptual ability (10.09±2.29) than the control group (10.73±2.07) (p<0.05).

Within the exposure group, men and women did not differ in terms of their total score (p=0.668). For men, the overall score was 10.08±2.23, whilst for women subjects, it was 10.11±2.66.

Table I. Sniffin' Sticks test results for 12 odors.

		Group 1 (n=43)			Group 2 (n=41)			p*
		n	%		n	%		
Odor 1	Absent	2	4.7		5	12.2		p=0.392 χ^2=1.564
	Present	41	95.3		36	87.8		
Odor 2	Absent	18	41.9		11	26.8		p=0.148 χ^2=2.098
	Present	25	58.1		30	73.2		
Odor 3	Absent	4	9.3		4	9.8		p=1.000 χ^2=0.005
	Present	39	90.7		37	90.2		
Odor 4	Absent	2	4.7		0	0.0		p=0.495 χ^2=0.465
	Present	41	95.3		41	100.0		
Odor 5	Absent	9	20.9		6	14.6		p=0.451 χ^2=0.567
	Present	34	79.1		35	85.4		
Odor 6	Absent	7	16.3		4	9.8		p=0.376 χ^2=0.785
	Present	36	83.7		37	90.2		
Odor 7	Absent	17	39.5		5	12.2		p=0.004 χ^2=8.115
	Present	26	60.5		36	87.8		
Odor 8	Absent	2	4.7		3	7.3		p=0.956 χ^2=0.003
	Present	41	95.3		38	92.7		
Odor 9	Absent	5	11.6		1	2.4		p=0.226 X^2=1.466
	Present	38	88.4		40	97.6		
Odor 10	Absent	12	27.9		11	26.8		p=0.912 χ^2=0.012
	Present	31	72.1		30	73.2		
Odor 11	Absent	6	14.0		2	4.9		p=0.296 χ^2=1.091
	Present	37	86.0		39	95.1		
Odor 12	Absent	0	0.0		2	4.9		p=0.453 χ^2=0.562
	Present	43	100.0		39	95.1		
Classification of total odor scores	Anosmia	4	9.3		4	9.8		p=0.089 χ^2=4.831
	Hyposmia	15	34.9		6	14.6		
	Normosmia	24	55.8		31	75.6		
Total odor score		Mean	Median	Std.Dev.	Mean	Median	Std.Dev.	p**
		10.09	11.00	2.29	10.73	12.00	2.07	0.046

*p-value shows the results of the Chi-square test. **p-value shows the results of Mann Whitney U test

Following the definitions of anosmia and hyposmia outlined above, we noted that 9.3% of the exposure group were anosmic, compared to 9.8% in the controls. Some 34.9% of the exposure group were deemed hyposmic, but only 14.6% of the controls fulfilled the criteria for this diagnosis (p=0.089, χ^2=4.831).

For the exposure group, the following factors were found not to correlate significantly with the overall score: age (p=0.167, r=- 0.215); sex (p=0.673, r=0.066), length of employment (p=0.111, r= - 0.247), tobacco (p=0.888, r=0.022) or alcohol use (p=0.414, r=0.128).

Discussion

It is currently unknown how common olfactory impairment resulting from being exposed to chemicals at work actually is. The frequency amongst olfactory disorders of any type has been put at anywhere between 0.5 and 5%. This is based on a history of being exposed to chemicals or medicinal drugs. It is likely that this figure is an underestimate, bearing in mind that exposure through work may represent a large portion of those cases currently categorized as idiopathic. Currently, idiopathic olfactory disorders account for between 10 and 25% of all reported disorders of smell. There are reports linking long-term exposure to specific metals and abnormal olfactory function, specifically cadmium, chromium, manganese, mercury, and lead bound to organic molecules, as well as to arsenic. Other substances implicated in occupation-related olfactory disorders are acrylic acid, styrene, and solvents. The pathogenetic mechanisms producing abnormality of olfaction are unknown at present, but the data suggest the olfactory epithelium is where damage occurs. Since olfactory perceptual impairment is rarely reported spontaneously, there is a need for quantitative testing of olfaction if cases are to be correctly identified[11].

Workers may be exposed to flour dust in a number of different settings, such as a plant bakeries, artisan bakeries, factories producing cakes or biscuits, pastry manufacturies, supermarket bakeries, and pizzerias. There are statutory limits on how much flour dust an employee may be legally exposed to, with the relevant regulations being covered by COSHH 2002 in the UK[12]. The limit at present (maximum exposure limit, MEL) is 10 mg.m^{-3} over a period of 8 hours (TWA – time-weighted average). For periods not exceeding 15 minutes, a short-term exposure limit (STEL) has been defined, namely 30 mg.m^{-3}.

There are reports in the literature of prolonged dust exposure provoking low-grade chronic inflammation. Nasal cytology smears taken in this situation contain abundant neutrophils with paucicellularity of ciliated respiratory-type epitheliocytes[13-15]. Nasal cytology undertaken in workers in bakeries revealed the absence of cilia-bearing epitheliocytes. The same cytological appearances were noted in samples from individuals without allergic symptomatology. The appearances may therefore represent vasomotor rhinitis of non-hypersensitive type, triggered by chronic exposure to a dust-filled atmosphere[16].

For this study, the ability to smell normally was evaluated using the Sniffin' Sticks test battery in individuals employed in bakery trades. The overall olfactory score in the exposure group (10.09±2.29) indicated a lower olfactory ability than in the healthy controls (10.73±2.07), and this difference was statistically significant. In the individuals exposed to flour dust, the impairment did not differ significantly between men and women. Although possible correlations were sought with age, sex, length of time employed, tobacco or alcohol use, and overall olfactory score, none were established.

A study undertaken by Crivellaro et al[17] examined how symptoms of upper or lower respiratory tract disorder, inflammatory markers, and being exposed to flour dust through employment were related. This research involved a thorough assessment of the entire respiratory tract. Symptoms indicative of a disorder in the lower tract were present in 7% of subjects, with symptoms indicating the involvement of the upper tract present in 22%. Allergic hyper sensitization was present in 55% of the sample, with 37.1% having evidence of sensitivity to allergens encountered in bakery-related trades. Although nasal cytological smears revealed neutrophil-dominated rhinitis in virtually all the workers employed in bakery trades, the peak nasal inspiratory flow (PNIF) was normal. There was also a significant correlation between the degree of neutrophilia in the smear and the length of time for which the individual had been exposed to flour dust (p=0.030). The frequency of hyposmia in this study was reported as 23.8%. The authors drew the conclusion that being chronically exposed to flour dust potentially triggers a low-grade allergic inflammatory response in the nose.

In the exposed group we studied, using our definition of anosmia and hyposmia, which relies on the overall olfactory score, 9.3% of individuals were anosmic, whilst 34.9% were hyposmic. This compares with a rate of 9.8% for anosmia, and 14.6% for hyposmia, in the healthy controls. Thus, the rate of olfactory impairment, taken to include the partial or complete absence of smell perception, was 44.2% in the group exposed to flour dust. In the study by Crivellaro et al[17] cited above, only 23.8% of bakery trade employees had an impairment of the ability to smell, with 76.2% having normal abilities. Thus, our study reveals a higher frequency of olfactory impairment than that shown by Crivellaro et al[17]. However, the rate of tobacco use in our sample was 53.6%, and alcohol use was 14.0%, and this may partially explain why we found a higher incidence of impaired ability to smell.

An assessment of the adequacy of dust control measures by an occupational hygienist indicated a satisfactory application of working practices and ventilation. In around 50% of the workplaces examined, the precautions against dust exposure were considered at a level ensuring the MEL and STEL were not exceeded[18].

In most of the workplaces examined, there were still individuals undertaking dry sweeping and manual flour dusting. This may have been because the individuals lacked awareness of occupational safety or because safe practices were being neglected. A further way to combat dust exposure risk is for employees to avoid specializing in tasks where dust exposure is high, but rather to rotate around tasks. This seems to be why employees of smaller bakery workplaces are less exposed since they need to fulfil a variety of different roles during the working hours[18].

There have been frequent reports in the last two decades implicating wheat flour (*Triticumaestivum*), rye (*Secale cereale*) or barley (*Hordeum vulgare*) as the main sources of allergens triggering allergic responses and asthma in workers in bakery trades[19-23]. However, another key category of substances with high allergenic potency is the enzymes used to improve the quality of bread, introduced in the 1970s. There are a variety of reports suggesting that the principal culprits responsible for allergic reactions and asthma in bakery workers are, in fact, α-amylases[24-26].

A review that examined the causes of smell impairment in workers exposed to various toxins and the effects long-term concluded that a variety of chemicals and metals were to blame[27]. Metals that have established olfactory toxicity include cadmium, chromium, copper, mercury, nickel, and zinc, as well as the metalloid, arsenic. Chemicals that also impair smell through exposure include acetone, acrylic acid, methacrylic acid, benzene, methylbenzene, trichloroethene, dimethyl benzene and organic solvents[28]. There is a lack of evidence to quantify the level of risk for olfactory toxicity for these known hazards or for those engaged in handling them. A study undertaken by Schwartz et al[29] specifically reported the odds ratio for impairment of the sense of smell as 3.1 (95% confidence interval: 1.2-7.7) in workers exposed to vaporized acrylic or methacrylic acid.

A study undertaken by Watanabe and Fukuchi[30] assessed the ability to smell in 33 individuals employed in a factory manufacturing chromate. They noted impairment of the sense of smell in 54.5% of their sample. The effect on olfaction of exposure to vaporized cadmium was studied by Rose et al[31] who studied 55 individuals engaged in brazing. The overall rate of impaired ability to smell was 56.4%, consisting of 43.6% classified as mildly impaired, with 12.7% moderately or severely hyposmic. Cadmium exposure was also studied by Mascagni et al[32], who assessed the sense of smell of 33 employees engaged in cadmium fusion, sintering, and alloy lamination. The rate of impairment this study noted was 30.3%. Exposure to both cadmium and nickel during battery manufacture and how it affects olfaction was the subject of a study by Rydzewskiet al[33]. These researchers report a dysfunctional sense of smell in 45.2% of the sample, consisting of 26.0% hyposmia, 17.8% parosmia, and 1.4% anosmia.

Amongst commercial bakery trades, the greatest volume of exposure to dust occurs in those engaged in bread production, where the geometric mean exposure (GM) is 1.06 $mg.m^{-3}$. These workers are exposed to high volumes of allergens originating from both wheat flour and α-amylases. Traditional type bakeries producing bread were the locations where the highest exposure to such allergens occurred, with reported GM exposures of 22.33 $\mu g.m^{-3}$ for wheat and 0.61 ng/m^{-3} for α -amylase in those baking the bread, whilst for those engaged in packing, the reported values were 2.79 $\mu g.m^{-3}$ for wheat and 0.15 $ng.m^{-3}$ for α-amylase[34].

Harris-Roberts et al[35] reports on allergic symptoms experienced amongst workers with occupational exposure to flour dust. They note that irritation of the nose occurred with the highest frequency (28.9%), after which came ocular irritation (13.3%) and occupational coughing or the feeling of a tight chest (10.2% each). There was a significant association between feeling the chest was tight and having a co-occurring sensitivity to wheat flour and enzymatic additives (OR 7.9, 1.3-46.0). There was no correlation between employment in a bakery lacking sufficient risk mitigation and complaining of occupation-related breathing symptoms (OR 1.3, 0.4-3.7). There were 51 employees with atopy, and 14% (n=23) had a sensitivity to occupational allergens. Possession of an atopic disorder was the most powerful risk factor for developing sensitivity to occupational allergens (OR 18.4, 5.3-64.3). After correction for the length an individual had been exposed to flour dust or enzymatic additions and current exposure, smoking only modified the risk (OR 4.7, 1.1-20.8) in cases of pre-existing atopy. Some workers had also been sensitized to allergens that are infrequently employed in the process, such as the enzyme cellulase, hemicellulase, and xylanase, manufactured from *Aspergillus niger*, or a mixture of glucose oxidase and amyloglucosidase. Tobacco uses in workers with atopy may add to their risk of becoming sensitized to these allergens.

Conclusions

There are already studies in the literature which assess the allergenic potential of exposure to flour dust in the baking trades. There is a lack of evidence, nonetheless, for how occupation-related allergic conditions, in particular, allergic rhinitis, affect the ability to smell. Olfactory rating may serve a reference for early diagnosis[36]. This study, therefore, focuses on how being exposed to flour dust may cause impairments in olfactory function. The authors make the recommendation that workplaces, where flour is handled, should ensure adequate ventilation and provide protective masks to their employees.

Conflict of Interest

The authors declare that they have no conflict of interest.

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Ethical Approval

SBÜ Antalya Training and Research Hospital Clinical Research Ethics Committee on the date 03.03.2022 and number 5/23.

Informed Consent

All subjects in the study and control groups gave verbal consent to participate the study.

Author Contributions

Mustafa Altintaş: Planning, designing, data collection, literature survey, interpretation of the results, active intellectual support. Murat Kar: Planning, designing, data collection, literature survey, interpretation of the results, active intellectual support. Nuray Bayar muluk: Planning, designing, literature survey, statistical analysis, interpretation of the results, active intellectual support, writing, submission Cemal Cingi: Planning, designing, literature survey, interpretation of the results, active intellectual support, English editing.

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