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# AIRBORNE CONTAMINANTS AND FARMERS HEALTH IN SWINE FARMS WITH HIGH AND LOW PREVALENCE OF RESPIRATORY DISEASES IN PIGS

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**Abstract:** The main purpose of this study was to investigate the relationship between prevalence of respiratory disease in swine and respiratory health of swine farmers. Fourteen farms were selected based on clinical history and slaughtercheck evidence of respiratory problems in pigs. The farms were divided into two groups with either high (n = 7) or low (n = 7) prevalence of respiratory disease in pigs. Airborne dust, endotoxin and peptidoglycan were measured once in farrowing, gestation, nursery and finishing of each farm. Respiratory health of farmers in participating farms was evaluated by questionnaire and pulmonary function test. A mean of 71% of the pigs in high prevalence farms had pneumonic lesions at slaughter, compared with 7% in low prevalence farms. No significant relationship was found between prevalence of respiratory disease in pigs and airborne dust, endotoxin or peptidoglycan. More farmers in high prevalence farms reported chest tightness ($p = 0.038$). The percentage predicted $FEF_{25\%-75\%}$ was lower ($p = 0.046$) in farmers working in high prevalence farms. Significant differences disappeared after adjusting for smoking status. Our study suggests that farmers working on farms with a high prevalence for respiratory disease in pigs may have more respiratory problems than farmers working in farms with low prevalence of such diseases.

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The major airborne contaminants in swine confinement buildings are dust, endotoxin, microorganisms and ammonia [9, 14]. Airborne dust in swine confinement buildings primarily originates from feed, dried fecal materials, skin debris, bacteria and molds [7, 10, 14, 25]. Recently, Martin *et al.* [25] suggested that in addition to the pigs, farm workers and environment (i.e. soil, water, feed, plants, etc.) are also significant sources of the microbial flora in airborne dust. This was concluded after microbiological evaluation of dust in swine farms indicated the presence of microorganisms of human and environmental origin. Biologically active agents in dust include endotoxin (a cell wall component of Gram-negative bacteria), ß-1,3-glucan (a cell wall component of molds) and peptidoglycan (a cell wall component of all bacteria) [9, 24].

Respiratory problems, such as occupational asthma and chronic bronchitis, are common in swine producers [9, 13, 15, 16, 19, 29]. The relationships between organic dust exposure and respiratory symptoms have been thoroughly investigated in swine producers around the world [4, 9, 11, 16, 28, 29, 35]. In particular, exposure to airborne endotoxin, even in the presence of relatively low dust concentrations, is considered a risk factor for respiratory problems and lung function changes in swine producers [10, 18, 29, 31, 33, 35].

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**Table 1.** Summary of slaughtercheck data for farms with high and low respiratory problems in pigs.

| | Respiratory lesions | | |
|---|---|---|---|
| Farm Type[a] | Pneumonia | Pleuritis | Atrophic rhinitis |
| High (N = 7) | 70.7% (53–87)[b] | 22.7% (10–45) | 29.1% (0–50) |
| Low (N = 7) | 6.7% (0–17) | 9.1% (0–20) | 3% (0–12) |

[a]Mean pigs examined/farm: High = 23 pigs examined, Low = 21 pigs examined; [b]range in %.

Similar to respiratory problems in swine producers, respiratory disease in swine cause important problems for the swine industry all over the world. In several studies, chronic pneumonia lesions and atrophic rhinitis have been observed at slaughter in 100% of swine herds tested and pleuritis in 70% of the herds [2, 6, 17, 27]. Pneumonia and rhinitis are estimated to cause annual losses of several hundred million dollars due to mortality and reduced weight gain [6]. Various infectious agents (viruses, bacteria, mycoplasmas) have been identified as primary etiological agents of swine respiratory disease. However, non-infectious airborne contaminants in swine confinement buildings might be critically important predisposing causes. In addition, the irritant and inflammatory nature of the environment in swine farms might impair the respiratory disease resistance of the pig [7, 20].

Few studies have investigated the relationship between respiratory problems of swine producers and their pigs, and airborne contaminants and respiratory problems in pigs. Bongers *et al.* [4] reported a significant association between altered pulmonary function of the farmers and frequency of lung disease in their pigs at slaughter. Donham [8] found high correlations between pneumonia in pigs at slaughter and total and respirable concentrations of airborne bacteria.

In this study, 14 farms were selected, based on prevalence and clinical history of respiratory diseases in pigs, location and willingness to participate. Prevalence was determined at slaughter and farms were assigned to a high or low prevalence group for respiratory disease. Airborne concentrations of total dust, endotoxin and peptidoglycan were measured and compared in both prevalence groups. In addition, the respiratory health of farmers working in the participating farms was evaluated by questionnaire and pulmonary function test (PFT) and was compared between prevalence groups.

## MATERIALS AND METHODS

**Farms**. Seven farrow-to-finish swine herds, located in southern Wisconsin and northern Illinois, were selected for high prevalence of respiratory diseases in pigs based on clinical history and slaughtercheck evidence of chronic respiratory problems in pigs. Another 7 herds were selected for low prevalence of such diseases (Tab. 1). During an initial farm visit, the investigator recorded:

**Table 2.** Description of the selected farms.

| No. | Farm size[a] | Hygiene[b] | AIAO[c] | Respiratory Lesions[d]: Pneumonia | Pleuritis | AR | Prevalence[e] |
|---|---|---|---|---|---|---|---|
| 1. | 600 | 2 | 1 | 87 | 23 | 33 | H |
| 2. | 200 | 1 | 3 | 60 | 16 | 44 | H |
| 3. | 200 | 1 | 1 | 5 | 5 | 0 | L |
| 4. | 90 | 1 | 2 | 21 | 0 | 12 | L |
| 5. | 200 | 1 | 1 | 54 | 33 | 0 | H |
| 6. | 75 | 3 | 2 | 10 | 10 | 0 | L |
| 7. | 100 | 2 | 3 | 65 | 9 | 50 | H |
| 8. | 130 | 2 | 2 | 5 | 9 | 9 | L |
| 9. | 400 | 2 | 1 | 10 | 10 | 0 | L |
| 10. | 600 | 1 | 1 | 0 | 10 | 0 | L |
| 11. | 75 | 1 | 2 | 0 | 10 | 0 | L |
| 12. | 100 | 3 | 3 | 75 | 45 | 50 | H |
| 13. | 450 | 2 | 2 | 75 | 30 | 50 | H |
| 14. | 100 | 3 | 3 | 80 | 30 | 0 | H |

[a]Number of sows; [b]Hygiene-Subjective score 1=high, 2=fair and 3=poor; [c]AIAO-All In/All Out - Subjective score 1=yes (i.e. AIAO in farrowing, nursery and finishing), 2=both (i.e. AIAO farrowing, continuous flow in nursery and/or finishing), 3=no (continuous flow in farrowing, nursery and finishing); [d]% of pigs with pneumonia, pleuritis or atrophic rhinitis (AR) lesions at slaughtercheck; [e]H=high prevalence of respiratory diseases in pigs, L= low.

1) herd size; 2) all-in all-out procedures - i.e. the simultaneous removal of all pigs from one room into another; 3) farm hygiene (Tab. 2). All-in all-out and hygiene procedures were subjectively scored on a scale from 1 to 3, with a lower mean score indicating better procedures. The farms used mostly confinement housing and mechanical ventilation systems. The study was conducted from January to March, 1995.

**Environmental sampling.** On each farm, one 1-hour total dust sample was collected on the same day in farrowing, gestation, nursery and finishing rooms with large volume dust samplers (LVS). Dust samplers were connected to a timer and sampled 10 minutes per hour over a 6 hour period. Flow rates of the LVS were calibrated and ranged between 324 and 354 l/min. Samples were obtained about 80 cm above the floor in the center of each room on PFTE (Teflon) filters with a Goretex support. The sampling time included one feeding period.

**Analysis of the samples.** Dust concentration was measured by gravimetric analysis of the filters pre-and post sampling and results were expressed as mg/m$^3$. The filters were washed in 10 ml of pyrogen-free water for 1 hour while agitating and the washing solution was centrifuged (3000 rpm, 30 min). Supernatants were analyzed for endotoxin, using the turbidimetric Limulus

**Table 3.** Summary of selected airborne contaminants measured in different locations of the selected swine farms.

| | Airborne contaminant | | |
|---|---|---|---|
| Location | Dust (mg/m$^3$) | Endotoxin (ng/m$^3$) | PG (ng/m$^3$) |
| Farrowing | 2.2 ± 1.2[a, d] (0.6–5.1) | 20.0 ± 12.8 (3.1–53.1) | 469.2 ± 246.6 (163.2–1047.4) |
| Gestation | 3.1 ± 2.5 (0.3–9.1) | 40.1 ± 47.7[b] (0.0–83.1) | 325.9 ± 206.6[b] (26.3–694.7) |
| Nursery | 3.8 ± 1.9[b] (0.3–6.7) | 36.2 ± 24.1[c] (3.1–93.0) | 787.5 ± 501.4[b] (257.9–1621.1) |
| Finishing | 5.1 ± 2.9 (0.0–10.4) | 37.9 ± 26.4[b] (0.5–92.8) | 365.6 ± 206.9[b] (100.0–847.4) |

[a]mean ± standard deviation (range), n = 14 ; [b]n = 13; [c]n = 12; [d]value significantly lower compared to finishing ($p < 0.05$); PG=peptidoglycan; 1 ng of endotoxin = 10 EU.

amoebocyte lysate (Limulus-ES II test, LAL ES-II test, Wako Pure Chemical Ltd, Japan), and for peptidoglycan and β-1,3-glucan, using the Silk Larvae Plasma reagent set (SLP, Wako). In the LAL ES-II, carboxymethylated curdlan is co-lyophilized with LAL, making this test specific for endotoxin. In the SLP test, peptidoglycan and β-1,3-glucan bind to a respective recognition protein, initiating the prophenoloxidase cascade system [34]. Prophenoloxidase is converted to phenoloxidase, which in turn catalyzes oxidation of 3, 4-dihydrophenylalanine, followed by the formation of melanin pigment. Increased absorbance due to melanin formation is read at 650 nm with a microplate reader. The concentration of peptidoglycan and β-1,3-glucan is obtained according to a standard curve. In this study, the SLP result primarily originated from peptidoglycan in the dust. The dust samples were extracted in pyrogen free water, which does not allow extraction of the water-insoluble β-1,3-glucan present in dust [30]. Endotoxin and peptidoglycan results

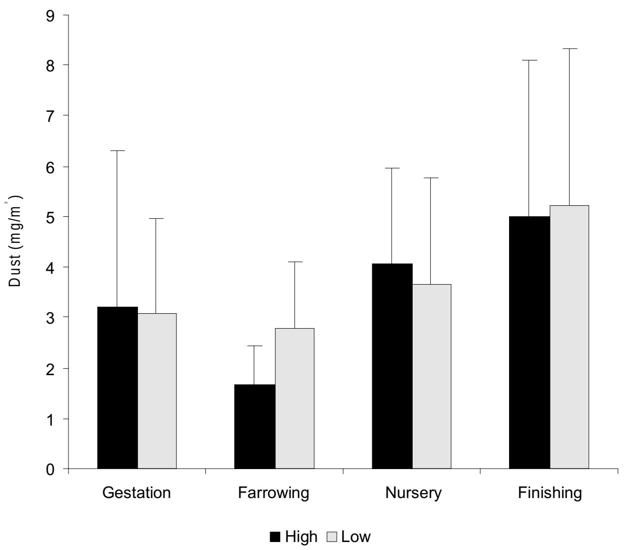


**Figure 1.** Dust concentrations (average ± standard deviation) in farms with high or low prevalence for respiratory diseases in pigs.

were expressed as ng/m$^3$. Analysis of supernatant was carried out by M. Tsuchiya and A. Takaoka at Wako Pure Chemical in Japan.

**Farmer's pulmonary status and function evaluation.** A trained technician visited each farm with a van equipped with a daily calibrated CPF-S/O spirometer for evaluation of pulmonary functions (Medical Graphics Corporation, St. Paul, MN). The technician instructed the workers and demonstrated the PFT technique according to standard procedures [3]. The farm workers performed the procedure during the work shift while seated and with the assistance of the technician. The best forced vital capacity (FVC), forced expiratory volume in one second ($FEV_1$) and forced expiratory flow during the middle half of an FEV maneuver ($FEF_{25\%-75\%}$) of 3 attempts were chosen for calculation of predicted values.

During the same farm visit, each worker also completed a modified American Thoracic Society (ATS) respiratory disease questionnaire. The questionnaire covered respiratory symptoms, work history, including agricultural and non-agricultural exposures, hours worked per day in swine facilities, and time spent on selected specific tasks.

**Data analysis.** Descriptive statistics for the environmental parameters were obtained with Quattro Pro for Windows spreadsheet program (Version 6). Multivariate analysis of environmental data against site and prevalence was generated with Statistical Analysis System (SAS Institute Inc., NC, USA). This model analyzed all response variables (dust, endotoxin and peptidoglycan) together and included 7 farms in each prevalence category and 4 sampling locations in each farm. Partial correlation coefficients examined relationships between dust, endotoxin and peptidoglycan in each sampling location, independent of prevalence.

Farmer data were analyzed with SAS and LogXact (CYTEL Software Corporation, MA, USA). Population characteristics were evaluated using descriptive statistics. The relationship between swine respiratory disease prevalence and presence of chronic respiratory disease in farmers was tested with a chi-square or Fisher's exact test, depending on the cell frequency. The relationship between symptoms, pulmonary function status, and behavioral variables such as smoking status, were examined using exact conditional logistic regressions given the small data set.

## RESULTS

All-in all-out procedures were more common in herds with low prevalence for respiratory diseases in pigs as indicated by a lower mean score (=1.57), compared to the higher mean score in herds with high prevalence (=2.29) (Tab. 2). Similarly, farm hygiene in low prevalence herds was scored lower on average (=1.57) than in high prevalence herds (=2.00) (Tab. 2), suggesting better hygiene procedures in those herds.

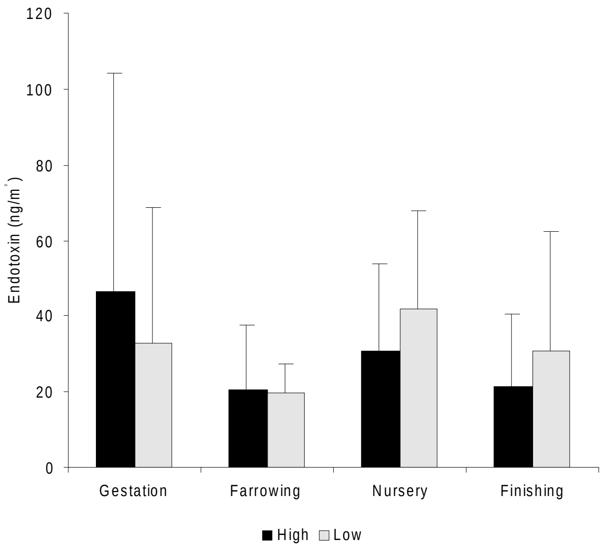


**Figure 2.** Endotoxin concentrations (average ± standard deviation) in farms with high or low prevalence for respiratory diseases in pigs.

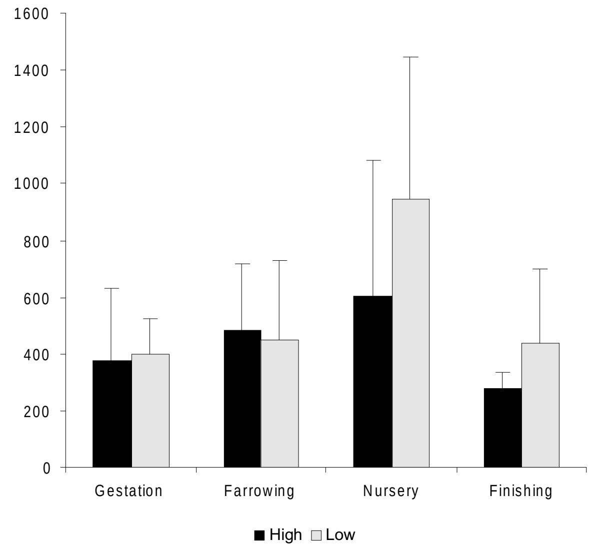


**Figure 3.** Peptidoglycan concentrations (average ± standard deviation) in farms with high or low prevalence for respiratory diseases in pigs.

Results of airborne contaminants are presented in Table 3 and Figures 1-3. Dust, endotoxin or peptidoglycan concentrations were not significantly different between prevalence groups. A significant difference was found between dust concentration in farrowing and finishing rooms (Tab. 3). Positive significant correlations were found between dust and peptidoglycan in gestation ($r = 0.652$, $p = 0.0156$) and finishing rooms ($r = 0.609$, $p = 0.0355$), and between peptidoglycan and endotoxin in gestation ($r = 0.766$, $p = 0.0023$) and farrowing rooms ($r = 0.682$, $p = 0.0102$).

The characteristics of participating farmers and their PFT are summarized in Tables 4 and 5. The farmers in both groups were white, had a high school diploma and were very similar in age, years farmed, number hours/day working in the barn, smoking history and respirator use. The average age of all farmers was 8 years younger than farmers on average in Wisconsin. Consequently, their occupational experience was shorter. More farmers in the high prevalence farms reported symptoms, i.e. cough, phlegm, wheezing or chest tightness. A significantly ($p = 0.038$) higher percentage of farmers in high prevalence farms reported chest tightness in relation with working in the barns (Tab. 4). Pulmonary function results suggested relatively high FVC and $FEV_1$, regardless of farm type (Tab. 5). $FEF_{25\%-75\%}$, $FEV_1$/FVC and % $FEV_1$/FVC values were lower compared to those reported in other studies conducted during the winter in swine farms. The % predicted $FEF_{25\%-75\%}$ was also significantly ($p = 0.046$) lower in farmers working in high prevalence farms. One farmer in the low prevalence group demonstrated marked decrease in pulmonary function for unknown reasons. However, removal of this case during data analysis did not change statistical significance.

**Table 4.** Descriptive statistics of the farmers working on farms with high or low prevalence of respiratory disease in pigs.

| | Farm Type | |
|---|---|---|
| | High Prevalence | Low Prevalence |
| Number of farmers | 15 | 16 |
| Age | 42.6 ± 12.6[a] | 43.3 ± 13.5 |
| Years farmed | 20.6 ± 13.3 | 22.5 ± 13.7 |
| Hours/day in barn | 5.5 ± 3.0 | 5.7 ± 2.5 |
| Ever smoke | 6 (40.0%) | 6 (37.5%) |
| Respirator use | 11 (73.3%) | 10 (62.5%) |
| Farmers with symptoms | 13 (86.7%) | 11 (68.8%) |
| Cough | 6 (40.0%) | 7 (43.8%) |
| Pleghm | 3 (20.0%) | 5 (31.3%) |
| Wheezing | 10 (66.7%) | 7 (43.8%) |
| Chest tightness | 12 (80.0%)[b] | 7 (43.8%) |

[a]mean ± standard deviation; [b]value significantly higher compared to low prevalence ($p < 0.05$)

**Table 5.** Pulmonary function test results of farmers working on farms with high or low prevalence for respiratory disease in pigs.

| | Farm Type | |
|---|---|---|
| Pulmonary Function Test | High Prevalence (n = 15) | Low Prevalence (n = 16) |
| % Predicted FVC | 101.7 ± 14.5[a] | 98.1 ± 15.8 |
| % Predicted $FEV_1$ | 93.3 ± 11.1 | 95.6 ± 17.5 |
| % Predicted $FEF_{25\%-75\%}$ | 72.9 ± 19.4[b] | 88.4 ± 28.0 |
| $FEV_1$/FVC | 75.7 ± 7.1 | 80.0 ± 7.5 |
| %$FEV_1$/%FVC | 81.9 ± 1.3 | 82.3 ± 1.6 |

[a]mean ± standard deviation; [b]value significantly lower compared to low prevalence ($p < 0.05$); FVC - Forced Vital Capacity; $FEV_1$ - Forced Expiratory Volume in 1 second; $FEF_{25\%-75\%}$ - Forced Expiratory Flow during the middle half of an FEV maneuver.

**Table 6.** Relationship between prevalence of respiratory disease in pigs and respiratory symptoms in farmers after adjusting for smoking status[a].

| Respiratory symptom | p-value | Odds ratio | 95% CI |
|---|---|---|---|
| Wheeze | 0.447 | 2.69 | (0.38, 23.84) |
| Cough | 0.993 | 0.75 | (0.12, 4.17) |
| Phlegm | 0.756 | 0.56 | (0.07, 3.63) |
| Chest tightness | 0.100 | 5.68 | (0.78, 58.89) |
| Respirator use | 0.648 | 2.02 | (0.31, 16.51) |
| Symptoms | 0.545 | 2.76 | (0.30, 39.34) |

[a] Smoking status was defined as: ever smoked cigarettes (>20 packs of cigarettes or 12 ounces of tobacco in a lifetime).

**Table 7.** Relationship between prevalence of respiratory disease in pigs and pulmonary function test in farmers after adjusting for smoking status[a].

| Pulmonary function test | p-value | Odds ratio | SE estimate[b] |
|---|---|---|---|
| % Predicted FVC | 0.552 | 3.35 | 5.66 |
| % Predicted $FEV_1$ | 0.703 | -2.06 | 5.40 |
| % Predicted $FEF_{25\%-75\%}$ | 0.105 | -13.82 | 8.24 |
| $FEV_1$ / FVC | 0.143 | -3.82 | 2.54 |
| %$FEV_1$ / %FVC | 0.587 | -0.294 | 0.54 |

[a]Smoking status was defined as: ever smoked cigarettes (>20 packs of cigarettes or 12 ounces of tobacco in a lifetime); [b] SE - standard error.

After adjusting for smoking, no significant relationship was detected between both prevalence groups and the odds of respiratory symptoms or pulmonary function tests in farmers (Tables 6 and 7).

## DISCUSSION

The main objective of this paper was to compare airborne contaminants in swine farms and respiratory health of swine farmers with prevalence of respiratory disease in pigs. The study was conducted during the winter in farms with either high or low prevalence of respiratory disease in pigs. Overall, no differences were found in dust, endotoxin and peptidoglycan concentrations between the 2 prevalence groups. Possible explanations include the low number of farms, the variability between the farms within prevalence group and the collection of only one total dust sample in each farm area. Since our results originate from an area sampling rather than a personal sampling, the actual exposure of the worker might be slightly underestimated [35]. Such factors could interfere with the interpretation of the environmental data.

Total dust concentrations in the different farms were within previously reported ranges of 1.5 to 20 mg/m$^3$ [5, 9, 10, 14, 23, 26, 35]. Farrowing units had the lowest average total dust concentration at 2.2 mg/m$^3$ while finishing units had the highest at 5.1 mg/m$^3$. Although the results of this study cannot be fully compared with others due to the different sampling techniques, the trend is in agreement with Donham *et al.* who reported increasing concentrations of total dust and a decreasing respirable dust fraction (particle size < 5 µm) from farrowing to finishing [14]. The average total dust concentrations in gestation, nursery and finishing were higher than 2.5 mg/m$^3$, a concentration which has been associated previously with a significant cross-shift decrease in $FEV_1$ in swine farmers [10, 12, 29].

Total endotoxin concentrations in the different farm areas were at the lower end of previously reported ranges of 10 to 4100 ng/m$^3$ (100 to 41,000 EU/m$^3$) and were the lowest in farrowing units [9, 18, 21, 29, 35]. Overall, average endotoxin concentrations were slightly below 80 ng/m$^3$ (800 EU/m$^3$), which has been proposed by Donham as a no-response threshold level in swine confinement [10, 29]. Airborne endotoxin has been found to play a more important role than dust in inducing symptoms and lung function changes in swine farmers [10, 18, 23, 29, 33, 35]. Higher endotoxin concentrations and cross-shift PFT changes have also been correlated in a study where farmers were followed for almost 2 years [31].

Bacterial contamination in swine confinement buildings primarily consists of Gram-positive bacteria and the highest concentrations are in farrowing and nursery facilities [1, 5, 7, 14, 25]. In this study, peptidoglycan, part of the cell wall of mainly Gram-positive bacteria, was measured as an indicator for bacterial contamination. The highest peptidoglycan concentration was also present in farrowing and nursery. In addition, peptidoglycan and endotoxin concentrations were correlated in gestation and farrowing. This is the first report which describes airborne peptidoglycan in swine confinement buildings. At this point, the significance of these peptidoglycan concentrations on respiratory health of pigs and farm workers is unknown. However, peptidoglycan can stimulate the immune response by activation of receptors on inflammatory cells, such as alveolar macrophages [22]. This could indicate a possible contributory role for airborne peptidoglycan in causing respiratory problems, although more studies are needed to confirm such hypothesis.

Even though concentrations of airborne contaminants in both prevalence groups were not different, significantly more farmers in high prevalence farms reported chest tightness and had lower % predicted $FEF_{25\%-75\%}$ than farmers in low prevalence farms. However, the statistical significance disappeared after adjusting for smoking status because the number of farmers in each prevalence group became very small. This could explain why the relationship between farmers and swine respiratory health remains inconclusive. In addition, the respiratory health of farmers was only evaluated once during the work shift, which is in contrast with studies of over the work shift change [10, 29, 31]. Other frequently reported respiratory symptoms in both prevalence groups were cough, phlegm and wheezing. These results as well as PFT results were in agreement with those reported by others [4, 9, 10, 13, 15, 16, 18, 19, 31, 32, 35].

## CONCLUSION

Our study suggests that farmers working in farms with a high prevalence for respiratory disease in pigs have more respiratory problems than farmers working in farms with low prevalence of such diseases. Unfortunately, the small number of farms and farmers and the variability between farms made it difficult to confirm the relationship between farmers health and swine health, and health and airborne contaminants. Our results are in agreement with other studies that swine farmers have a high prevalence of respiratory problems. This is also the first report about the presence of airborne peptidoglycan in the swine confinement buildings.

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