Distribution and Quantification of Bioaerosols in Poultry-Slaughtering Plants†

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ABSTRACT

Four poultry-slaughtering plants (2 turkey, 2 duck) were investigated for airborne concentration of microorganisms, including mesophilic and psychrotrophic bacteria and yeasts and molds. Approximately 40 sites were sampled in each plant during four visits (fall, winter, spring, and summer) by using an Anderson N-6 Air Sampler containing either tryptic soy agar (for mesophilic and psychrotrophic bacteria), or Rose Bengal agar (for yeasts and molds). Sampling sites inside the plants were categorized into the following areas: shackling, picking, evisceration, post chiller, cut-up, portion packaging and whole bird packaging. Areas outside the plant were sampled as controls. Airborne microbial counts in each plant were highest in shackling areas and decreased toward the packaging areas. Bacteria were the most common airborne microorganisms identified. In general, mesophilic bacterial counts ranged from an average high of 6 log CFU/m3 in shackling to an average low of 2.5 log CFU/m3 outside the plant. Mean psychrotrophic bacterial levels were usually within 1 log unit (90%) less than mesophilic bacterial levels and ranged from 2.5 to 5 log CFU/m3. Yeasts and molds typically represented only a small proportion of the microbial population and usually were between 2.5 to 4 log CFU/m3. Air flow, distribution, temperature, relative humidity, and design of the slaughtering facility were all important factors affecting overall bioaerosol contamination. This study identified the sources and concentrations of bioaerosols that may affect product safety and shelf life. This information is useful for developing appropriate strategies for poultry-slaughtering plant design.

Key words: Bioaerosol, airborne, microorganisms, poultry

Several studies have been done to examine the microflora in poultry-slaughtering plants by sampling the carcass, equipment, and plant surfaces (8, 11, 14). Typically, these studies have identified and quantified the existence of spoilage microorganisms and/or pathogenic microorganisms present on the product or product contact surfaces. However, the use of air sampling for characterizing the microbial flora of the processing environment is becoming more important for evaluating product quality and safety. The use of air sampling for bioaerosols can identify potential microbiological contamination due to product contact with air.

Bioaerosols are generally defined as airborne viable contaminants resulting from a biological source. They may be solid, liquid, carried on another particle, or suspended in a liquid droplet. Depending on their mode of generation and environmental conditions, bioaerosols can vary greatly in size, from 0.1 μm to greater than 100 μm in diameter. Bioaerosols may be bacteria, fungal spores, fungi, or fungal spores, antigens, toxins, viruses, plant pollens, and fecal material (1). When these substances are airborne in a food-processing plant, air can serve as a vehicle for contamination of the food and can affect worker health.

Some research has been reported on bioaerosols in the poultry industry for improving product safety and quality and for assessing worker exposure. Lenhart et al. (9) sampled viable airborne bacteria in the shackling and live-hanging area of a poultry processing plant. They identified predominantly gram-positive bacteria, including Bacillus spp. and Staphylococcus spp., and gram-negative bacteria including Acinetobacter calcoaceticus, Proteus mirabilis, and Escherichia coli. Identification of high concentrations of gram-negative enteric bacteria suggested a fecal origin. The authors sampled for total aerobic bacteria with an Anderson six-stage viable impactor in both the morning and afternoon of 2 days and found average concentrations of $3.6 \times 10^5$ and $6.5 \times 10^5$ CFU/m3, respectively, on the first day, and $9.7 \times 10^3$ and $6.5 \times 10^3$ CFU/m3 on the second day. Kotula and Kimmer (7) evaluated airborne bacterial levels using an Anderson six-stage impactor at several locations within two poultry-processing plants during the morning and afternoon. They found average levels of $3.1 \times 10^4$ in the morning and $1.1 \times 10^5$ CFU/m3 in the afternoon in the shackling area. Samples taken further in the process flow showed an average of $8.1 \times 10^3$ CFU/m3 in the eviscerating area.

Potentially, the greatest sources of bioaerosol concentration in the slaughtering plant are the live bird holding and shackling areas. Lenhart et al. (9) noted that 62% of the

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isolates of bacilli from air samples taken in the shackle
area were E. coli, a common bacterium of fecal matter. They
also noted only small differences between levels of gram-
negative bacteria, thought to be of fecal origin, at the
entrance to the shackling line and the point at which the line
enters further processing. Other sources of airborne microor-
ganisms in the shackling area include flaked bird skin debris,
aerosolized feed, broken feather barbules (5), nuisance dust
particles (12), feathers, and other immunogenic agents
originating on or growing in poultry-house litter (6).

As the poultry carcass enters the evisceration and cut-up
areas, the total microbial concentrations present on carcass
surfaces are from those naturally present on the carcass
and those picked up during slaughtering. An important source
of carcass contamination may be due to environmental contami-
nation, namely, airborne contamination. Bacteria that have
been found on further processed poultry carcasses include
Pseudomonas spp., Alteromonas putrefaciens, Acinetobac-
ter spp., Clostridium perfringens, and Staphylococcus au-
reus (11). Psychrotrophic bacteria isolated from chicken
carcasses include Pseudomonas spp., Acinetobacter spp.,
Flavobacterium spp., Corynebacterium spp., Aeromonas
spp., species of Enterobacteriaceae, lactic acid bacteria,
species of Micrococccaeae, and Bacillus spp. (8).

Other sources of bioaerosols could exist at a poultry-
processing facility that are not directly related to the product.
These might include contaminants from the waste treatment
process, solid waste handling and disposal, building mainte-
nance problems, fungal or bacterial growth in the plant, poor
sanitation practices, etc. The geographical location of the
facility is also a factor influencing the microbial population
in and around the facility, e.g., waste disposal on the
farm directly upwind of the plant, as well as seasonal and
weather-related factors. Facility employees may also be a
source of bioaerosols from contaminants carried to work on
clothes, skin, or hair, or expelled from the respiratory tract.
Fecal contaminants of human origin may also be introduced
into the workplace as a result of poor personal hygienic
practices.

The facility’s ventilation system and design play an
important role in aerosolation and distribution of airborne
microorganisms (3). Air flow and distribution should be
regulated and controlled so that air is traveling from finished
product areas to raw ingredient receiving areas. The ventila-
tion system may be a source of microorganisms. Poor
system design and lack of proper maintenance, or failure to
make needed modifications or updates, can affect the
dispersion and quantity of bioaerosols. As microorganisms
are generated from a source, they are dispersed throughout
the room where they originated and/or into adjacent spaces
by air flow patterns or air mixing (3). Bioaerosols can then
be carried anywhere the air travels, such as from the
live-bird holding area to the slaughtering area to evisca-
ration, cut-up, packaging, etc. The ventilation system directly
affects other contributing factors such as relative humidity
and temperature. This system may influence the viability of
bioaerosols present, the time spent airborne, and the size of
carrier droplets, all of which help determine the effect of the
bioaerosol on exposed food products or personnel (4).

The overall objective of this study was to characterize
bioaerosol concentrations in turkey- and duck-slaughtering
plants for the entire slaughtering process. The two major
objectives were (i) to study the bioaerosol concentrations at
seven common areas of the plant: shackling, picking,
evaporation, chilling, cut-up, portion packing, and whole-
bird packing, and (ii) to monitor four environmental factors
(ai temperature, relative humidity, ai flow rates, and ai
distribution) that affect bioaerosol concentration. The experi-
ments described in this paper were designed to provide
comprehensive information about bioaerosol concentrations
in existing poultry-slaughtering plants.

MATERIALS AND METHODS

General experimental design

This study comprised bioaerosol sampling and ventilation
surveys of four different poultry slaughtering plants. Each plant
was visited four times, once each in the fall, winter, spring, and
summer. During each plant visit, bioaerosol samples were taken in
duplicate at approximately 40 sampling sites in the morning,
and again in the afternoon. Therefore, for each given site, four samples
were taken per visit for mesophilic bacterial, psychrotrophic
bacterial, and yeasts and molds counts.

During bioaerosol sampling, the ventilation system in each
plant was evaluated. Air distribution and air flow rates were
determined using an ultrasonic anemometer, a smoke generator,
and a hot-wire anemometer. Air temperature and relative humidity
were also recorded.

Description of the plants

Plants A and C were turkey-slaughtering facilities that em-
ployed approximately 550 and 775 workers, respectively, and
processed an average of 20,000 birds per day. Plant A operated 8 h
per day in a single shift and plant C operated 16 h per day in two
shifts. Plants B and D were duck-slaughtering facilities that em-
ployed approximately 250 and 270 workers, respectively, and
processed an average of 20,000 and 22,500 birds per day, respec-
tively. Both duck plants operated 8 h per day in a single shift.

Air sampling and instrument calibration

Microbial bioaerosols were measured using a single-stage N-6
Anderson viable sampler (Graseby Anderson, Atlanta, Ga). This
method was chosen due to the broad range of bioaerosol concen-
trations expected in a poultry-slaughtering environment and because
of the large numbers of samples to be handled and analyzed.

The air samplers were calibrated with a primary flow meter
(Dry Cal, BIOS International, Pompton Plains, NJ) and adjusted to
a flow rate of 28.3 ± 0.1 liters/min before and after each plant visit
for each of 14 pumps (115v AC vacuum pump with motor) and the
corresponding samplers that were used. Flow rates were checked
throughout sampling with precalibrated rotameters.

Air-sampling procedure

Sampling was done during plant visits by four sampling teams
using mobile aluminum carts with aluminum trays. The samplers
were placed on the aluminum trays to represent food product height
during processing and the worker breathing zone. Carts could also
be equipped with telescoping arms which allowed sampling to be
done in hard-to-reach sampling sites.

Each sampling team was equipped with a set of three pumps
and three samplers. One of the samplers contained microbial media
for mesophilic bacteria, another for psychrotrophic bacteria, and the third for yeasts and molds. The pumps were placed on the carts along with power strips, extension cords, and ground fault circuit interrupters. A supply of sampling petri plates containing microbial media were also carried on the cart. The sampling cart was moved from site to site, accessing electrical outlets throughout the plant.

For each site sampled, the following procedure was followed:

1. Using aseptic technique, the sampler was prepared using sterile pads containing a 70% isopropyl alcohol solution, beginning with the inlet orifice and ending with the bottom exhaust plate. An area on the aluminum tray of the cart was prepared using sterile pads containing a 70% isopropyl alcohol solution. After petri plates (containing the microbiological medium) were placed into the sampler, the petri dish lids were placed onto the prepared area on the cart.

2. Each petri plate was labeled with a unique number that would identify sampling site, sampling time, and the pump used with the sampler. Each plate was aseptically transferred and placed within the sampler. Petri plate lids were placed face down on the prepared area of the cart. Pumps and timers were started simultaneously and samples were taken for the appropriate sampling time, from 10 s to 10 min depending on the expected level of airborne contamination.

3. While air sampling was being conducted, the sampling teams observed activities of personnel near the sampling sites and noted these and other process-related activities. Temperature, time of day, and relative humidity were also recorded.

After sampling, the impactor was disassembled, and the lid of the petri dish was placed on the petri dish. Each petri dish was then immediately transferred to a mobile incubator held at either 37°C (mesophilic bacteria), 7°C (psychrotrophic bacteria), or 21°C (yeasts and molds).

**Microbial media, incubation, and colony enumeration**

Tryptic soy agar was used as a nonselective medium to recover and enumerate mesophilic bacteria after incubation at 37°C for 48 h, and psychrotrophic bacteria after incubation at 7°C for 10 days. Dichloran chloramphenicol Rose Bengal agar was used to recover and enumerate yeasts and molds after incubation at 21°C for 5 days (13). Enumeration of mesophilic bacteria and psychrotrophic bacteria were recorded as a total plate count (TPC) and psychrotrophic plate count (PPC), respectively. Yeasts and molds were recorded as a yeast-mold count (Y&M).

All colonies were enumerated using an AO Quebec Darkfield Colony Counter with 1.5× magnification. The counting rules employed for this study were as follows.

1. If only one (i.e., the shorter sampling time) of the two samples taken at a site yielded less than 250 CFU/m³, the count on that plate only was used to determine the airborne microbial concentrations.

2. Counts for both plates were averaged to determine airborne microbial concentrations (CFU/m³) if both samples yielded less than 250 CFU/m³.

3. If both samples yielded more than 250 CFU/m³, the plate from the shortest sampling time was counted using the positive-hole-correction method to obtain countable data for areas with extremely high concentrations (2, 10).

**RESULTS AND DISCUSSION**

Figures 1, 2, and 3 show the quantity and distribution of airborne microorganisms for all four slaughtering plants for mesophilic bacteria, psychrotrophic bacteria, and yeasts and molds, respectively. Mean bioaerosol concentrations, described as CFU/m³, for seven different slaughtering-plant areas and the outside control are presented. Mean values for each slaughtering plant area represent an average of bioaerosol concentrations for all sampling sites taken during each of the four plant visits. Differences between slaughtering processing areas, using data for all four plant visits, were determined using a Tukey's multiple range test at the 5% level of significance. Those slaughtering-plant areas with different lower-case letters represented significantly (P < 0.05) different means. Lower-case "a" represented the area with the highest airborne microbial counts, "b," the area with the second highest, etc.

The highest concentrations of mesophilic airborne bacteria, indicated as TPC, in all four plants were observed in the raw-product receiving areas (Figure 1). As the slaughtering process continued, bioaerosol levels progressively decreased toward product-packaging areas for most plants. Bioaerosol concentrations in the shackling and picking areas were usually between 100- and 1,000-fold higher than outside concentrations. Outside concentrations were always lowest. Bioaerosol sources in shackling and picking rooms were probably due to bird feathers and excessive bird movement, i.e., flapping of wings. The "cleanest" plant appeared to be plant A, where bioaerosol concentrations from the evisceration area to whole-bird packing were not significantly different (P > .05) from the outside control. Bioaerosol levels in plants B, C, and D, from evisceration to whole-bird packing, decreased after the shackling and picking areas. However, the counts were often significantly (P < 0.05) higher than the outside. This suggests a source of airborne contamination from the shackling and picking operations to slaughtering areas toward the finished product. It is, therefore, very important to ensure that the flow of air is directed away from the finished food product and counter-currently to product flow.

Little differences in TPC were noted by season. Therefore, the data for all seasons were combined to identify overall trends and differences for different processing areas and for different processing plants. However, some seasonal trends could be noted. During the summer months, higher counts were observed in many processing areas, especially in the shackling and picking areas of plants A, C, and D. In some cases, higher counts were observed in the summer months for the outside control. Since mesophilic bacteria generally prefer warmer temperatures (optimal at 37°C), it is likely that warmer temperatures during the summer months may have contributed to higher airborne counts.

A similar trend could be noted for psychrotrophic bacteria (Figure 2), designated as PPC. In all four plants, higher counts could be observed in the shackling and picking areas; the counts then decreased toward whole-bird packing following the flow throughout the plant. Again, the cleanest plant appeared to be plant A, where significantly higher counts (P < .05) were only observed in shackling and picking areas. The distribution and quantity of airborne microorganisms appeared similar for plants B, C, and D. Compared to plant A, higher counts toward whole-bird packing in plants B, C, and D were observed. This may be a
FIGURE 1. Total plate count (TPC) for airborne microorganisms in various processing areas for turkey (A, C)- and duck (B, D)-slaughtering plants. Out, outside control; Shack, shackling area; Pick, picking area; Evis, evisceration area; Chill, post-chill area; Cut-up, cut-up area; PP, portion-packaging area; WBP, whole-bird-packaging area. Different lower-case letters inside each figure indicate significantly different (P < 0.05) TPC CFU/m³ for each processing area (data from all four visits).

FIGURE 2. Psychrotrophic plate count (PPC) for airborne microorganisms in various processing areas for turkey (A, C)- and duck (B, D)-slaughtering plants. Out, outside control; Shack, shackling area; Pick, picking area; Evis, evisceration area; Chill, post-chill area; Cut-up, cut-up area; PP, portion-packaging area; WBP, whole-bird-packaging area. Different lower-case letters inside each figure indicate significantly different (P < 0.05) PPC CFU/m³ for each processing area (data from all four visits).
result of environmental conditions in the slaughtering plant and/or airborne contamination from the shackling and picking areas.

Compared to TPC, fewer differences in PPC could be noted between seasons. However, plant C showed slightly higher counts during the summer visit. The similarities in distribution and concentration trends for mesophilic and psychrotrophic bacteria implied that one count may be useful as an indicator for the other count. In most cases, psychrotrophic bacterial counts were within 1 log unit less than mesophilic bacterial counts.

Yeast and mold counts, identified as Y&MC, were typically far less than (<1%) of bacterial counts (Figure 3). Compared to airborne bacterial counts, differences in airborne yeast and mold counts between each area of the slaughtering plant were less noticeable and not much different from the outside control. The only noticeable seasonal trend was for plant B where higher counts were noted during the summer months. Again plant A appeared to be the "cleanest" when compared to the other plants.

Figures 1, 2, and 3 indicate that airborne bacteria, rather than airborne yeasts and molds, are the primary source of airborne contamination in duck- and turkey-slaughtering plants. Most airborne microorganisms are probably brought in by the birds, especially the feathers of ducks and turkeys, as noted by high counts in shackling. Conversely, the primary source of yeasts and molds in the slaughtering plant is probably from outside air.

In an effort to explain some of the differences between airborne microbial counts between each of the poultry plants, a schematic of each plant is provided (Figure 4). For each plant, a basic facility layout is provided. Each processing room is designated within a solid block and the outside area is designated within a dotted block. Temperature (°C) and relative humidity (%) readings are included for each sampling visit. The solid arrow indicates process flow and the dashed arrow indicates net-air-flow direction. If no arrow is present, the net direction of air could not be determined (stagnant air). The symbols FL, WN, SP, and SU represent the four sampling visits in fall, winter, spring, and summer.

Plant A was segmented into 6 processing rooms. This plant had ideal airflow patterns as air traveled from clean areas of the plant (finished food product) to dirty areas of the plant (shackling and picking operations). Air was directed to the picking operation and then exhausted out of the plant. Of the four plants, plant A had the best temperature control, especially in packing operations (range 7 to 18°C). TPC (Figure 1A) correlated well with the facility design for plant A. Shackling and picking were the highest areas for airborne microorganisms, and, as the process continued, the counts

FIGURE 3. Yeasts and molds count (Y&MC) for airborne microorganisms in various processing areas for turkey (A, C) and duck (B, D)-slaughtering plants. Out, outside control; Shack, shackling area; Pick, picking area; Evis, evisceration area; Chill, post-chill area; Cut-up, cut-up area; PP, portion-packaging area; WBP, whole-bird-packaging area. Different lower-case letters inside each figure indicate significantly different (P < 0.05) Y&MC CFU/m³ for each processing area (data from all four visits).
Plant A (Turkey) - Facility Layout

SHACK
FL: 13C, 34%
WN: 12C, NA
SP: 110, 74%
SU: 27C, 67%

PICK
FL: NA, NA
WN: 20C, NA
SP: 26C, 100%
SU: 30C, 96%

OUT
FL: 9C, 35%
WN: 23C, 65%
SP: 14C, 56%
SU: 30C, 57%

EVIS/CHILL
FL: 19C, 74%
WN: 17C, 66%
SP: 16C, 96%
SU: 25C, NA

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Plant B (Duck) - Facility Layout

SHACK
FL: 16C, NA
WN: 16C, NA
SP: 19C, 56%
SU: 23C, 76%

PICK
FL: 20C, NA
WN: 23C, 64%
SP: 26C, 81%
SU: 28C, 95%

OUT
FL: 9C, 95%
WN: 12C, NA
SP: 22C, 40%
SU: 26C, 46%

CUT-UP
PP
FL: 24C, 19%
WN: 19C, 30%
SP: 21C, 10%
SU: 21C, 72%

EVIS
CHILL
WBP
FL: 22C, 57%
WN: 20C, 47%
SP: 20C, 71%
SU: 22C, 82%

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Plant C (Turkey) - Facility Layout

SHACK
FL: 13C, NA
WN: 16C, NA
SP: 11C, 69%
SU: 12C, 80%

PICK
FL: 20C, 74%
WN: NA, NA
SP: 18C, 96%
SU: 27C, 93%

OUT
FL: 12C, 65%
WN: 4C, 59%
SP: 10C, 55%
SU: 10C, 55%

CUT-UP
PP
FL: 11C, 76%
WN: 16C, NA
SP: 11C, 69%
SU: 12C, 80%

EVIS
CHILL
WBP
FL: 18C, 83%
WN: 17C, 61%
SP: 17C, 66%
SU: 18C, 89%

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Plant D (Duck) - Facility Layout

SHACK
FL: 17C, NA
WN: 20C, 59%
SP: 11C, 57%
SU: 24C, 86%

PICK
FL: 20C, 78%
WN: 23C, 78%
SP: 22C, 81%
SU: 24C, 81%

OUT
FL: 9C, 68%
WN: 3C, 57%
SP: 15C, 75%
SU: 23C, 89%

WBP
FL: 20C, 71%
WN: 18C, 54%
SP: 12C, 74%
SU: 24C, 82%

EVIS
CHILL
CUT-UP
PP
FL: 17C, 75%
WN: 17C, 62%
SP: 16C, 54%
SU: 22C, 67%

decreased almost in a stepwise pattern. Confining processing operations to a separate room, controlling air flow direction, and maintaining low temperatures are all important to minimizing airborne contamination. All of these factors probably contributed to plant A being the "cleanest."

Plants B, C, and D, were each segmented into 4 processing rooms. The air-flow patterns in plant B and plant D were good. The facility design (Figures 4B, 4D) and distribution of airborne microorganisms (Figures 1B, 2B, 3B, 1D, 2D, 3D) in Plant B was very similar to that observed in plant D. Air was flowing in the opposite direction of product flow. However, both of these plants possessed deficiencies in temperature control. Relatively high temperatures throughout the process flow, including finished food product areas, probably led to higher bioaerosol concentrations.

In plant C, all areas within the plant had significantly higher (P < .05) microbial counts compared to outside air (Figures 1C, 2C, 3C). A significant air-flow problem in plant C was identified. Air from the scalding-picking operation was traveling toward the room containing the evisceration, post-chill, and whole-bird-packing procedures (Figure 4C). Consequently, higher airborne mesophilic counts were recorded in these areas (Figure 4C). Evisceration, post-chill, and whole-bird-packing operations were contained in the same processing room. As expected, microbial counts in these areas were similar. There was some temperature control in plant C but it was limited to the cut-up and portion-packaging areas only. As a result, airborne mesophilic bacterial (Figure 4C) and airborne psychrotrophic bacterial (Figure 2C) concentrations in these areas were significantly (P < .05) lower. This information confirms that air flow and location of processing operations is related to microbial levels. Efforts to increase air flow in this room toward incoming raw carcasses would probably help reduce airborne microbial contamination from incoming carcass sources. Upon further investigation, it was determined that the exhaust system in the picking-scalding room was inadequate for sufficient removal of contaminated air in that room. A more efficient exhaust system may change air-flow patterns so that air from scalding-picking is not introduced into other areas of the plant.

Airborne contamination can be reduced by controlling air flow through proper ventilation systems and good facility design. It is important to keep bioaerosols away from finished food-product-processing areas. To accomplish this positive air flow, ventilation systems need to be designed so that air moves in the direction from finished food product (packing) to raw-ingredient receiving (live-bird shackling). This would reduce potential airborne contamination and

FIGURE 4. Facility design, direction of air flow, temperature (°C), and relative humidity (%) for turkey (A, C)- and duck (B, D)-slaughtering plants. Out, outside control; Shack, shackling area; Pick, picking area; Evis, evisceration area; Chill, post-chill area; Cut-up, cut-up area; PP, portion-packaging area; WBP, whole-bird-packing area; FL, fall sampling visit; WN, winter sampling visit; SP, spring sampling visit; SU, summer sampling visit.
may help to ensure better quality and microbiologically safer food. The direct effect of airborne contamination for food safety and quality of duck or turkey products in a slaughter-
ing environment has not been evaluated. Further research to establish the effect of airborne contamination on food shelf life and types and numbers of pathogenic microorganisms present is needed.

This study was intended to characterize the amount and distributions of bioaerosols within poultry-slaughtering environments. The following general guidelines can be provided.

1. Air flow should be controlled so that air is moving from finished-product areas (cut-up, PP, WBP) toward the evisceration processes; air flow should be countercurrent to product flow. Bioaerosol concentrations were always highest in shackling and picking areas. Therefore, controlling the movement of air from shackling and picking operations to other areas of the plant is most critical. An effective, well-maintained exhaust system in the picking area will facilitate movement of highly contaminated air out of the plant.

2. If possible, finished food product operations (cut-up, PP, WBP) should be physically separated (in a different room) from prior processing operations. A physical separation of these critical areas may help reduce the possibility of airborne contamination.

3. In general, higher temperatures and higher relative humidity are more conducive to microbial survival and growth. Temperatures and relative humidity should be optimized to reduce the survival and growth of foodborne and airborne microorganisms. More research is needed to support this statement and to establish ideal environmental processing conditions.

The extent and significance of environmental airborne contamination in poultry slaughtering plants is unknown. The overall effect on food safety is probably minimal since this food product requires sufficient cooking to render it safe. The relationship of airborne contamination to safety of further-processed foods, especially ready-to-eat foods, is certainly a much more critical area that needs to be addressed. The effect on food quality may be an important area to further investigate. It is possible that bacteria in the air could contaminate and have a detrimental effect on food quality and shelf life. Further research is needed to determine the impact of airborne contamination on the overall quality of the finished food product.

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