Exposure of poultry processors to microbial agents in poultry abattoirs

JL Harmse, JC Engelbrecht, JL Bekker
Department of Environmental Health, Faculty of Science, Tshwane University of Technology, South Africa

Correspondence: JL Harmse, Department of Environmental Health, Faculty of Science, Tshwane University of Technology, South Africa, Private Bag X680, Pretoria 0001, South Africa. e-mail: harmsejl@tut.ac.za

Leon Harmse is a Southern African Institute for Occupational Hygiene (SAIOH) member.

ABSTRACT

Background: Poultry processors are exposed to occupational health hazards which include microbial hazards. Several micro-organisms find birds a favourable habitat and can affect poultry abattoir processing workers' health during primary and secondary processing, including value-adding processes such as portioning and preparing ready meals.

Objective: This review addresses aspects of microbial hazards, such as the occurrence, exposure, effects and related diseases, as well as applicable legislation. It includes a non-exhaustive overview of research relating to the effect of microbial agents on the occupational health of poultry processors, excluding the effects of poultry dust and viral carcinogenic exposures. The review is intended for use by researchers, occupational health specialists, and the poultry industry, to indicate the extent of microbial exposure and to illustrate the need for instituting and managing applicable controls, thereby providing a healthy work environment.

Methods: A search of PubMed, MEDLINE and Science Direct online databases was conducted, using specific keywords.

Results: Even though microbial agents have an affinity for certain processing areas, they can occur in other areas. The review highlights that microbial agents cause various health effects and diseases, including infections, diarrhoea, warts, skin irritation and allergies, occupational asthma, reduced lung capacity and respiratory irritation.

Conclusion: Several pathogenic microbial agents present in poultry abattoirs can affect the health of poultry processors. Employers, in terms of the Occupational Health and Safety Act of 1993, need to institute antimicrobial measures to provide a healthy work environment. We recommend control and management measures which include legal compliance, housekeeping and hygiene aspects to protect employers and workers.

Keywords: poultry processing, microbial agents, microbial exposure, poultry processing health effects

INTRODUCTION

Demand for poultry meat continues to increase, and the United Nations (UN) estimates a 1.6% growth in the industry, globally, to an annual production of approximately 109 million tonnes of meat.[1] Worldwide, the poultry industry is a major contributor to the gross domestic product (GDP).[2] In South Africa (SA), the poultry industry is the largest individual agricultural sector, contributing 15% to the GDP in 2016.[3]

Hazardous biological agents (HBAs) in poultry abattoirs include parasites, viruses, bacteria and fungi, as well as by-products of micro-organisms, such as endotoxins. Transmission may be via inhalation, direct contact, contact with body fluids, and/or vehicular transmission, such as water and food, or by vectors.[4] Worker injuries, cuts or poultry bone splinters can compromise the skin, allowing microbial entry during slaughtering and handling of carcasses and meat.[5] Workers are also exposed to bird faeces that contain microorganisms, during receiving, shackling and stunning of birds.[6] Increased profit and production demands lead to an increase in line speeds, which may contribute to increasing prevalence of microbial-related exposure and hence health effects.[7,8] During production there is a dual concern: the workers might contaminate the product, and they might contract a microbial-related disease from the birds.[6,9] Disease agents, hosts and the environment comprise an ecosystem that is in a dynamic balance. When occupational exposure occurs, disease agents impact on the health of the host and disturb this balance, resulting in an occupational disease. Compromised immunity, diet, and other personal factors may contribute to the imbalance.[10,11] Exposure may cause infections, e.g. dermatitis, rhinitis, pneumonitis, bronchitis, diarrhoea; respiratory effects, e.g. respiratory irritation, reduced lung function, asthma, lesions; neurological symptoms; and antibody formation.[12]

Similar to categorisation in the United Kingdom (UK), the SA Hazardous Biological Agents Regulations classifies HBAs into four categories, according to their disease-causing abilities, the disease severity in humans, and the availability of treatment protocols. Most poultry-related HBAs are classified as containment category 2, indicating that the organism may cause disease, that effective prophylaxis and treatment are available, and that community spread is unlikely. Only *Chlamydophila psittaci*, *Mycobacterium avium* complex and the West Nile virus are classified as containment category 3, which means the organism may cause severe disease, effective prophylaxis and treatment are available, and there is a risk of community spread.[13,14]

The inter-governmental World Organisation of Animal Health (OIE) provides standards on animal health and zoonoses for international trade by publishing a list of notifiable terrestrial animal diseases, annually, that includes avian diseases caused by *Salmonella* spp., Newcastle disease virus and avian influenza virus.[15,16] The International Labour Organization (ILO) and SA state that the onus rests on the employer

to provide a healthy workplace.[14,17,18] Worldwide, approximately 2.3 million occupational deaths occur annually, of which 2 million are attributed to occupational disease.[19] The burden of disease induced by zoonotic pathogens affects thousands annually, leading to chronic infections and causing significant economic, medical and livestock-related losses.[20]

Mortality in poultry slaughtering and processing workers due to microbial disease, and deaths involving cardiovascular, neurological, endocrine, gastrointestinal and reproductive systems have been observed, illustrating that workers may be at increased risk of mortality from certain microbial diseases and infections.[21,22] In countries where enteric infections, hepatitis B, HIV/AIDS, malaria, measles and tuberculosis are endemic, the disease risk is escalated and further aggravated by poor socio-economic conditions or compromised immune systems.[23,24]

The purpose of this review is to present the extensive role that poultry abattoir processing plays in the development of ill health amongst workers exposed to pathogenic microorganisms. In order to achieve this objective, the review addresses aspects of poultry meat production, occupational impacts and diseases, applicable legislation, and the management of microbial risk. Emphasis is placed on primary processing which includes receiving, shackling, stunning, bleeding, scalding, de-feathering, evisceration and recovery, as well as secondary processing such as portioning, brining, filleting, chilling, freezing, packaging and dispatching. Poultry dust exposures and oncogenic viral exposures are excluded. Although auxiliary activities at poultry processing plants, such as laboratories, water and sewerage treatment plants, boiler plants, laundries, rendering plants, and solid waste disposal plants might result in worker exposure to microbial agents, they are not included in this review.

METHODS

Information sources and literature search

The online bibliographic databases, PubMed, MEDLINE and Science Direct, were searched for studies published in English, from 1999 to 2015, relating to microbial agents' prevalence, exposures and health impacts on poultry abattoir processing workers in primary and secondary processing. Bibliographic lists and references from the selected papers and reviews were used as leads for identification of additional studies. The search was conducted using the following terms: microbial agents in poultry processing, prevalence of microbial agents in poultry processing, zoonosis in poultry processing, fungal exposures in poultry processing, poultry diseases, ectoparasites in poultry processing, bacterial resistance, as well as several specific poultry processing microbial disease keywords. The search included grey literature from websites of recognised institutes, corporations, international agencies and international and national governmental agencies and departments, using the following keywords: occupational health legislation, poultry abattoir processing worker health, occupational disease statistics, management of occupational hazards, and management of microbial agents. Examples of these organisations include the International Labour Organization (ILO),[25] the Health and Safety Executive (HSE),[26] the Department of Labour (DoL),[27] the United Nations (UN),[28] the South African Poultry Association (SAPA)[29] and the National Institute for Occupational Safety and Health (NIOSH).[30] Sources were managed using EndNote reference manager.

Study selection

Studies were included in the review if they explicitly reported on microbial agent prevalence, exposures and/or health impacts (symptoms and disease) on poultry abattoir processing workers in primary or secondary processing.

This article forms part of a broader study and has been approved by the Tshwane University of Technology (TUT) Ethics Committee (reference number REC2012/08/005).

RESULTS

The literature search provided findings related to microbial agents' prevalence, exposures and health impacts in the entire poultry production process, ranging from the rearing of chicks, to the growing of birds and the slaughter and production of poultry meat in abattoirs. Information obtained from the 51 sources that fulfilled the inclusion criteria is summarised in tables reflecting the country, study design, target population, health effects prevalence, and health impacts.

No poultry production area is free of microbial agents.[31,32] Bacteria, viruses, protozoa, fungi, ecto- and other parasites occur throughout poultry abattoirs, from bird reception until meat is chilled and packed. The type and level of microbial agents present depend on the production rate and activities performed. For example, live handling, and evisceration or cutting, have different associated pathogenic microbial agents. Some pathogenic microorganisms occur throughout the abattoir, but at differing levels.[31,33]

Exposure to pathogenic bacteria

Table 1 provides a non-exhaustive list of pathogenic bacteria in poultry abattoirs and indicates the detail and origin of the study, the microbial agents that are present and potential health effects. Although all production areas show levels of microbial agents above the human infectious dose, the receiving, shackling and killing areas have the highest counts for *Pseudomonas* spp., *Listeria* spp., *Salmonella* spp. and *Bacillus* spp.[33] Poultry abattoir workers are exposed to gram-positive bacteria, namely *Staphylococcus* spp., *Listeria monocytogenes* and *Bacillus cereus*, as well as gram negative bacteria, such as *Salmonella* spp., with some studies indicating *Staphylococcus* spp. as being most prevalent throughout the production area.[34,35] Bird faeces were identified as the major source of airborne gram negative bacteria and endotoxins.[31,32] The average mesophilic bacterial counts in processing are up to 8 000 times higher than the background concentrations in residential areas.[31] Infection from some microbes, e.g. *Campylobacter* spp., *Escherichia coli* and *Salmonella* spp., may cause diarrhoea in workers, whereas others, such as *M. avium*, *Chlamydia* spp. and *Staphylococcal* spp., cause respiratory related problems.[36-39]

Poultry workers showed an elevated risk of developing neurological symptoms, as well as an increase in ganglioside antibodies which, amongst others, can be associated with exposure to *Campylobacter* spp. Skin-related conditions and skin infections occurred in workers due to *Staphylococcus aureus*.[40-42] Factors such as the type of organism, its virulence, environmental conditions, and worker susceptibility, also play a role in disease development. Microbial agents, such as mesophilic bacteria, aerobic bacteria, *B. cereus*, coliforms,

Clostridium perfringens, *Enterobacteriaceae* spp., *Enterococcus* spp., *Pseudomonas aeruginosa*, *Yersinia enterocolitica*, and *Sagenomella sclerotialis* occur throughout several production areas.[43-48]

Of concern is microbial drug resistance, originating from overuse of antibiotics in humans as well as in agriculture, including poultry production.[49] It is estimated that 11.2 million kg of antibiotics are administered to livestock, compared to 1.4 million kg for human medical use in the US.[50] A high prevalence of resistant strains is present in poultry abattoir workers.[56] Resistance to several antibiotics was found for *E. coli* and *Staphylococcus* spp.[51,52] A SA study found that *Campylobacter jejuni* antibiotic resistance in broilers was highest to tetracycline (98%), ceftriaxone (96%), ciprofloxacin (91%), gentamacin (98%), erythromycin (50%), clarithromycin (45%), ampicillin (68%), and nalidixic acid (64%).[53] In the US, the number of quinolone-resistant infections acquired increased due to the acquisition of resistant strains from poultry. The use of fluoroquinolones in poultry since 1995 has created a reservoir of resistant *C. jejuni*.[54] Multi-resistance was detected in 23% of the broiler isolates.[53] Microbial antibiotic resistance in *E. coli* strains and in poultry abattoir workers was also detected.[52,55] Increase in resistance to various antibiotics was observed in *L. monocytogenes* and *Salmonella enterica* strains after exposure to concentrations of decontaminant chemicals (trisodium phosphate, acidified sodium chlorite, citric acid, chlorine dioxide or peroxyacetic acid). This raises concerns over the application of certain poultry decontaminants since they could contribute to the development of microbial resistance.[56]

Exposure to viruses

Table 2 provides a non-exhaustive list of viruses in poultry abattoirs and indicates the detail and origin of the study, microbial agent, area present and the level of organism(s) in general, or specifically, that may affect workers. Avian influenza virus, Newcastle disease virus and Papilloma virus are zoonotic disease agents that can be transmitted from infected birds to humans; outbreaks have been reported in China, Hong Kong, India, Vietnam, Europe and SA.[57, 58] Newcastle disease virus is a highly contagious but mild disease that causes conjunctivitis and mild flu-like symptoms in humans.[59] Avian influenza (AI) conversely, may be transmitted to humans, causing flu-like symptoms, conjunctivitis and severe respiratory distress.[60] Poultry workers have been infected with different strains of the AI virus. Outbreaks are associated with the culling of entire flocks.[61-63]

Exposure to protozoa, yeasts and moulds

Table 3 provides a non-exhaustive list of yeasts and moulds in poultry abattoirs and indicates the detail and origin of the study, microbial agent, area present and the level of organism(s) in general or specifically, which may affect workers. Fungi in poultry dust may originate from soil, feed and bedding matter, and from birds.[92] Fungi, such as *Aspergillus* spp., *Penicillium* spp., *Chladosporium* spp. and *Histoplasma capsulatum*, are airborne and are capable of causing respiratory disorders such as allergies, wheezing, asthma and decreased lung function.[93-95] The mycotoxin AFB1, a recognised hepato-carcinogen, and possibly carcinogenic to the lungs, is produced by *Aspergillus* spp; *Aspergillus flavus* is present in significant levels in airborne samples.[96] Mycotoxins are not inherently volatile but enter the respiratory system through inhalation when present in poultry dust.[96-99] Also present in poultry dust is (1-3) β-D-glucan, a non-allergenic water insoluble cell wall component found in most fungi, some bacteria and plants; it may cause decreased lung function when inhaled.[92,95,100,101] The protozoa, *H. capsulatum*, was found to cause an influenza/tuberculosis productive cough, weight loss, shortness of breath and the development of ocular histoplasmosis syndrome in poultry workers.[102]

DISCUSSION

There is no doubt that several microbial agents are present during poultry processing and the footprint may vary between processes in primary and secondary processing.

Biological risk at work requires a complex approach with regard to risk assessment and risk management, which is complicated by the wide variety of microbial agents, working environments and working techniques that play crucial roles in exposure.[103] Poultry processing has unique features that make control of microbial contamination more difficult than other meat processing, including the rapid rate of processing, keeping the carcass whole, and removing the viscera through a small abdominal opening, with the skin providing a complex surface which is capable of trapping bacteria after evisceration.[104] Surface samples from equipment for *Listeria* spp. as well as for *Campylobacter* spp. (e.g. *C. jejuni*) show microbes surviving even after cleaning procedures.[70,78]

Occupational health legislation in SA places the primary responsibility of providing a healthy work environment for employees on employers.[17] Failing this, employers will suffer the consequence of an unmotivated workforce with high absenteeism rates. This will decrease production, efficiency, bottom-line profit and product quality which, in the case of microbial agents, is of public health importance.[112,113] Similar to the UK, the SA Regulations for HBA set several legal obligations upon employers to:[14,18]

- conduct occupational health risk assessments to identify microbes, hazards and exposures;
- monitor exposure levels in identified areas for microbial agents, which include surface and air sampling;
- conduct medical surveillance (MS) on poultry processors where exposure occurs, or if a disease or likelihood thereof is related to the exposure;
- have the health of poultry processors appraised by an occupational health practitioner when processors are appointed, annually, and at exit due to resignation or retirement;
- as part of the appraisal, include suitable and relevant medical tests to conduct a proper health evaluation on poultry processors;
- report any infectious incident occurrence amongst processors, or death from a microbial agent, to the Department of Labour;
- keep proper records of assessments, monitoring and medical surveillance for a period of 40 years.

In addition, employers may:

- implement a hierarchy of control measures by instituting controls relative to:[57,114-116]
  - exposure prevention;
  - adequate exposure control;
  - restricted access to areas;
  - separating processes or enclosing areas;

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Table 1. Prevalence and effect of pathogenic bacteria present during poultry processing

Study origin	Study design/population	Health effects present	Prevalence and health effects
Campylobacter spp.			
Sweden[64]	Investigative study 37 cases	Diarrhoea Acute gastroenteritis	Greater occurrence in part-time workers (71%) versus full time workers (29%)
UK[65]	43 short-term workers 78 long-term workers 40 controls	Antibody production	Long-term workers had significantly higher levels of IgG antibodies than short-term workers
Ireland[66]	Investigative study in packing workers in a poultry abattoir	Campylobacteriosis	Workers three times more susceptible to infection
US[42]	Comparative study 20 poultry process workers 40 controls	Guillain-Barre syndrome	Significantly high *Campylobacter* IgG antibodies present Neurological sequelae risk high
UK[67,68]	Unspecified	• Severe diarrhoea • Abdominal pain • Dehydration • Neurologic risk • Neuropathologic antibodies developed	80% birds contaminated with *C. jejuni* or *Campylobacter coli* Worker exposure from splitting of bird intestines; Symptom onset (83%) within one month of exposure; Median worker age 29 years
US[69]	High throughput poultry abattoir 300 000-350 000 birds per day 1 000 process workers 29 *Campylobacter* case-patients 2008-2011	• Campylobacteriosis • Diarrhoea • Abdominal cramping • Fever • Nausea/vomiting • Muscle cramps • Headaches	Prevalence highest in primary process workers (93%); lower in secondary process workers (7%)
France[70]	Four poultry abattoirs Study on the cleaning, disinfection and survival rate of *Campylobacter*	Bacterial enteritis	*C. jejuni* survived overnight after abattoir disinfection and cleaning Carcasses and workers contaminated
Chlamydophila psittaci			
UK[71]	Outbreak investigation	Avian Chlamydiosis	Antibodies in 23% workers
France[72]	Comparative study Outbreak 82 poultry abattoir workers 82 controls	Chlamydiosis with symptoms: • fever and chills • nausea and vomiting • muscle and joint pain • diarrhoea • weakness • fatigue • (dry) cough	Antibody response including IgA, IgG & IgM; 30/82 infection evidence or antibodies provoked; Short-term workers with acute infection signs (55%); workers antibody positive (72%); antibodies in control group (19%)
France[73]	Investigative study Outbreak in two poultry abattoirs	• Fever • Headache • Vomiting • Gastrointestinal pain	All areas significantly contaminated
Belgium[35]	Zoonotic risk assessment study in a poultry abattoir	• Pneumonia • Necrosis • Inflammation	85% broiler flocks slaughtered positive; 8% poultry workers positive Frequently occurs in reception and evisceration area
India[59]	Review	• Fever • Arthralgia • Conjunctivitis • Vomiting • Gastrointestinal pain/cramps • Headaches	Significant infection risk exists for poultry processors in poultry processing plants
Erysipelothrix rhusiopathiae			
Australia[74]	Review	• Scabies-like lesions • Irritant dermatitis • Erysipeloid • Diffuse cutaneous form with septicaemia • Endocarditis	None
US[75]	Review	• Skin rash • Erysipeloid • Skin lesions • Lymphadenopathies • Septicaemia	38% mortality, even with treatment

Table continued overleaf

Table 1 continued from previous page

Study origin	Study design/population	Health effects present	Prevalence and health effects
Escherichia coli			
Netherlands[52]	Poultry-slaughtering workers: faecal samples *E. coli* in poultry populations	Antibiotic resistance	Prevalence significantly higher in exposure group than in controls Transmission of *E. coli* from poultry to humans – workers at high risk
SA[55]	High throughput poultry abattoir 29 workers 28 controls	Antimicrobial drug resistance	Resistant isolates higher in packers and eviscerators than control group
Kenya[76]	Cross-sectional study 200 raw abattoir meat samples	Antibiotic resistance	Contamination rate (78%); resistance to antibiotics (75%); unacceptable high counts (67%); (60%); Tetracycline resistance – highest
Saudi Arabia[36]	117 poultry abattoir workers 100 controls	Gastroenteritis Bloody diarrhoea	57-99% presence of *E. coli* resistance to antibiotics; 9-30% presence of *E. coli;* resistance to non-poultry production antibiotics; data reflects very high individual and multiple resistance to antibiotics in *E. coli*. Antibiotics are overused
Netherlands[77]	Poultry flocks at abattoirs	Haemorrhagic diarrhoea Kidney failure	Presence of Verocytotoxin-producing *E. coli* at 1.3% Poultry is a source of O157 VTEC – human pathogen
Listeria spp.			
Iceland[78]	Primary and secondary processing in two poultry processing plants	Listeriosis	Cleaning did not eliminate *Listeria* Problem areas: brine, marinade, skin machines, floors, drains, cutting tables boards, conveyors; air samples were *Listeria* free; *Listeria*-positive workers at 42%; *L. monocytogenes* 21-24%; *L. innocua* most prevalent in ready-to-eat products (value added)
Mycobacterium avium			
Czechoslovakia[79]	Serological analysis of 44 disease cases	Pulmonary and non-pulmonary disease	*M. avium* infection from poultry in processors; Serotypes I, II isolated
Sweden[80]	Poultry abattoir workers	Pulmonary effects Flu-like symptoms	Prevalence higher in immuno-compromised workers Poultry processors commonly exposed
India[81]	Review	Lymphadenitis Pulmonary effects Wound infection Swollen lymph nodes	Serotypes 4-20 in abattoir workers
Salmonella spp.			
Brazil[39]	Descriptive study Poultry abattoirs across 15 cities	Diarrhoea Septic shock	3% prevalence in bird carcasses *Salmonella* Spp. prevalence: *S. enteritidis* 49%; *S. infantis* 8%; *S. typhimurium* 7%; *S. Heidelberg* 6%. All 250 strains tested antibiotic resistant; 18 Serotypes (53%) multidrug resistant
Denmark[82]	*Salmonella typhimurium* Poultry abattoirs	Salmonellosis	*Salmonella* phage type DT41 Poultry common infection source
Staphylococcus spp.			
Sweden[34]	Medical surveillance and spirometry 23 shacklers in four poultry abattoirs	Lung function effects	Mean vital capacity decrease 3% forced expiratory volume at 4% due to bronchial damage; an over-shift increase in respiratory symptoms was found
UK[40]	*S. aureus* in 15 poultry processors	Skin infection Impetigo Paronychia	*S. aureus* present in eight (53%) of the lesions
Netherlands[41]	466 abattoir workers at six poultry abattoirs	Methicillin-resistant *S. aureus* risk (MRSA)	Live animal contact increase the MRSA risk; 405 broilers (7%) positive on arrival; positive workers 6% infection risk in hanging broiler area 20% Workers can become carriers Live animal contact an increased Electric stunning: 10% MRSA risk compared to CO_2 stun at 2% risk

  - appropriate work procedures such as proper handling, use, maintenance, cleaning and waste disposal;
  - demarcation of microbial agents areas;
  - displaying of appropriate biohazard signs.
- set procedures for adequate housekeeping, cleaning, and sanitation of all surfaces;
- restrict eating, drinking, smoking or application of cosmetics in microbial agents areas;
- provide proper supervision to ensure all procedures are followed;
- provide appropriate and approved personal protective equipment (PPE) for the activity;
- provide for handling of contaminated PPE;

• inform workers of the rules of reporting any exposure-related aspect, e.g. sick or dead birds or health complaints;
• provide workers with vaccinations and medical treatment;
• record processor absenteeism and reasons provided.

It is important that employers and poultry processors be informed and trained about microbial agents' prevalence and impact.[117-120] Training of processors should include information on:

• disease symptoms in birds and humans;
• the sources of exposure;
• the effects of exposures;
• procedures to be followed to minimise exposures;
• decontamination procedures;
• the use and maintenance of PPE, including gloves and respirators, and inform workers on their limitations;
• prompt seeking of medical care/attention in case of any exposure symptoms;
• procedure to remove contaminated PPE;
• importance of regular hand washing.

Lastly, employers should provide systems of reporting that are effective in establishing, implementing and maintaining systems. This will ensure that workers can seek advice and medical help from appointed primary caregivers, enabling management to fulfil their vision and mission, and enable them to be compliant to systems such as ISO 9001 and 22001.[17, 121-124]

Limitations

The limitations of this review are that little research has been conducted in SA poultry abattoirs. Most studies relate only to larger poultry abattoirs, with no clear picture of exposure footprints at smaller abattoirs. Further research is required.

CONCLUSION

Poultry abattoir workers can be exposed, directly or indirectly to various microbial agents. Health conditions that can develop are complex and difficult to diagnose, posing a challenge to primary caregivers. Employers should assess the risk to health associated with microbial agents, measure levels of exposure, provide medical surveillance for workers, and train workers regarding symptoms and preventive measures.

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Table 2. Prevalence and effect of viral pathogens present during poultry processing

Study origin	Study design/population	Health effects	Prevalence and health effects
Avian influenza virus (AIV)			
Japan[83]	Poultry abattoir workers – Review	AIV infection; > 200 human cases due to A/H5, A/H7, A/H9	> 50% case fatality rate for A/H5N1 infections; infection from poultry-to-human transmission
Hong Kong[84]	Follow-up cohort study of 293 culling workers and 1525 poultry workers	Influenza	Seropositive 3% culling workers H5 antibody in 10% poultry workers; high exposure linked with presence of anti-H5 antibody; high infection risk for avian influenza
Netherlands[85]	Investigative study	Conjunctivitis 78 Influenza-like illness five	Workers that handled affected poultry; three family members were infected
China[86]	Comparative study 382 poultry workers 100 controls 100 serum samples	Influenza Deaths	2.3% (nine) positive for H9N2 anti-bodies; LPAIV H9N2 could have a possible public health threat
Australia[87]	Investigative study H10N7 Poultry abattoir workers	Conjunctivitis Upper respiratory tract infection	Symptoms in seven workers Infection in two workers
Human papilloma virus			
France and UK[88]	Investigative study Poultry abattoirs	Viral warts	Wart prevalence 47%; ages 25-29: 39%; working period 4-6 years: 41%; ages 25-29: 39%; working period 4-6 years: 41%; appearance – Myrmecia with a keratonic ring around a deep formation (48/103)
Canada[89]	569 poultry abattoir workers	Warts	Present in 29%; ages 25-29 years: 39%; work period: 4-6 years: 41% Skin infection from high humidity skin abrasion from too large gloves
New Zealand[90]	Work practice analysis 106 poultry abattoir workers	Wart-like lesions on hands and arms after start of employment	Present in 44%; 79% was HPV 7; 75% with HPV 7 handled poultry meat
Newcastle disease virus			
Ethiopia[59]	Review	Red, watery eyes Oedema conjunctivitis Conjunctival haemorrhaging	Handling of infected birds/meat
Papova virus			
UK[91]	UK	Viral warts	Present on worker hands 38%; control group (12%); wearing of gloves protected worker hands

Table 3. Prevalence and effect of yeasts and moulds present during poultry processing

Study origin	Study design/ population	Effect on processors/Impact	Prevalence and health effects
Yeasts and moulds			
US[46]	Poultry abattoirs – poultry processors	Yeasts: infection in people with compromised immune systems Moulds: asthma, respiratory symptoms	Levels generally lower (± 1%) of bacterial counts Higher yeasts and moulds in summer Present from receiving to packaging
Croatia[94]	41 poultry workers 45 controls	Asthma Decreased lung function Eye and skin effects	*Aspergillus, Penicillium mucor* spp. present Demonstrate disease symptoms IgG mould antibodies present
Aspergillus fumigatus			
Iran[105]	Sequential trails 105 poultry abattoir workers 76 controls	Asthma from work Allergic bronchopulmonary mycoses (ABPM)	Skin Prick test 55% positive; specific anti-*A. fumigatus* IgE in 49 (47%) and IgG in 70 (67%)
***Aspergillus flavus* complex producing Aflatoxin B_1 (AFB_1)**			
Portugal[99]	Serum 31 poultry workers by: enzyme-linked immune sorbent assay (ELISA) and air samples 30 controls	Liver carcinogen Liver disease Respiratory effects	18 poultry workers (59%) with detectable levels of AFB_1 at <1 to 4.23 ng/ml; *A. flavus* species in 7%; AFB_1 was not detected in the serum from any controls; AFB_1 inhalation represents a risk that needs to be recognised
Portugal[106]	Surface and air samples in poultry abattoirs *A. flavus* and *A. fumigatus*	Unspecified	Air samples: 75 versus 1% Surface samples: 24 versus 16%
India[59, 107]	*A. flavus* investigative study 39 workers tested for pulmonary mycoses	Fever; weight loss; productive cough; breathlessness; asthma Haemopty	*A. flavus* infection was isolated in a 47-year-old male worker
Candida albicans			
UK[108]	High throughput poultry abattoir	Skin lesions Common warts	Compensation claimed by 47% workers present
Japan[109]	Occupational dermatitis incidence in poultry abattoirs	Dermatitis	*C. albicans* was detected in fungual (nail) lesions Cotton gloves not suitable protection for abattoir workers – incidence lower for glove-wearing workers
US[110]	Dermatological study in 150 poultry workers	Dermatitis	*Candida* infections occurred Warts prevalent
Cladophialophora carrionii			
Iran[105]	Sequential trails 109 poultry abattoir workers 76 controls	Asthma from work Acute bronchial pulmonary distress	Positive skin prick test (SPT) 39% IgE 37% response IgG 71% response SPT important in the identification of poultry workers with fungal sensitisations
Dermatophytic fungi (*Trichophyton* genus)			
US[111]	North Carolina Male poultry abattoir workers	Onychomycosis – fungal nail infections 76% Tinea pedis, athletes foot and ringworm 72% Acne 64%	No workers sought medical treatment

DECLARATION

The authors declare no conflicts of interest.

LESSONS LEARNED

- Various pathogenic microorganisms are present in poultry abattoirs, with the HBA footprint varying between processing areas.
- Pathogenic microorganisms can cause severe health impacts and several diseases in workers.

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