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Bacteria in the Air of Housed Swine Units[1]

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Two housed, swine-growing-finishing units were studied for numbers of total bacteria, fecal coliforms, *Staphylococcus*, and *Salmonella* in the air. At 30.5 and 122 cm from the floor, total colony-forming particles, as tested, averaged 3.4×10^5 and $1.3 \times 10^5/m^3$ of air, respectively; whereas fecal coliform counts averaged 24×10^3 and $1.9 \times 10^3/m^3$ of air, respectively. Only 41% of the organisms growing on *Staphylococcus* 110 medium tested as *Staphylococcus*. Of 458 *Staphylococcus* isolates, 5 were coagulase-positive. No *Salmonella* were detected in the air of the units tested.

Completely housed, swine-growing-finishing units have become popular in the Midwest. Pigs are placed in the units at 16 to 18 kg and marketed at approximately 100 kg after 100 to 110 days. During this time, the animals are closely confined, which can cause many environmental problems, one of which is bacterial.

Curtis et al. (5) reviewed information that indicated that respiratory disease may cause $2/hog loss nationally and that mild pneumonia can reduce the rate of weight gain as much as 10%. Curtis et al. (5), Gordon (7), and D. J. Greenloh, S. E. Curtis, A. H. Jensen, J. Simon, and B. G. Harmon (J. Anim. Sci. 33:1139, 1971) found that aerial bacteria in these swine units varied from 10^3 to 7×10^5 colony-forming particles (CFP)/m^3 of air. Greenloh et al. (J. Anim. Sci. 33:1139, 1971) reported that the organisms were predominantly *Staphylococcus* and *Streptococcus* with low coliform populations. In other studies, Robinson et al. (8) showed *Salmonella*, *Streptococcus*, and *Staphylococcus* could survive more than 8 days in aerated swine urine, indicating that swine units could be favorable for these organisms.

Studies have been conducted on aerial bacteria in other housed animal units. R. P. Singh (Ph.D. thesis, Univ. of Minnesota, Minneapolis, 1964) showed that *Staphylococcus aureus* was present in poultry house air. Sotiracopoulos and Dondero (9) studied airborne bacteria in four different high-density poultry management systems. They found the most microorganisms (29,340 CFP/ft^3 of air) in the unit that used the oxidation ditch. In the four systems tested, *S. aureus* ranged from 38 to 73 CFP/ft^3 of air (73 CFP/ft^3 of air equals 2,577 CFP/m^3 air). These investigators reported *Salmonella* in the oxidation ditch was less than 0.02 cells/ml. Goodrich et al. (6) found bacteria in housed beef and turkey units ranged from 100,000 to 200,000 CFP/m^3 of air in the beef unit and up to 2,700,000 CFP/m^3 in the turkey unit. They presented data showing the beef oxidation ditch did not contribute microorganisms to the air, which contradicts the results of Sotiracopoulos and Dondero (9) obtained in the poultry units.

In 1972, Curtis (4) noted the need for more data on the air environment in housed swine units and discussed the possible effects of airborne bacteria on the swine respiratory tract. The purpose of this study was to measure numbers of bacteria in the air of housed swine units, to determine numbers of *Staphylococcus* and coagulase reaction, and to determine numbers of *Salmonella*.

MATERIALS AND METHODS

A housed, swine-growing-finishing unit (12.2 by 18.3 m) at the University of Nebraska Field Laboratory, Mead, Neb., stocked at 1.7 m^2/animal was used as one study area. Airborne bacteria were sampled periodically from June 1973 to December 1974. During this period, for airborne *Salmonella* testing, several air samples were obtained from a similar unit at a cooperator site stocked at about 1.5 m^2/animal near Elmwood, Neb. Manure was collected beneath a slotted floor at both sites. In both units the pens were arranged in a block with 1.8-m-wide service alleys along the walls.

Airborne bacteria were sampled in the units by collecting air samples midway in the buildings, one sample on each side of the pens at 30.5- and 122-cm heights. Sterile 0.2% peptone-water (50 ml) in ster-

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ile all-glass impingers (Millipore Corp.) was used to collect samples. Air from each sampling area was pulled through the peptone solution at 2 liters/min for 1 h. Air flow was controlled with a 2-liters/min orifice and checked with a flow meter. The impinger was kept on cracked ice until processed.

Serial 10-fold dilutions of the trapping solution were quadruplicate plated in nutrient agar pour plates for total counts. The plates were incubated at 35°C for 2 days, and the colonies were counted. Serial 10-fold dilutions of the trapping solution were each incubated in five lactose broth tubes at 35°C for 48 h. Tubes showing gas production were used to inoculate EC medium that was incubated at 44.5°C for 48 h (1). The EC medium results were used to calculate total fecal coliforms by the most-probable-number technique. For the measurement of *Staphylococci*, a portion of the trapping solution was aseptically filtered through a membrane filter (0.45-μm pore size; Millipore Corp.). The filter was aseptically placed on predried *Staphylococcus* 110 agar and incubated at 30°C for 48 h and colonies were then counted. One-fourth to one-half of the colonies from appropriate plates were selected and tested for anaerobic fermentation of glucose according to Baird-Parker (2, 3). The organisms that fermented glucose anaerobically were classified as *Staphylococcus* and were maintained on nutrient agar slants. When several isolates were obtained, they were tested for the coagulase reaction by the procedure described in the Baltimore Biological Laboratories manual (3a).

For the determination of *Salmonella*, duplicate tubes of tetrathionate and selenite-cystine broths were respectively inoculated with 1 and 10 ml of the trapping solution, and the tubes were incubated at 37 and 41.5°C. After incubation for 18, 24, and 48 h, the enrichment solutions were used to inoculate SS, MacConkey, XLD, bismuth sulfite, and Hektoen enteric agar plates, which were incubated at 37°C for 24 h. Organisms showing typical *Salmonella* colony morphology on these agars were used to inoculate triple sugar iron agar slants. Organisms testing positive for the genus *Salmonella* were inoculated into lysine iron agar and MR-VP, tryptone, citrate, and lactose broths. Organisms that reacted negatively in these media were not considered *Salmonella*. Media used in this study were obtained from Baltimore Biological Laboratories.

RESULTS AND DISCUSSION

Table 1 presents results of the total counts and fecal coliform counts. The total counts averaged 3.4×10^5 and 1.3×10^5 CFP/m^3 of air at the 30.5- and 122-cm heights, respectively. Fecal coliform most-probable-number estimates averaged 2.4×10^4 and 1.9×10^3 CFP/m^3 of air at the 30.5- and 122-cm heights, respectively. On this basis, it would seem fecal coliforms were a small percentage of the total airborne bacteria. A decline in fecal coliforms with height from the floor would be expected. However, total counts differed little with height. The fairly low fecal coliform levels agreed with data from other investigators (Greenloh et al., J. Anim. Sci. 33:1139, 1971), and total count data were similar to those of Curtis et al. (5), Gordon (7), and Greenloh et al. (J. Anim. Sci. 33:1139, 1971).

TABLE 1. *Average number of bacterial CFP and fecal coliforms in the air of completely housed swine unit at Mead, Neb.*

Sampling date	Total count (CFP/m^3 of air)		Fecal coliforms (CFP/m^3 of air)	
	30.5 cm[a]	122 cm	30.5 cm	122 cm
1973				
June 14		3.7×10^4		
June 19	4.8×10^4	6.8×10^4		
June 26	4.8×10^4			
June 29	4.7×10^4	6.4×10^4		
July 3		2.4×10^4		
July 16	4.3×10^4			
Dec. 28	2.8×10^4	6.7×10^3	4.2×10^2	4.6×10^3
1974				
Jan. 8	1.3×10^6	3.8×10^4	6.5×10^4	2.0×10^3
Jan. 15	7.4×10^3	3.8×10^4		8.8
Jan. 22	4.5×10^4	1.5×10^6		2.6×10^1
Jan. 28	2.8×10^6	4.2×10^2	3.0×10^4	$<4.0 \times 10^2$
Feb. 4	3.0×10^4	6.4×10^4	1.6×10^3	5.0×10^2
Feb. 11	1.2×10^5	4.1×10^4	3.0×10^4	4.1×10^3
Feb. 25		2.0×10^4		1.4×10^3
Mar. 4		1.0×10^4		
Mar. 25	8.0×10^5	1.5×10^4		
May 6	3.1×10^4	4.8×10^4	1.3×10^4	
May 14	4.5×10^4		3.3×10^4	
May 23	3.9×10^4			
June 5	4.9×10^4			
June 10	3.8×10^5			

[a] Distance from the floor at which measurements were taken.

Table 2 shows that the average number of CFP growing on *Staphylococcus* medium 110 was quite high, averaging 5.4×10^4 and 6.9×10^5 CFP/m^3 of air at the 30.5- and 122-cm heights, respectively. If the high October 29 value for the 122-cm height is omitted, the average is 2.5×10^4 CFP/m^3 of air. This omission may be justified since only one replicate had an unusually high value, which increased the average from 10^4 to 10^6 CFP/m^3 of air. If the lower average (2.5×10^4 CFP/m^3) obtained with *Staphylococcus* medium 110 is used, 16 and 19% of the counts found on plate count agar were found on *Staphylococcus* 110 medium at the 30.5- and 122-cm heights, respectively.

Growth of organisms on *Staphylococcus* 110 medium does not mean that the organisms are *Staphylococcus* according to Baird-Parker (2, 3). Of 1,112 colonies isolated from *Staphylococcus* 110 medium, only 41% (458) fermented glucose anaerobically (Table 3). No correlation was found between animal health or size and the percentage of *Staphylococcus* organisms. At

TABLE 2. *Average number of CFP/m³ of air growing on Staphylococcus 110 medium inoculated with samples obtained from the air of a housed swine unit at Mead, Neb.*

Sampling date	Avg no. of bacteria (CFP/m³ of air)	
	30.5 cm[a]	122 cm
1973		
June 29	1.4×10^4	3.6×10^4
July 10	7.3×10^4	
Dec. 28	2.3×10^4	5.0×10^3
1974		
Jan. 8	1.9×10^5	1.3×10^4
Jan. 15	3.7×10^3	2.1×10^4
Jan. 21	1.0×10^4	2.0×10^5
Jan. 28	3.6×10^5	2.1×10^2
Feb. 4	7.5×10^3	1.8×10^4
Feb. 11	6.0×10^4	1.5×10^4
Feb. 25		6.0×10^3
Mar. 4		$<4.0 \times 10^3$
Mar. 25	6.7×10^3	8.3×10^3
May 6	2.5×10^4	
May 14	2.8×10^4	
May 23	3.1×10^4	
June 5	3.1×10^4	
June 10	2.1×10^4	
June 16	3.7×10^3	
Aug. 12		5.5×10^4
Sep. 2	3.3×10^4	4.4×10^4
Oct. 2	2.0×10^4	1.5×10^4
Oct. 15	1.6×10^5	1.0×10^4
Oct. 29	6.3×10^4	4.7×10^6
Nov. 12	8.3×10^2	1.3×10^4
Dec. 6	1.3×10^4	1.3×10^4

[a] Distance from the floor at which measurements were taken.

the 30.5-cm sampling height 47.7% were *Staphylococcus*, and at the 122-cm height 36% were *Staphylococcus*. Out of 458 organisms testing as *Staphylococcus*, only five (1%) were coagulase positive, which indicated a low pathogenic potential.

Air changes per hour, temperature, and relative humidity were measured in the Mead swine unit during 1974 (Table 4). Relative humidity was fairly constant. Comparing 1974 CFP, measured with plate count agar, with air changes per hour for the periods January 8 to February 11 (3 air changes/h), March 4 to May 14 (6 air changes/h), and May 23 to June 10 (12 air changes/h), CFP averaged 7.1×10^5, 2.9×10^5, and 1.6×10^5, respectively. For the periods January 8 to February 11 (3 air changes/h), March 25 to May 14 (6 air changes/h), May 23 to June 10 (12 air changes/h), June 16 (60 air changes/h), September 2 to October 2 (30 air changes/h), October 15 to October 29 (4 air changes/h), and November 12 to December 6 (3 air changes/h), CFP on *Staphylococcus* 110 agar averaged 10.5×10^4, 2×10^4, 2.8×10^4, 0.4×10^4, 2.6×10^4, 11×10^4, and 0.7×10^4, respectively. Surprisingly, there appeared to be

TABLE 3. *Numbers of organisms that grew on Staphylococcus 110 medium capable of fermenting glucose anaerobically*

Date	Total no. of colonies isolated		Total[a] fermenting glucose		% *Staphylococcus*[b]	
	30 cm[c]	122 cm	30.5 cm	122 cm	30.5 cm	122 cm
1974						
May 23	110		51		46	
June 5	101		64		63	
June 10	56		39		70	
June 16	33		18		55	
Aug. 12		31		24		77
Sep. 2	35	54	13	23	37	43
Oct. 2	45	26	42	16	93	62
Oct. 15	120		81		68	
Oct. 29	40	43	12	9	30	21
Nov. 12	29	100	7	4	24	4
Dec. 6	40	72	12	26	30	36
1975						
Jan. 28	93	84	8	9	9	11

[a] Total number of *Staphylococcus* isolated was 458.

[b] Five organisms (1%) were coagulase positive.

[c] Distance from the floor at which measurements were taken.

TABLE 4. *Climatic conditions within the Mead swine unit during 1974 sampling*

Sampling date (1974)	Air changes per h in unit	Temp (°C)	Relative humidity (%)
Jan. 8	3	15.6	64
Jan. 15	3	15.8	66
Jan. 22	3	16.4	61
Jan. 28	3	15.6	62
Feb. 4	3	15.0	55
Feb. 11	3	16.1	55
Feb. 25	3	15.6	50
Mar. 4	6	19.0	34.5
Mar. 25	6	15.5	60
May 6	6	17.8	64
May 14	6	16.7	62
May 23	12	21.4	30
June 5	12	22.8	63
June 10	12	17.8	60
June 16	60	18.0	41
Aug. 12	60	26.7	65
Sept. 2	30	21.1	62
Oct. 2	30	13.3	43
Oct. 15	4	17.2	52
Oct. 29	4	10.6	62
Nov. 12	3	18.3	42
Dec. 6	3	18.3	43

little correlation between air changes and CFP/m^3 of air in the unit.

Twenty-eight air samples from the Mead and Elmwood units were tested for *Salmonella*, and no detectable *Salmonella* genera were found.

This study showed that fecal coliforms in the air of a housed unit were a low percentage of the total bacteria counted. Because no airborne *Salmonella* and few coagulase-positive *Staphylococcus* were isolated during this study, it would seem these genera represent a low pathogen hazard in the units tested.

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