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Agriculture Meets Academia: Examining Biosafety Knowledge And Training Among Student Workers On University Dairy Farms

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AGRICULTURE MEETS ACADEMIA: EXAMINING BIOSAFETY KNOWLEDGE
AND TRAINING AMONG STUDENT WORKERS ON UNIVERSITY DAIRY
FARMS

A Thesis Presented

By

Machara Renz

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Thesis Examination Committee:

John W. Barlow, D.V.M. Ph.D., Advisor

Kate Mays, Ph.D., Chairperson

Julie Smith, D.V.M. Ph.D.

Holger Hoock, DPhil, Dean of the Graduate College

ABSTRACT

Biosafety education and training are critical components of university-run dairy farm programs, where student workers gain hands-on experience in herd management, animal health, and agricultural operations. Despite the growing recognition of the importance of biosafety, there remains a lack of standardized education on biosafety topics including biosecurity, zoonotic disease prevention, and antimicrobial resistance (AMR) within these programs. This research assesses the current state of biosafety training for student workers at institutional dairy herds and identifies key gaps in knowledge that could impact both animal and human health.

Through an evaluation of existing training protocols and experiential learning opportunities, this study highlights inconsistencies in knowledge and attitudes around biosecurity, zoonotic disease risk mitigation, and AMR among student workers. While these farm employment programs provide essential hands-on experience, it is unclear if student workers are being adequately educated on the crucialness of biosafety topics in relation to their work in the agriculture industry.

This study underscores a need for a comprehensive, One-Health focused biosafety curriculum within university dairy employment and training programs. A structured approach to biosafety will better prepare students for careers in the agricultural industry, veterinary medicine, and public health. As these individuals transition into careers, their understanding of biosafety practices will be vital in promoting sustainable livestock management and safeguarding public health. By addressing these educational gaps, universities have a unique opportunity to equip future industry leaders with the tools needed to mitigate disease spread, enhance farm biosecurity, and combat the ongoing global threat of AMR.

DEDICATION

I dedicate this thesis to my mother who has so graciously and fervently fought (and won!) her battle with breast cancer, all while remaining an unwavering beacon of support for my academic journey.

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First, I would like to acknowledge and thank my research advisor, Dr. John Barlow, for his patience and major guidance throughout my graduate school journey. Without his help and expertise, none of this would have been possible. I would further like to thank the rest of my committee, Dr. Kate Mays and Dr. Julie Smith for their continuous efforts, time, and support in helping me reach my graduate school goals.

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CHAPTER 1: LITERATURE REVIEW

Biosafety Education and Training: A Review of Programs on Dairy Farms at U.S. Academic Institutions and Related Sample Populations

1.1. INTRODUCTION

Several colleges and universities across the United States offer students hands-on employment or learning opportunities at dairy farm facilities run by each respective institution. The maintenance of these dairy herds is often in conjunction with research and teaching missions, as exemplified by Land Grant Universities. The dairy herds operated by Land Grant Universities maintain the largest share of top-tier research institutions in the United States and sustain education, research, and outreach programs in agricultural sciences (Lee and Graff, 2017). Students may have multiple options of working as dairy farm employees or enrolling in dairy farm experiential learning courses as a part of their curriculum.

When students work hands-on with cattle through these employment experiences, they must receive a foundation of biosafety knowledge to ensure the safety of themselves, the animals, and the greater university population (Bagley, 2024). This importance is reinforced by the increased risk of zoonotic disease infection in those with occupations that involve close contact with agricultural animals (Archibald, 2022). This review will serve to explore dairy farms in academic institutions in the United States that employ student workers and describe the information available detailing their approach, policies,

and procedures in educating and training these students on biosafety topics such as zoonotic diseases, antimicrobial resistance, and biosecurity measures. Due to limited peer-reviewed literature on many topics touched on in this review, web-based resources will be used to support and highlight information, particularly regarding individual programs and their curriculums.

1.2. U.S. COLLEGE AND UNIVERSITY DAIRY FARM RESEARCH AND EDUCATION

The number of colleges and universities across the United States offering educational opportunities in animal and dairy sciences is unclear, as programs vary from certificates to Bachelor of Science and graduate degrees. Estimates for animal science undergraduate degree programs fall around 100 (US News Rankings, 2024). Degree programs for dairy science in the United States are represented by various academic institutions, with over 50 four-year undergraduate programs currently in existence (Lewis, 2024). Additionally, institutions combine animal and dairy science departments, with variations around the department names, structures, and undergraduate degrees awarded. Various program mission statements address the importance of educating students to be future leaders in their respective fields, along with prioritizing outreach, research, and advancement of animal, human, and environmental health (Iowa State University Department of Animal Science, 2016; Cal Poly Animal Science Department, 2024; Auburn University College of Agriculture, 2024). Some institutions promote practical experience learning opportunities or interactive and hands-on approaches in teaching and learning (e.g., The University of Vermont Department of Animal and Veterinary Sciences, 2024; University of Maine School of Food and Agriculture, 2024; University of New Hampshire Agriculture, Nutrition, and Food Systems, 2024).

The number of colleges and universities in the United States offering students opportunities to work on institution-run dairy farms is unknown. These employment opportunities vary by intensity and commitment, with some institutions having experiential learning programs tied to an academic curriculum and others offering general employment through the facility (The University of Vermont Department of Animal and Veterinary Sciences, 2024; Oregon State University College of Agricultural Sciences, 2019). The experiential learning programs may dedicate an on-campus facility or herd of cattle as an educational resource for students who enroll in the program. Alternatively, some institutions may meet education and research missions with the same herd. The experiential learning programs consist of vetted groups of students working collectively to maintain and run all aspects of the dairy's operations, as exemplified by The University of Vermont Cooperative for Real Education in Agricultural Management (CREAM) Program, The University of New Hampshire CREAM Program, and Washington State University's Cooperative University Dairy Students (CUDS) Program (The University of Vermont Department of Animal and Veterinary Sciences, 2024; UNH CREAM, 2024; Washington State University Animal Sciences, 2024). Students earn academic credit for participating in these programs, and often it is a significant time commitment (in the author's experience 15 to 20 hours per week). These experiential learning programs provide students with hands-on working opportunities with cattle and the ability to learn the intricacies of a functional dairy operation. Programs emphasize learning in a variety of areas such as cattle handling, herd health, farm financial management, nutrition, milk quality, leadership, collaboration, and decision-making. Various academic institutions also have work opportunities attached to pre-veterinary or

veterinary curriculums, emphasizing the pre-veterinary opportunities in their programs and targeting students interested in large animal medicine as employees (Cook et al., 2004; Smith, 2004; Timms, 2006). In a search of the internet for program websites, no examples of a standardized curriculum or training among these dairy experiential learning programs was found (The University of Vermont Department of Animal and Veterinary Sciences, 2024; UNH CREAM, 2024; Washington State University Animal Sciences, 2024).

Alternatively, students may access traditional employment experience at some colleges and universities at the institution's dairy herd(s) not tied to an academic curriculum. These opportunities can be offered from the employment avenues through each specific college or university, including federal work-study positions (Oregon State University College of Agricultural Sciences, 2019; OSU Ferguson College of Agriculture, 2020; Penn State Department of Animal Science, 2024). There is limited information on the frequency of this practice on university dairy herds. The time commitment and specifics of work intensity are unknown for these student positions beyond what is advertised in individual postings by each institution's employment forums.

1.3. FARM WORKER HEALTH RISKS: BIOSECURITY, ZOOSES, AND ANTIMICROBIAL RESISTANCE

The World Health Organization (WHO) defines zoonosis as any disease or infection that is naturally transmissible between vertebrate animals and humans (World Health Organization, 2024). Other organizations recognize that humans may also be a source of some pathogens for animals (i.e., “reverse zoonoses” or zoono-anthroposes

(Hubálek, 2003). Zoonotic pathogens fall into many categories including bacterial, viral, parasitic, fungal, rickettsial, chlamydial, protozoal, and even acellular non-viral pathogenic agents like prions (Rahman et al., 2020). It is estimated that 3 out of every 4 new or emerging infectious diseases in people is zoonotic and zoonoses can be spread to humans through direct contact, indirect contact, vector-borne, foodborne, and waterborne pathways (Centers for Disease Control and Prevention, 2024). Zoonoses pose significant public health threats and require a One Health, multi-sectoral approach for their prevention and control worldwide (Rahman et al., 2020). In the United States, the people most vulnerable to zoonotic diseases are those working hands-on with farmed animals (Harvard Law School Animal Law & Policy Program, 2023). Additionally, global trends show an increase in incidents of emerging and reemerging infectious diseases linked to agriculture that are characteristically zoonotic (Jones, et al., 2008; Otte and Pica-Ciamarra, 2021). This can be seen as recently as March 2024, when a novel outbreak of highly pathogenic avian influenza (HPAI) H5N1 occurred in United States dairy cattle, and related human cases were identified (Neumann and Kawaoka, 2024).

Zoonotic pathogens that are found in farm environments or are associated with cattle can pose a risk to the health of employees and the animals that they work with (. Examples of zoonoses associated with dairy cattle environments include Q fever, dermatophytosis (ringworm), leptospirosis, cryptosporidiosis, *Escherichia coli*, campylobacteriosis, Methicillin-resistant *Staphylococcus aureus* (MRSA), chlamydiosis, listeriosis, yersiniosis, *Mycobacterium paratuberculosis*, rabies, and Anthrax, with many of these diseases creating moderate to high hazard for worker exposure (Centers for Disease Control and Prevention, 2024; Washington State University Institutional Animal

Care and Use Committee, 2021; Donham, 2006). Many of these zoonoses can present with little to no signs in cattle, but present with more serious illness in humans, as well as carry risks of antimicrobial resistance (Washington State University Institutional Animal Care and Use Committee, 2021). The threat of continued emergence of antimicrobial resistance (AMR) in zoonotic pathogens is on the rise, with multiple bacteria of concern found in dairy farm environments such as *Salmonella enterica*, *Campylobacter*, methicillin-resistant *Staphylococcus aureus* (MRSA), *Escherichia coli*, *Klebsiella* spp., and *Enterococcus* spp. (Davies and Wales, 2019). Antimicrobial resistance (AMR) is seen as a major public health threat, posing risk to livestock and humans alike, causing untreatable, prolonged infections, as well as increased morbidity and mortality associated with infectious disease (Manyi-Loh et al., 2018; Davies and Wales, 2019). Additionally, zoonotic pathogens can pose exposure and risk of illness to those outside the farm, like household and family members of infected workers (Izadi et al., 2014; Pal et al., 2024). For this reason, it is crucial for farmworkers to be adequately educated on these pathogens and the biosecurity measures necessary to protect themselves, the animals, and the wider community from illness.

1.4. REGULATIONS, TRAINING, AND EDUCATION FOR INSTITUTIONS AND WORKERS

1.4.1. IACUC

There are clear gaps in quantifying how many experiential learning programs and individual student employment opportunities are available on college and university dairy farms in the United States. Regarding student worker education and training, it is known that many of the universities that have dairy farm facilities are Land Grant Universities,

which engage with the three missions of education, research, and outreach with a focus on agriculture (Lee and Graff, 2017). Further, institutions that have animal use supported by the Public Health Service, including rodents, livestock, and non-human primates, are federally required to use an Institutional Animal Care and Use Committee (IACUC) to oversee the care and use of these animals and their facilities (Mohan and Huneke, 2019). IACUC is responsible for the ongoing oversight of each institutional animal care and use program and the regulations and components of successful facilities can be found in the *Public Health Service Policy on Humane Care and Use of Laboratory Animals* and the *Guide for the Care and Use of Laboratory Animals* (NIH Office of Laboratory Animal Welfare, 2021). The *Public Health Service Policy on Humane Care and Use of Laboratory Animals* lays the framework for institutions utilizing vertebrate animals and ensuring their appropriate use and care by each facility (National Institutes of Health, and U.S. Department of Health and Human Services, 2015). The *Guide for the Care and Use of Laboratory Animals* defines laboratory animals as, “any vertebrate animal (i.e., traditional laboratory animals, agricultural animals, wildlife, and aquatic species) produced for or used in research, testing, or teaching” and animal use as, “proper care, use, and humane treatment of laboratory animals produced for or used in research, testing, or teaching (National Research Council et al., 2011).” , The *Guide for the Care and Use of Laboratory Animals* does not extensively address agricultural animals used for production, research, or teaching. Still, it provides general principles and ethical considerations that apply to all species (National Research Council et al., 2011). Though not addressed in detail, university-run dairy herds fall under the defined terms for using animals in research and teaching, making these regulations applicable to the experiential

learning programs and employment opportunities previously described. For the specific regulations and guidance concerning agricultural animals, the *Guide for the Care and Use of Agricultural Animals in Research and Teaching* is utilized (Tucker et al., 2020).

The *Guide for the Care and Use of Laboratory Animals* details the training and education regulations of personnel employed by animal research and teaching facilities stating, “All personnel involved with the care and use of animals must be adequately educated, trained, and/or qualified in basic principles of laboratory animal science to help ensure high-quality science and animal well-being (National Research Council et al., 2011).” It explains, “Personnel caring for animals should be appropriately trained, and the institution should provide for formal and/or on-the-job training to facilitate effective implementation of the Program and the humane care and use of animals. Staff should receive training and/or have the experience to complete the tasks for which they are responsible. According to the program scope, personnel with expertise in various disciplines (e.g., animal husbandry, administration, veterinary medical technology) may be required (National Research Council et al., 2011).” Additionally, it states, “On-the-job training, supplemented with institution-sponsored discussion and training programs and reference materials applicable to their jobs and the species in their care, should be provided to each employee responsible for animal care (Kreger 1995; National Research Council et al., 2011).” It is required for each institution to maintain an occupational health and safety program that maintains control and prevention strategies for risks involved with the occupational environment (National Research Council et al., 2011). This includes the training of personnel to manage their own risks during employment such as maintaining personal hygiene, being knowledgeable about work environment

hazards, understanding the proper selection and use of equipment, following established facility procedures, and using provided personal protective equipment (PPE) (National Research Council et al., 2011). The *Guide for the Care and Use of Agricultural Animals in Research and Teaching* further emphasizes the importance of appropriate training programs for individuals caring for and utilizing these agricultural species, placing the responsibility for monitoring and organizing these opportunities with the home institution where the facility is located (Tucker et al., 2020). The focuses of appropriate training programs can range from hands-on husbandry experiences including handling, minimizing pain and distress, and proper use of analgesics, tranquilizers, and nonpharmacologic methods to occupational health and safety education for workers (Tucker et al., 2020).

When it comes to specific training topics, *The Guide for the Care and Use of Laboratory Animals* highlights the critical need for personnel to be well informed about safety protocols, as the facility's overall safety depends on properly trained staff (National Research Council et al., 2011). The guide dictates that personnel training should include clearly defined procedures for workers, proper and appropriate PPE use, the implementation of required safeguards, zoonoses, chemical, biologic, and physical hazards, unusual agents included in experimental procedures, handling waste materials, personal hygiene, and cautions to be taken with individuals who may be pregnant, sick, or immunocompromised (National Research Council et al., 2011). Further, *The Guide for the Care and Use of Agricultural Animals in Research and Teaching* specifies occupational health and safety training should include “an educational component to teach personnel about agricultural animal and zoonotic disease, physical hazards, and

personal hygiene (Tucker et al., 2020).” This guide emphasizes the serious risk of zoonoses on workers who are consistently in close proximity to agricultural species and explains all at-risk personnel “who have contact with or an opportunity for contact with animals, their waste products, or tissues should be made aware of identified hazards (Acha and Szyfres, 2001, 2003; Fontes, 2008; Tucker et al., 2020).” It states that each institution with agricultural research or teaching animals has the responsibility to maintain an appropriate occupational health and safety program for evaluating the risks posed to human health by potential zoonoses and program veterinarians, scientists, or instructors should collaborate to establish preventative medicine programs and husbandry practices to decrease incidence of pathogen transmission (Tucker et al., 2020).

1.4.2. Institutional Collaboration: CITI Program

To meet personnel training regulations some individual institutions will partner with outside organizations such as the Collaborative Institutional Training Initiative Program (CITI). CITI programs provide animal workers and staff with online materials covering topics relevant to their personnel training and occupational health and safety (CITI Program, 2024). CITI states their online courses titled “Animal Care and Use Core” (ACU Core) are included in organizational subscriptions for use within institutional programs, designed to fulfill federal training mandates and guidelines (CITI Program, 2024). The ACU Core courses are designed for animal care and use workers (IACUC members, animal workers, staff, students, investigators, and research assistants) to fulfill their federal training requirements due to their involvement with animal work (CITI Program, 2024). The ACU Core package of courses available for institutions includes basic modules such as “Working with the IACUC” and “Essentials for IACUC

Members” that detail foundational information for workers surrounding IACUC and the necessary protocols involving animal use, personnel training, and occupational health and safety (CITI Program, 2024). A specific course for cattle is included in the ACU Core package and is titled “Working with Cattle in Agricultural Research Settings” (CITI Program, 2024). Within the cattle course are modules that are individually titled “Introduction to Working with Cattle in Agricultural Research Settings,” “Research Mandates and Animal Care,” “ Biological Features,” “ Veterinary Care- Part 1,” “Veterinary Care- Part 2,” and “Occupational Health Hazards and Zoonoses” that provide further details on the specific concerns, protocols, and hazards associated with cattle (CITI Program, 2024).

Though access to the content of the individual course modules is not publicly available, though authors were able to access the content of specific modules from our home institution, The University of Vermont, having a partnership with CITI Programs. The individual modules of “Working with Cattle in Agricultural Research Settings” were assessed on whether they contained educational or training material relevant to biosafety topics such as biosecurity, zoonotic disease, and antimicrobial resistance. A small section within the module “Veterinary Care- Part 1” is dedicated to biosecurity, defining the topic as “meant to prevent the introduction and spread of disease in a group of animals (CITI).” The small section describes the best means to prevent and reduce the spread of disease including testing imported cattle, quarantining new animals, practicing hygiene measures, and isolation, testing, and treatment/culling of infected cattle (CITI). This module also addresses how workers should be monitoring cattle for signs of disease including changes to their Body Condition Score (BCS), skin, hair, udder, ears, eyes,

nose, teeth, hooves, and overall attitude and behavior (CITI). The module “Veterinary Care- Part 2” details infectious diseases often associated with cattle but makes no connections to those diseases also having an impact on human health or how they can be zoonotic (CITI). Neither of the modules focusing on veterinary care discusses antimicrobial resistance or the importance of responsible antimicrobial use when treating disease in cattle. The “Occupational Health Hazards and Zoonoses” module goes the most in-depth regarding biosafety topics compared to other modules in the cattle-specific course, though is mostly focused on physical injury rather than the risk of disease or illness (CITI). The module discusses the importance of PPE in reducing the risk of injury, exposure to chemicals, and diseases when working with cattle, but does not tie PPE to biosecurity (CITI). This module has a section dedicated to zoonoses but says “washing hands with soap after handling animals is the most important precaution” in disease prevention and details no other biosecurity measures of importance (CITI). Overall, the section is not comprehensive, as it highlights only a few pathogens of concern, speculated to be because of their commonality in the farm environment, including ringworm, *Salmonella*, *E. coli*, *Giardia*, *Cryptosporidium*, and rabies (CITI). This module does not mention antimicrobial resistance and following a search of all cattle-specific course modules, no mention of the subject is found in any regard (CITI).

CITI recognizes that its programs should not be utilized as the only forms of training for personnel working with animals and emphasizes that they should only be one component of a wider framework of training at each institution (CITI Program, 2024). They recommend combining CITI Program content with “face-to-face training, one-on-one mentoring, and other types of learning opportunities as appropriate to the particular

topics and their organizational cultures (CITI Program, 2024).” This idea of not having program training be a “one-size-fits-all” is further exemplified by Benjamin Fontes in his article proposing an occupational health and safety program for animal handlers where he highlights that training should be tailored to the workers based on their individual environment, and the risks and hazards associated with the species of focus (Fontes, 2008). The *Guide for the Care and Use of Agricultural Animals in Research and Teaching* lists various topics that may be used in worker training and education programs specific to relevant responsibilities of the individuals including, “animal husbandry, behavior, nutrition, environmental physiology, experimental surgery, veterinary clinical and diagnostic medicine, agricultural engineering, instrumentation, and others as deemed appropriate,” leaving room for personalization at varying facilities (Tucker et al., 2020).

These federal regulations and institutional collaborations give a broad overview of themes that might be used in the training and education of dairy experiential learning programs and student employment positions but provide no official list of core competencies or training initiatives being utilized across all programs. It can be assumed that since both IACUC and CITI Program courses list occupational safety, zoonoses, and hazard mitigation as themes, personnel training should address that student workers in institutional dairy facilities are being introduced to these topics in some capacity.

Through a search done on the aforementioned materials, antimicrobial or antibiotic resistance is not mentioned in any capacity within the *Guide for the Care and Use of Laboratory Animals*, the *Public Health Service Policy on Humane Care and Use of Laboratory Animals*, or in any descriptors regarding CITI Program ACU Core or cattle specific modules (National Research Council et al., 2011; National Institutes of Health,

and U.S. Department of Health and Human Services, 2015; CITI Program, 2024). The *Guide for the Care and Use of Agricultural Animals in Research and Teaching* mentions discouraging the use of prophylactic antibiotics in regard to safeguarding from antibiotic resistance, and resistance in parasitic pathogen control (Tucker et al., 2020). The guide includes no other mentions of responsible antimicrobial use or the possible risks of antimicrobial resistance. It is not publicly known whether every program that participates in collaborations like CITI is required to have workers utilize all course modules or if individual institutions can customize what their workers have access to. This further confuses whether IACUC participating programs offer standardized training curriculums across all participating institutions or if the information differs based on what institution each worker is associated with. No further information regarding a standardized curriculum, including training in biosafety, biosecurity, zoonotic disease, and antimicrobial resistance being taught by these institutional farm facilities to their student worker population is available.

1.5. PRIOR LITERATURE EVALUATING SIMILAR RELEVANT SAMPLE POPULATIONS

It is vital to the functionality of the dairy operation that the student workers are adequately informed on biosafety, biosecurity and the risks of zoonotic pathogens in their occupational environment. This is because disease outbreaks are often linked with major economic losses due to increased culling or decreased production and product shortages (Hussain and Dawson, 2013; Farahat et al., 2023). Labor may also become impacted by outbreaks, as employees who contract various gastrointestinal zoonoses can experience serious symptoms such as gastroenteritis (Preiser, Preiser, and Madeo, 2003), diarrhea, vomiting, fever, and abdominal pain (Cacciò and Chalmers, 2016; Igwaran and Okoh,

2019). Previous literature supports the idea that farm workers have higher incidences of exposure and development of zoonotic diseases than people who do not work hands-on with farmed animals (Palomares Velosa et al., 2021; Archibald, 2022; Wappes, 2024; Chaiklieng et al., 2023). Connections have also been made to higher incidences of exposure, colonization of antimicrobial-resistant bacteria, and infection by zoonotic pathogens in family or household members of those who work with farmed animals, deepening the importance of disease mitigation to protect the greater community (Izadi et al., 2014; van Cleef et al., 2015; Pal et al., 2024). Increased animal contact intensity is linked to higher exposure risk (Graveland et al., 2011), further supporting the idea of zoonoses presenting an occupational hazard for farm workers (Enbom et al., 2023). The idea of increased exposure from increased animal contact suggests student farm workers on institutional dairy herds are in a key position to receive education and training on zoonoses. This is because preventing the occurrence and increased incidence of zoonoses requires appropriate biosecurity and training from medical schools, veterinary schools, and other universities (Saegerman et al., 2012). Saegerman et al (2012) elaborate that these training programs must be adapted to prepare stakeholders, veterinary, human medical, and public health professionals for their role in disease prevention, control, and surveillance. This aligns with the idea that institution-associated dairy farms are at the forefront of cultivating the future leaders of the agricultural industry, as they emphasize the importance of comprehensive education and training (Lewis, 2024), ensuring that professionals are prepared to address current and future biosafety risks.

A search of the literature was done to look for peer-reviewed studies involving knowledge and awareness of biosafety topics such as biosecurity, zoonotic disease, and

antimicrobial resistance in student farm workers of institution-run dairy herds. Specifically, literature was targeted that assessed baseline knowledge of biosecurity, zoonotic diseases, and/or antimicrobial resistance. As no references were found to be studying this exact target population, it appears to be novel, and we expanded our review of the literature to include the publications of these topics in similar sample populations such as farmers, farm workers, veterinary students, and students enrolled in animal-related secondary education programs. These searches spanned across various platforms including Google Scholar, JSTOR, ScienceDirect, and Pubmed and included search terms such as, “animal science student awareness of zoonoses,” “biosecurity training in dairy science students,” “biosecurity knowledge veterinary students,” “knowledge and awareness of zoonoses in animal science students,” and “knowledge of zoonoses risks in animal science.” More advanced searches included “(((farm) AND (dairy)) AND (worker)) AND (zoonotic) OR (zoonoses)” and “((((farm) AND (dairy)) AND (worker)) AND (zoonotic) OR (zoonoses)) AND (infection) OR (prevalence).”

The inclusion of veterinary students, a population of higher educational level than undergraduate students, is supported by the idea that many students enrolled in dairy experiential learning programs or employed on university herds may fall under the “pre-veterinary” category, showing a possible trend in where these students will end up after their farm employment (Conroy, 2019). Veterinary students similarly have work opportunities on institution-run dairy farms, some of which are the same facilities that employ undergraduate student workers (Cook et al., 2004; Smith, 2004; Timms, 2006). Moreover, many of the hazards encountered by farm workers, such as heightened exposure and incidence of disease, similarly impact veterinary students, making them a

relevant population to study (Sánchez et al., 2017; Furtado et al., 2024). Much of the peer-reviewed literature focuses on agriculture in areas and countries often characterized as LMIC (low and medium income countries) or in a rural or isolated locations. The inclusion of these studies is supported by the idea that the cases of emerging diseases and zoonotic outbreaks are not solely focused in developing countries and are often linked to issues heavily present in systems across North America like agricultural intensification (Jones et al., 2013). This concept is exemplified in the current avian influenza outbreak affecting dairy farms across the United States (Neumann and Kawaoka, 2024). Thus, the health and occupational hazards presented by lack of knowledge and education surrounding biosafety risks that impact students and livestock farmers abroad also will impact our U.S. student farm workers.

1.5.1. Students

Five studies from the peer-reviewed available literature were identified that target knowledge and perceptions of biosecurity and zoonoses by student populations including veterinary and animal science students (Rahaman et al., 2022; Emikpe et al., 2024; Nyokabi et al., 2024; Humblet et al., 2017; Hardefeldt et al., 2018). The publications reviewed are all set in countries outside the United States, as a lack of peer-reviewed publications in this area is noted. The countries involved include Australia, Ghana, Ethiopia, and Belgium.

Table 1.1.: Summary of studies evaluating veterinary and animal science students' knowledge and perceptions of biosecurity and zoonoses

Publication	Target Population	Population Size
Humblet et al. (2017)	Veterinary students in Belgium	n=56 in slaughterhouse n=122 in necropsy room
Rahaman et al. (2022)	BSc Animal Science, BSc Veterinary Bioscience, Doctor of Veterinary Medicine (DVM) students at University of Adelaide	n=317
Hardefeldt et al. (2018)	Australian DVM graduates from 2017 and 2018	n=476
Nyokabi et al. (2024)	Veterinary students in Ethiopia	n=154
Emikpe et al. (2024)	Veterinary and Medical students in Ghana	n=174 veterinary students n=384 medical students

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Table 1.1 presents the target populations and collected sample sizes from each respective peer-reviewed publication (Rahaman et al., 2022; Emikpe et al., 2024; Nyokabi et al., 2024; Humblet et al., 2017; Hardefeldt et al., 2018). Most publications favored the use of convenience sampling to collect respondent data via a survey distributed to their target population, except for Humblet et al. (2017) who used an observational study method (Rahaman et al., 2022; Emikpe et al., 2024; Nyokabi et al., 2024; Humblet et al., 2017; Hardefeldt et al., 2018). Several of these studies were conducted in countries where students enter veterinary degree programs immediately after secondary education (i.e., high school). This contrasts with US and Canadian veterinary education where students generally complete 3 or more years of undergraduate training before matriculating into a “post-baccalaureate” professional degree program. There are no included studies utilizing target populations from the United States or Canada .

Humblet et al. (2017) collected data via direct observation of Belgian veterinary students when in a necropsy room and a slaughterhouse, then graded students on their compliance with an established checklist of biosecurity behaviors. In the necropsy room, students were observed for 31 biosecurity rules and were found to visibly disregard 18 of them (Humblet et al., 2017). Similarly, in the slaughterhouse students were observed for 35 biosecurity rules, were found to disregard 22 of them, and had 8 rules disregarded by every student observed (Humblet et al., 2017). Overall, mean compliance rates were 42% and 37% for the necropsy room and slaughterhouse, respectively (Humblet et al., 2017). The study classified these mean compliance rates as “intermediate,” citing a previous study that considered low compliance <25% and intermediate compliance to fall between 26% and 74% (Humblet et al., 2017; Haynes, Taylor, & Sackett, 1979). This study further highlights that although these mean compliance rates can be classified as intermediate based on the previous study, it reveals a disconnect between real-life practices and the biosecurity standard operating procedures (Humblet et al., 2017). The study connects the importance of veterinary student compliance with biosecurity measures in these scenarios, as both slaughterhouses and necropsies present a level of uncertainty as to what possible infectious agents students will be exposed to (Humblet et al., 2017). Further, the importance of compliance with biosecurity measures is highlighted as essential to reducing the wider spread of disease beyond the veterinary students being observed, as the authors speculated students may act as reservoirs for asymptomatic transmission of pathogens such as *E. coli* and MRSA (Humblet et al., 2017). Given the risks of possible infection and disease reemergence that come from both necropsy and slaughterhouse environments, it is recommended that educational measures,

such as online modules, should be given to students to ensure their awareness of the importance of biosecurity and increase regulation compliance (Humblet et al., 2017). Non-compliant behavior presented by veterinary students in these settings presents a concerning disconnect between how students perceive their risk to the biohazards they are working with and their biosecurity protocol compliance. This idea is further explored by Shannon et al. (2018), detailing how increased awareness of biosecurity does increase one's perception of risk and biosecurity behavior among field researchers. The disconnect lies between what a person understands to be “good biosecurity practice,” as higher perceptions of risk did not correlate with better biosecurity practices (Shannon et al., 2018). The study concluded that field experience, awareness of educational materials such as biosecurity campaigns, and guidance are key components for behavior change and better biosecurity practices among the study population (Shannon et al., 2018). These findings could be used to explain low biosecurity compliance among veterinary students in Humblet et al. (2017) and may support similar application of protocol compliance for university dairy farm workers.

Nyokabi et al (2024) presented biosecurity findings similar to Humblet et al (2017). The survey revealed veterinary students demonstrated poor knowledge of biosecurity measure adoption and infection control practices (ICPs) that are used to reduce the health and safety risks posed by zoonotic pathogens (Nyokabi et al., 2024). The survey revealed low usage of appropriate PPE, low adoption of ICPs such as work boot disinfection, and inconsistent cleaning methods of reusable medical supplies such as needles, syringes, scalpels, and razors (Nyokabi et al., 2024). Contrarily, veterinary students involved in the survey demonstrated an awareness of the occupational risks of

zoonotic diseases, including their potential impacts on animal and human health (Nyokabi et al., 2024). This study revealed significant gaps in the students' knowledge surrounding biosecurity and zoonotic disease, as they do not connect the importance of both topics in preventing disease emergence and spread in their occupational environments. This is relevant for undergraduate dairy farm workers, as it is crucial to make the connections between practicing biosecurity protocols to prevent increased incidence of disease. Further, the respondents identified it as being difficult to access information on new treatments, antibiotic resistance, and disease outbreaks when navigating their various sources of scientific information (Nyokabi et al., 2024). This study proposes changes to the veterinary curriculum of Ethiopian institutions, suggesting the adoption of a standardized curriculum in line with the One Health concept to increase student knowledge of biosecurity and its impact on zoonoses (Nyokabi et al., 2024).

The Australian study “Q Fever Vaccination: Australian Animal Science and Veterinary Students’ One Health Perspectives on Q Fever Prevention” focused on the knowledge of veterinary (DVM) and animal science students surrounding Q fever, a zoonotic pathogen contracted by humans from livestock, wildlife, and companion animals (Rahaman et al., 2022). Across all degree programs, students showed suboptimal knowledge of Q fever, particularly concerning disease transmission (Rahaman et al., 2022). Overall, 46% of student respondents reported little to no knowledge of Q fever, with DVM students possessing overall greater knowledge than other degree program respondents (Rahaman et al., 2022). Further, 61% of animal science students were unvaccinated for Q fever compared to 5% of DVM students (Rahaman et al., 2022). This paper presents a dichotomy of knowledge between the groups of students but shows how

exposure to high-risk animals remains moderate to high across all groups (Rahaman et al., 2022). Responsibility was further placed on both individual students and universities for preventing cases of Q fever, emphasizing and supporting the need for mandatory training on zoonotic diseases, currently only provided to respondents in the 4th year of the DVM program (Rahaman et al., 2022). The study highlights the need for increased access to educational materials on biosecurity and zoonotic diseases, particularly in disease transmission, for animal science and veterinary students and suggests the possibility of incorporating them into existing curriculums for programs that do not already have courses established (Rahaman et al., 2022). This reinforces the opportunity for increased education and training on the same topics for dairy farm workers in institution-run employment opportunities.

A second Australian publication “Veterinary Students’ Knowledge and Perceptions About Antimicrobial Stewardship and Biosecurity- A National Survey” surveyed the graduates of Australian Veterinary Institutions from the years 2017 and 2018 (Hardefeldt et al., 2018). When evaluated for the use of appropriate personal protective equipment (PPE) in varying scenarios, four scenarios stood out where most students would use insufficient PPE (Hardefeldt et al., 2018). All these scenarios involved the risk of a zoonotic pathogen, with avian psittacosis, Q fever, and Hendra virus posing a hazard to the high percentage of graduates who selected insufficient PPE use (Hardefeldt et al., 2018). Hardefeldt et al. (2018) goes on to describe the need for further studies in this area of student zoonoses knowledge, as it highlights the fatalities previously caused by the Hendra virus to Australian veterinarians. The survey also shares respondent knowledge on antimicrobial resistance (AMR) and reveals students are aware

of the importance of the topic with 88% of respondents identifying veterinary antimicrobial use as having a “moderate” or “strong” impact on overall AMR (Hardefeldt et al., 2018). Most students reported having a good understanding of AMR mechanisms as well as antimicrobial stewardship but further acknowledged that these topics were being taught less than they felt necessary in the classroom (Hardefeldt et al., 2018). This paper overall reveals gaps in AMR and antimicrobial stewardship being taught in Australian vet schools with the need to unify what is being taught in preclinical and clinical years (Hardefeldt et al., 2018). This standardization should create clearer guidelines for veterinary students to follow and improve the identification of high-importance antimicrobials common in veterinary clinical settings (Hardefeldt et al., 2018).

Emikpe et al. (2024) examined the knowledge and perceptions of Ghanaian medical and veterinary students of zoonoses and their significance to public health. 83.6% of respondents perceived the public health significance of zoonoses as high, with a clear indication that students perceive zoonoses to be more threatening in countries like Ghana (Emikpe et al., 2024). When further broken down, the study indicated more students in their clinical year of study (54.9%) perceived the public health significance of zoonoses as high when compared to pre-clinical students (28.7%) (Emikpe et al., 2024). This draws a connection between increased years of education and better informed students on the topic of zoonotic diseases, and may also highlight the relevance of experiential education (as would be found in clinical years of study) in reinforcing knowledge. This idea is further supported by 60.9% of clinical students demonstrating high-level knowledge of zoonoses, compared to 17.7% of pre-clinical students across

veterinary and medical students (Emikpe et al., 2024). This study acknowledges the possibility of increased overall knowledge of zoonoses being tied to the fact that the survey only asked about zoonoses common in Ghana, where the students are studying (Emikpe et al., 2024). Overall, the study showed that veterinary students exhibited higher rates of knowledge of zoonotic disease when compared to medical students and proposed the curriculums of all programs be reviewed for possible alteration (Emikpe et al., 2024). The study suggests that incorporating information surrounding zoonoses into pre-clinical years of education will better prepare these students to address their roles in maintaining effective control of these diseases in the future (Emikpe et al., 2024). This publication, as well as the others, supports the crucial role that education plays in the maintenance of public health safety in the face of zoonotic diseases. The consensus of these studies is that equipping students, the future professionals of the field, with essential knowledge and skills through education is vital in reducing the risks they may encounter surrounding biosecurity, zoonotic disease, and antimicrobial resistance.

Antimicrobial resistance is revealed to be a topic associated with gaps in students' knowledge, exemplified by two additional studies beyond Hardefeldt et al. (2018) and Nyokabi et al. (2024) (Odetokun et al., 2019; Anyanwu et al., 2018). Odetokun et al. (2019) surveyed veterinary students in Nigeria and found unsatisfactory knowledge of AMR issues, with less than 25% of respondents being aware of antimicrobial stewardship and global efforts in AMR. This presents concerning information, as AMR is a large global public health threat with antimicrobial abuse, misuse, and overuse in animals having serious consequences on the health of humans, animals, and the environment (Odetokun et al., 2019). Anyanwu et al. (2018) surveyed Nigerian veterinary students on

similar topics in their final year of veterinary study. This study supports the previous findings by revealing poor perception and knowledge of antibiotic resistance and antibiotic stewardship of Nigerian veterinary students (Anyanwu et al., 2018). These two publications on antimicrobial and antibiotic resistance affirm the belief that educating our future prescribers on the importance of responsible antimicrobial use is crucial to aiding in the efforts to reduce global resistance. Acknowledgment by students of AMR's global threats in combination with multisector collaboration is said to be an important step to effectively addressing the issue and its posed risks (Primeau et al., 2023).

1.5.2. Farmers

A literature review surrounding knowledge and perceptions of biosafety issues involving farmers was done. Farmer perceptions and knowledge were included in this review due to experiential learning programs often putting student workers in positions of running farm operations (The University of Vermont Department of Animal and Veterinary Sciences, 2024; UNH CREAM, 2024; Washington State University Animal Sciences, 2024). This makes farmer attitudes and knowledge relevant to the review and farmers a vital population of study. Five publications focused on livestock farmers and addressed their awareness, knowledge, and overall health literacy regarding zoonotic diseases and biosecurity (Bose and Kumar, 2024; Ngoshe et al., 2022; Cao Ba et al., 2020; Singh et al., 2019; Baye et al., 2024). As shown in Table 1.2, the publications ranged in sample size from 42 to 859 and represented various countries including India, South Africa, Vietnam, and the United States (Bose and Kumar, 2024; Ngoshe et al., 2022; Cao Ba et al., 2020; Singh et al., 2019; Baye et al., 2024).

Table 1.2. Summary of studies evaluating livestock farmer and producer knowledge and perceptions of biosecurity and zoonoses

Publication	Target Population	Population Size
Bose and Kumar (2024)	Dairy farmers from the Wayanad district of Kerala, India	n=42
Ngoshe et al. (2022)	Livestock farmers from KwaZulu-Natal province, South Africa	n=504
Cao Ba et al. (2020)	Livestock farmers in Thai Nguyen Province, Vietnam	n=218
Singh et al. (2019)	Livestock farmers from India	n=859
Baye et al. (2024)	Swine producers in the United States	n=422

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Baye et al. (2024) focused on swine producers in the United States to assess biosecurity compliance and found producer characteristics significantly influence attitudes around biosecurity. This publication addresses the importance of biosecurity compliance in food production systems, as outbreaks of disease, such as the 2018 African swine fever (ASF) outbreak, often create significant impacts on producers (Baye et al., 2024). The study found producers who fall in an “ultra-compliant” biosecurity group are more likely to be higher-income producers and participate in disease eradication programs (Baye et al., 2024). Alternatively, biosecurity “skeptical” producers are associated with lower-income and smaller-scale farms not participating in disease eradication programs (Baye et al., 2024). The study revealed a positive effect of eradication programs on improving producer attitudes towards biosecurity, with attending at least one eradication program encouraging higher biosecurity compliance (Baye et al., 2024). Increasing the overall knowledge and risk perception of producers in this industry will aid in higher biosecurity compliance which is essential for disease prevention. This

study provides some insight on producer characteristics and biosecurity compliance. Noted behaviors and characteristics that produce high biosecurity compliance can be applied to institutional dairy farm biosafety training programs in an effort to create and maintain the most compliant and risk-averse employees.

Bose and Kumar (2024) focused on dairy farmers in the Wayanad district of India, as previous studies had identified the need for increasing farmer awareness around vector-borne zoonotic diseases such as dengue and chikungunya (Hundal et al., [2020](#); Khadayata and Aggarwal, [2020](#); Tebug et al., [2015](#)). These diseases were of importance to the study, as there have been 1305 cases of these diseases in the area within the last decade (Bose and Kumar, 2024). The data showed that 50% of respondents knew about chikungunya fever (Bose and Kumar, 2024). For dengue, the results were slightly better with 61.9% having awareness of the disease and 38.1% being unaware (Bose and Kumar, 2024). The study also revealed that 57.14% of farmers have insufficient disease mitigation practices such as mosquito nets, cleaning stagnant water, using repellents, and wearing full-sleeved clothes (Bose and Kumar, 2024). Overall, the study shows the need for increased farmer awareness and education about vector-borne zoonotic diseases, as working closely with livestock puts them at a higher risk of exposure (Bose and Kumar, 2024). A second study in India looked at the knowledge, attitudes, and practices relating to zoonotic diseases among livestock farmers in Punjab (Singh et al., 2019). Farmer respondents to this survey indicated they were unaware of the transmission, prevention, and control of many zoonoses commonly found in livestock environments (Singh et al., 2019). This study associates lower levels of knowledge on zoonotic disease with farmers who have low levels of formal education (Singh et al., 2019). The suggested solution to

this problem is creating policy development while tailoring and improving zoonotic disease educational programs for livestock farmers to help mitigate the occupational hazards presented by zoonotic diseases (Singh et al., 2019).

Ngoshe et al. (2022) further elaborates on the possible adverse impacts of zoonotic diseases on the lives of farmers and how decreased awareness of disease results in health risks and economic losses. Of the 504 farmers surveyed, 21.4% had poor knowledge and 25.4% had moderate knowledge of zoonotic disease transmission and prevention (Ngoshe et al., 2022). Further, only 59.3% of farmers knew that they could contract a disease from keeping animals adjacent to their homes, but overall knowledge of animal disease transmission was moderately high (Ngoshe et al., 2022). The study concluded that overall knowledge of livestock zoonoses in KwaZulu-Natal was moderate and showed older farmers were more knowledgeable and had better disease prevention and management practices, crediting more years of experience than younger farmers (Ngoshe et al., 2022). High levels of understanding of mosquito-borne diseases are attributed to the ongoing malaria control efforts in the study area, exemplifying the importance of community-based educational efforts for farmers (Ngoshe et al., 2022). Even with high levels of knowledge, over 40% of farmers had poor practices in place for disease prevention, revealing a disconnect between information regarding the mitigation of disease (Ngoshe et al., 2022). Trends in poor biosecurity practices are revealed, and policies are recommended to increase extension and veterinary services in the area to train farmers on animal diseases and adequate management practices (Ngoshe et al., 2022).

Cao Ba et al. (2020) assessed the health literacy of livestock farmers in Vietnam toward biosecurity in the prevention of zoonotic diseases. The median years of experience farming from the respondents was 15 years and 82% of respondents had moderate health literacy levels in regard to zoonoses (Cao Ba et al., 2020). Disease prevention measures were shown to be poor, as many participants were unaware of many practices of importance such as PPE use, disinfection measures, quarantining of sick animals, and use of preventative vaccinations (Cao Ba et al., 2020). 58% of survey participants reported improper use of antibiotics, including feed additives and the use of human antibiotics to treat sick animals (Cao Ba et al., 2020). This information is concerning, as AMR is an issue common in the livestock sector and 41.3% of respondents disagreed with that statement (Cao Ba et al., 2020). The knowledge of hazards involved with zoonotic disease seemed to be missing, as one farmer even admitted panicking and selling his pigs with known foot and mouth disease (FMD) (Cao Ba et al., 2020). Though FMD is not a direct public human health threat, it leaves the animals it infects unable to produce at the level they could before infection (APHIS, 2024) and causes staggering economic losses to agricultural systems during an outbreak (Knight-Jones and Rushton, 2013). Overall, the findings of Cao Ba et al. (2020) revealed increasing competencies of health information for farmers engaging in behaviors with known increased risks of zoonotic infection is crucial to minimizing the problems involved with misinformation and lack of access to these resources. As most farmers seem to get their information from public media outlets, Cao Ba et al. (2020) suggests farmers need more specific and customized information related to zoonoses and farm environments, possibly from veterinarians or local health workers. These collaborations

for detailed, targeted education for farmers should aid in the improvement of farmer knowledge and perceptions of zoonoses and increase biosecurity management practices (Cao Ba et al., 2020).

All reviewed literature publications support a need for more comprehensive education for farmers and students regarding biosecurity and zoonotic disease training measures to help mitigate health, economic, and production system risks. Additionally, the published literature that touched on antimicrobial resistance states the need for more comprehensive education programs on the topic, as historically knowledge in the area is low. As zoonotic diseases continue to emerge, reemerge, and spread nationally and globally, the quality of related education and training that our student workers receive is crucial to their ability to tackle these issues for the industry's future (Lewis, 2024; Chaisupa, 2023). If student dairy farm workers are required to complete IACUC training modules through their institution, they may be exposed to topics of zoonosis and occupational health safety. The IACUC module through CITI titled "Working with Cattle in Agricultural Research Settings," provides information on basic husbandry, handling, regulatory mandates, veterinary care, occupational health hazards, and zoonoses relating to cattle (CITI Program, 2024). This is the extent of what is known regarding the education and training of student farm workers around zoonoses, biosecurity, and occupational health safety and reveals the need for more updated protocols and further publication of curriculum standards by each institutional farm facility. It is widely accepted that hands-on work and experiential learning programs such as these often yield positive learning results for students, facilitating problem-solving and transforming their experience into utilized knowledge (Miles et al., 2005). While dairy educational

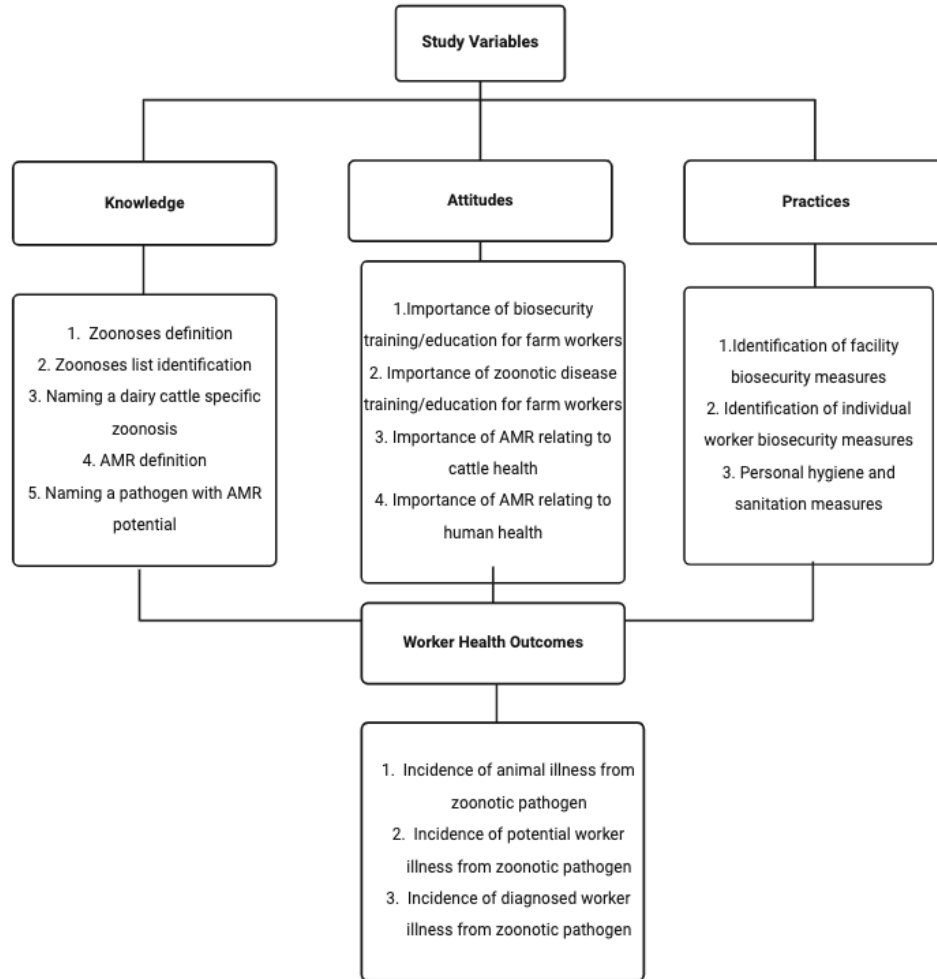
programs offer hands-on experience, the perceived lack of a standardized curriculum or core competencies across university farms can result in students missing essential learning outcomes and hinder knowledge transferability between other educational and professional environments (Zhao et al., 2023).

1.6. CONCLUSION

Dairy farms at academic institutions across the United States play a pivotal role in cultivating the future leaders of the agricultural industry using student work opportunities through traditional employment and educational experiential learning programs. These novel, hands-on opportunities allow students to gain practical experience in managing dairy operations, from working in direct contact with livestock to learning how to manage farm finances. Institutions that offer these programs, particularly through experiential learning models, provide a unique and immersive environment that works to support pillars of education, research, and outreach. However, despite the many benefits, there is a lack of standardization across programs concerning education and training in biosecurity, zoonotic disease, and antimicrobial resistance. Given the inherent risks associated with working with livestock, all student workers must receive consistent and comprehensive education on biosecurity, zoonotic diseases, and antimicrobial resistance. Following the concept of assessing knowledge, attitudes, and practices, a research project was conducted utilizing the following variables in Figure 1.1. below. Through the assessment of these variables, the goals are to understand how student farm workers are being educated and trained on the topics of biosafety, specifically looking at questions

about biosecurity, zoonotic diseases, and antimicrobial resistance. The results will be split into two different papers, which will be akin to Chapters 2 and 3 of this manuscript.

Figure 1.1. Visual flow chart of all variables being assessed within the scope of this research project



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The absence of a standardized curriculum further raises concerns about potential gaps in knowledge, particularly around zoonotic disease prevention and mitigation and supports the conduction of further research in this area. Student workers on institutional dairy farms face an increased risk of exposure to zoonotic pathogens, making proper

training a vital component of their education. Although institutions like Land Grant Universities may partner with external organizations, such as the Collaborative Institutional Training Initiative (CITI), to provide relevant training, there is little evidence to support uniformity across programs. Without clear standards or core competencies, the quality of education and training students receive can vary significantly, potentially leaving them unprepared to effectively manage these occupational health risks in both their current employment environment and in the future.

To address these challenges, institutions need to adopt a more structured and unified approach to worker education and training. Standardized training protocols in biosecurity measures, zoonotic disease management, and antimicrobial resistance awareness would ensure that all student workers acquire the necessary skills and knowledge to protect themselves, the animals, and the broader community beyond the farm. Gaps revealed surrounding awareness and knowledge of the topics in similar sample populations support the need for increased education measures and further research in the area. Moreover, given the critical role that these student workers will play in the agricultural industry's future, providing a thorough, standardized educational framework will be key to fostering a safe and educated occupational environment in these institutional farm facilities and in the future. By improving and expanding biosafety education, academic institutions can better equip their students to address the emerging public health challenges linked to zoonoses and antimicrobial resistance, ensuring the continued safety of food animal production systems and greater community public health.

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CHAPTER 2: BRIDGING THE GAP BETWEEN PROTOCOLS AND PRACTICE: ASSESSING STUDENT WORKER BIOSAFETY KNOWLEDGE AND ATTITUDES ON ACADEMIC DAIRY FARMS

2.1. ABSTRACT

University-run dairy farms provide student workers with invaluable opportunities for hands-on learning and practical agricultural work experience. However, these settings also expose student workers to risks associated with biosafety issues such as biosecurity and infectious zoonotic diseases. This study investigates the biosafety training programs in place for university student dairy farm workers as well as their knowledge and attitudes surrounding the topics. This research is guided by the One Health framework and approach emphasizing the interconnectedness of animal, human, and environmental health. An online survey was distributed to students involved with working on dairy farms at academic institutions. Survey responses were collected from 126 student workers at 27 different United States academic institutions with functional dairy herds and highlighted notable gaps in biosafety knowledge and training. Specifically, academic level and prior coursework taken in topics of biosafety emerged as key components in driving higher levels of knowledge for respondents. These gaps support the need for more comprehensive biosafety education and training for student workers at university dairy farms. The importance of comprehensive biosafety education for these workers is exemplified by the current novel and ongoing outbreak of highly pathogenic avian influenza (HPAI H5N1) in dairy cattle as well as other pathogens with more consistent risk of exposure in dairy farm environments. Gaps in biosafety education and training can leave workers and the agricultural systems they work with vulnerable to zoonotic disease

spread, demonstrating the need for immediate improvements in these programs.

Academic institutions can play a pivotal role in preparing the future leaders of the agricultural industry by instituting a robust and comprehensive standardized biosafety education and training program for their student workers, tailored to safeguard human, animal, and environmental health.

2.2. INTRODUCTION

The intersection of our agriculture industry and academic institutions provides a unique environment for experiential learning, particularly in programs that involve hands-on work with dairy herds. However, these settings also present specific challenges in ensuring the safety and preparedness of student workers. This study focuses on the education and training of students working on academic dairy farms in critical biosafety areas, including personal and facility level biosecurity measures as well as zoonotic diseases. Biosafety in the farm environment refers to the protocols and preventative measures put in place to reduce the risk of disease transmission, ensuring the protection of livestock, farm workers, and public health. These topics are of paramount importance not only for the health of the students but also for the broader implications on animal and human health, as well as the sustainability of agricultural practices. The One Health approach, which emphasizes the interconnectedness of human, animal, and environmental health, is crucial for framing this research. In agricultural contexts such as academic dairy farms, this perspective is particularly relevant because zoonotic disease prevention and biosecurity practices have implications beyond the immediate farm environment (Gibbs, 2014). The One Health approach will be useful in drawing

connections across these topics and how they impact the health of livestock, farm workers, and the broader food and agricultural system.

Individuals working directly with farmed animals are at the highest risk of exposure to zoonotic diseases, which are diseases transmissible from animals to humans (Karesh et al., 2012). Zoonotic diseases pose significant health risks, particularly to those who are not adequately trained in biosafety protocols (CDC, 2024). In academic dairy farms, students come from varied educational and farming backgrounds, leading to varying levels of experience and knowledge. This variation can result in differing levels of preparedness when handling livestock, potentially increasing the risk of exposure to zoonotic diseases for those with less training or familiarity with biosecurity measures. This is supported in previous literature that states zoonotic diseases can be often exacerbated by insufficient training and awareness (Karesh et al., 2012). The associated potential gaps in training and education have implications not only for the health and safety of student workers but also for the broader goals of responsible agricultural practices and preserving the health of the herd. If these established programs and employment positions on academic farm facilities fail to address these gaps, they risk perpetuating deficiencies in protocols that could pose significant risks to public health and the associated dairy industry and agricultural systems. By addressing these challenges through the One Health lens, this study seeks to assess and improve the preparedness of student workers in managing risks that directly impact not only their own safety but also broader societal health outcomes.

Biosecurity measures on farms are a well-documented necessity to prevent the introduction and further spread of infectious diseases (FAO, 2010). Academic dairy

farms, often serving as places of both teaching and research, have added vulnerabilities due to the frequent movement of people and animals. This is exemplified in experiential learning programs, such as Cooperative for Real Education in Agricultural Management (CREAM) at the University of Vermont and the University of New Hampshire, that enroll student workers for designated time periods. These time periods may include a fall/spring semester, a summer semester, or a full calendar year. Aside from semi-frequent employment changes, academic institutions may utilize these herds for teaching beyond the experiential learning curriculums. Other undergraduate and graduate students using the facilities will increase foot traffic on the farm, as well as open hours for outside visitors. These kinds of movement increase the opportunities for risk of biosecurity breaches often not seen or experienced by commercial dairy farms with closed access and low employment turnover. Recent outbreaks, such as the highly pathogenic avian influenza (HPAI H5N1) outbreak observed in dairy cattle (WOAH 2024), underscore the urgent need for rigorous biosecurity protocols and education in these areas of animal agriculture. Emerging infectious diseases remain a significant challenge in the agriculture industry, further complicating the safe operation of dairy farms and posing variable challenges and risks to facilities run by academic institutions.

Despite the recognized importance of biosafety in the agricultural sector such as strong biosecurity protocols and zoonotic disease prevention, little is reported about the level of education and preparedness of student workers on academic institution dairy farms. The questions we want to address with this research project are 1) Are student workers receiving training/education in biosafety regarding biosecurity and zoonotic diseases? 2) How is this training/education being delivered to student workers? And 3)

How do these trainings/educational materials impact student action and attitude toward farm biosafety? Subsequently, using this information, we aim to identify gaps and opportunities for biosafety training and education of student workers in University dairy farm settings. By doing this we infer whether these academic institution-run dairy farms are adequately training and educating their student workers on these topics and underscore the importance of proper and effective biosafety training. It is hypothesized that biosafety knowledge and awareness will be higher among students who receive more overall biosafety training, have a higher academic level, possess more educational experience, and have more dairy farm work experience. Increased exposure to the topics of biosafety through the channels of structured training and education programs or practical work experience is expected to increase levels of information retention and application during their university farm employment.

2.3. MATERIALS AND METHODS

The project was approved by the University of Vermont's Institutional Review Board (IRB) in compliance with all human subject protection regulations (IRB protocol [STUDY00002971](#)).

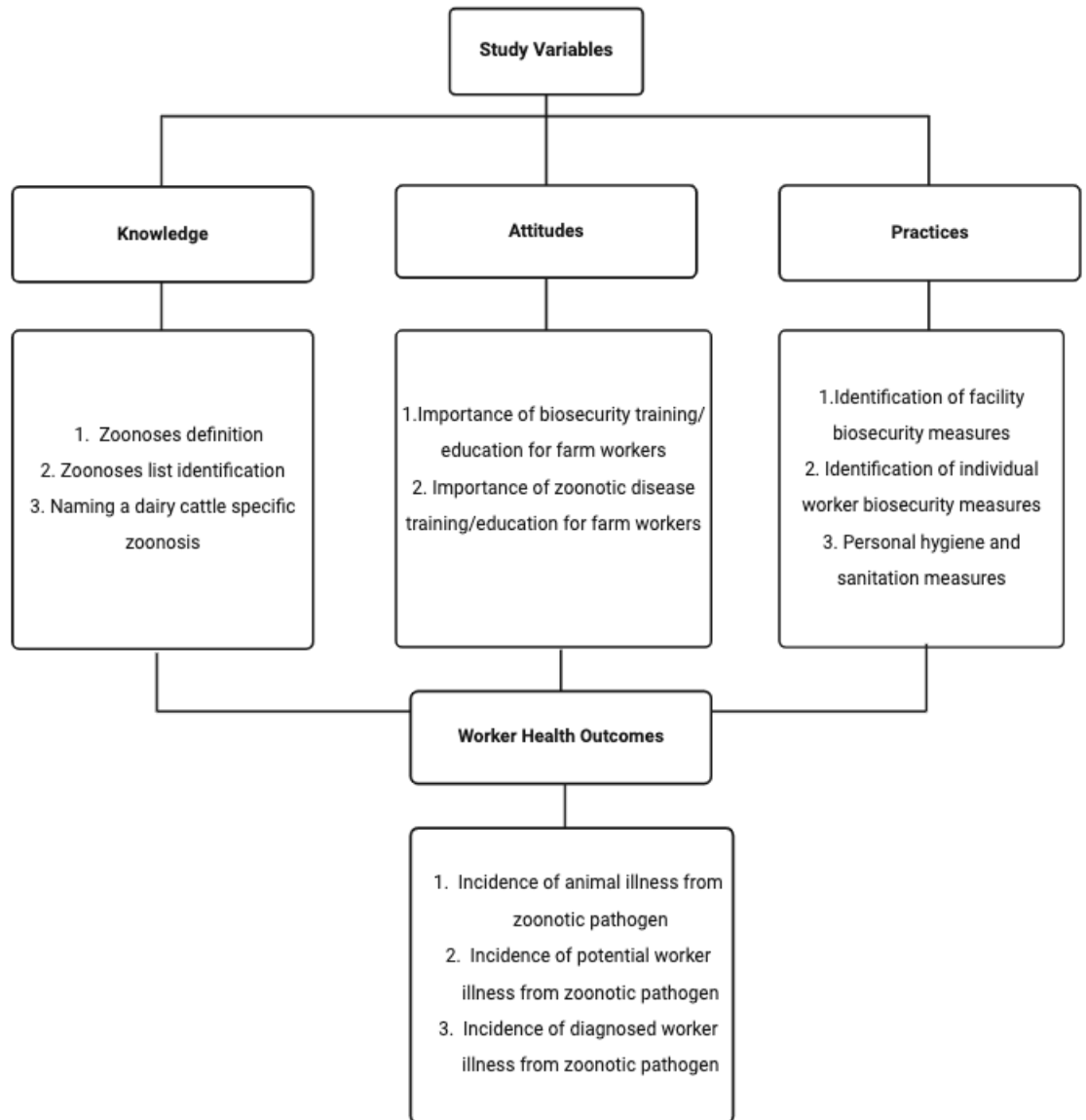
2.3.1. Study Design and Descriptive Variables

Our goal was to conduct a national survey of students employed by dairy farms or enrolled in dairy experiential learning programs run by higher educational institutions in the United States. The survey included a questionnaire administered via an online platform (Qualtrics, Provo, UT), and distributed between February and June of 2024 (supplemental data). Recruitment materials were distributed through emails sent to the

US Animal Science Department Chair Listserv and individual university departments, faculty, and staff. Without a master list of higher education institutions with dairy farms employing student workers, programs were identified from a Hoard's Dairymen web-site resource of 4-year colleges and institutions with dairy or animal science programs (Hoard's Dairymen, 2019), internet searches by the first author (MR), and word of mouth from other programs. Recruitment materials were distributed to 51 programs in 25 states (supplemental file 1) . The survey was meant to target student workers with a current or previous student status during their employment on academic institution-run dairy farms.

Information was collected anonymously via the survey responses and students were not asked any further identifiers such as name, email, or phone number. Students were asked to identify the academic institution they were associated with, but could opt out of supplying that information. The survey consisted of three sections including demographic information, biosecurity, and zoonotic disease/AMR questions. This paper is solely focusing on the sections involving demographic information, biosecurity, and zoonotic disease questions. The types of questions included were multiple choice, Likert scale, to open response. Student workers were asked to complete the survey to the best of their ability and could opt out of answering any of the questions. The variables assessed throughout this study are written out in Figure 2.1. below and adapted from Figure 1.1. in Chapter 1. These variables were used individually and often in combination with each other during further statistical analyses of the data.

Figure 2.1. Flow chart of variables assessed in this study within in each category of knowledge, attitudes, practices, and worker health outcomes



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Responses to few selected questions were graded using a scoring system to facilitate easier analysis of student knowledge, attitudes, or practices. The generated scores were used in the specific analysis of worker knowledge, attitudes, and practices of zoonotic diseases and biosecurity related questions.

2.3.2. Facility Protocols, Worker Behaviors, and Health Outcomes

To assess facility protocols in place at the respective dairy farms, respondents were asked to select biosecurity protocols in place at their farm facility from a list of 13 possible options (Appendix A, Question ___). Further, we assessed worker behaviors through asking respondents to select the use of personal hygiene measures while working their shifts at the farm facility from a list of 7 measures (Appendix A, Question ___). To assess further food related behaviors, we asked respondents about their eating habits on the farm premises and about hand-hygiene in relation to eating on the farm.

Health outcomes were measured based on how respondents answered questions relating to their health and health-related experiences while working on their university dairy farm. Respondents were then given an overall sickness score based on these responses, correlating to their likelihood of having contracted a zoonotic disease while working for their university dairy herd (Figure 2.1. Worker Health Outcome variables 1-3). This score is on a scale of 1-4 with 1 being the least likely to have gotten sick and 4 being the most likely to have gotten sick (or certain they did). A score of 1 indicates the student reported never having been diagnosed or ever presenting with any symptoms of a zoonotic disease during their employment. A score of 2 indicates the student indicated they had presented with symptoms of a zoonotic disease at one point in their employment. A score of 3 indicates students were formally diagnosed with a zoonotic disease rather than assumptions based off symptom presentation from score 2. A total score of 4 means the student has indicated they had multiple diagnoses or presentations of a zoonotic disease. Similarly, an animal sickness score was created to gauge incidents of sickness in cattle at the respective respondents' facility. This was scored 0-7 based on the

selection of seven different possible enteric diseases found in cattle. These two sickness scores were summed for various statistical analyses due to their collinearity.

2.3.3. Measuring Impact of Experience and Education on Knowledge

To assess the role of background experience, we created two 10-point summary scores: educational experience and prior work experience. The educational experience score was calculated as the sum of educational level (0-6; first year to fourth years of undergraduate education, levels 1 to 4, up to graduate level split between graduate students at level 5 and Doctor of Veterinary Medicine students at level 6), experience with IACUC training (0-1), biosecurity training given by the program (0-1), zoonotic disease training given by the program (0-1), and prior coursework in the given topics (0-1). The highest score possible was 10 points. The same type of 10-point summary score was done for prior work experience scores comprised of time working on their current farm (1-4), if they have worked on other farms (0-1), length of time with previous farm employment (0-3), currently working on more than one farm (0-1), and whether they grew up on a farm (0-1).

To further assess the education and knowledge of the respondents, they were asked to describe the definition of “zoonotic disease” to the best of their ability. These responses were graded on a scale of 0 to 4 by comparing the content of their answer to the World Health Organization definition, “Zoonoses are defined as those diseases and infections naturally transmitted between people and vertebrate animals (WHO, 2020),” . Subject responses were evaluated for the presence of key words: disease/infection/illness, transmission/spread/jump between, and humans/people AND animals/vertebrates/other

species. To receive a higher-end score of 3+, the respondent had to include the mention of both humans and other species/animals in their definition. The grading scale used was as follows:

- **Score of 0** provides a fully incorrect definition
 - Examples: “I don’t know” or “N/A”
- **Score of 1** includes 1 key word or factor but fails to include others
 - Example: “a disease.”
- **Score of 2** includes 2 key words/factors but they are used incorrectly and do not produce a correct or well-rounded definition
 - Examples: “a disease that affects animals.”
- **Score of 3** includes key words/ideas expressed by preexisting definition and conveys a complete and correct definition
 - Examples: “Disease that can be passed from animals to humans.”
- **Score of 4** goes above and beyond to create a definition- It is clear the respondent understands the transmission factors and gives clear use of scientific language or supplementary examples in their answer, indicating a higher level of thinking or knowledge.
 - Examples involving upper-level scientific language: “An infectious disease (bacteria, virus, parasite, etc.) which can be passed from animals to humans.”
 - OR
 - ” Zoonotic diseases are diseases that can transfer between species. example: ringworm can be found on both cows and people.”

All definition-based questions were graded by two separate individuals to ensure removal of any bias within the grading protocols. Respondents were not asked to give a definition of biosecurity, as their knowledge around that aspect of biosafety was gauged through other questions in that area. Students were further questioned about their knowledge of zoonotic diseases by being asked to identify zoonotic diseases among a list of pathogens. A grade for correctly identifying zoonotic diseases from a list of 12 options was calculated for each respondent. The original list of 13 diseases included Johne's disease, or *Mycobacterium avium* subspecies *paratuberculosis* infection. In final calculations, it was concluded that due to the potential controversial nature of the disease being considered "zoonotic" by some authors (Dow and Alvarez, 2022). Johne's was disregarded in the scoring process. Instead, the respondents were graded on the remaining 12 diseases and given a percent accuracy score out of 100 to be further used in data analysis. Respondents were additionally scored on their ability to identify a common pathogen in the farm environment that causes illness to cattle. The answers were scored 0 for incorrect and 1 for a correct answer. Finally, students were given a score of how many personal biosecurity hygiene measures they follow while working at their farm facility. There were up to 7 total hygiene measures for each respondent to choose from. The four scored response variables of defining "zoonotic disease," correctly identifying farm environment zoonoses from a list, correctly identifying zoonotic pathogen(s) of concern in dairy cattle and identifying personal hygiene/sanitation measures followed at work (Figure 2.1. Knowledge variables 1-3, Practice variable 2). These scores were out of 400 total points and each individual question was converted to a score out of 100 points.

2.3.4. Worker Training and Adequacy Perception

To assess the biosafety training of each respondent, a summary training score was tallied for everyone on a 3-point scale. This scale was based on the completion of IACUC, biosecurity, and zoonotic disease training for each survey respondent. These training variables were used to evaluate relationships with both knowledge and institutional biosecurity practices as well as student perceived adequacy of their biosafety training. Categorical variables of training delivery methods were also used in assessment and included online exclusive coursework, hybrid coursework, in person/ hands on coursework, and classroom didactic coursework. Assessment of worker perceived training adequacy was done on a scale from 1-3, with 1 being completely inadequate, 2 being somewhat adequate but needs improvement, and 3 being completely adequate with no improvements needed.

2.3.5. Data Management and Statistical Analysis

Following data collection in Qualtrics, the file was converted (.sav format) and exported to the IBM SPSS Statistics Program. The data was organized and analyzed primarily in IBM SPSS, but some further data manipulation and figure creation took place in Microsoft Excel. This data was analyzed with Pearson correlations, One-Way ANOVA tests, and multivariable linear regression models.

Pearson correlation analysis was used to explore relationships between variables including educational experience, prior work experience, training received, prior biosafety coursework, personal sickness scores, animal sickness scores, and total knowledge scores. Further correlations were used to examine associations between perceived training adequacy and overall worker training access.

One-way ANOVA statistical analysis was used to compare means across multiple groups. Specifically, mean zoonotic disease identification scores across the different respondent academic levels (1-6) were examined, as well as total knowledge scores across the varying training received groups (0-3). Post-hoc tests such as Games-Howell and Bonferroni were applied to those yielding significance between groups. Games-Howell is applied when homogeneity of variances is violated, and Bonferroni is applied when homogeneity of variances is assumed across the comparison groups. Statistical significance is measured by p values, where $p \leq 0.05$.

Linear regression models were run to pinpoint predictors for outcome variables. Specifically, multivariable models were constructed utilizing backward selection to eliminate non-significant predictors from the final models. These models were used to identify predictors of total knowledge scores, number of biosecurity protocols implemented at each institution, perceived training adequacy, and worker health outcomes. The first model for total knowledge score predictors utilized the variables of educational experience and prior work experience. The second model included these variables as well as added prior biosafety coursework and sum sickness scores. The model focusing on biosecurity protocols implemented at each facility included the variables of access to IACUC training, access to biosecurity training, and access to zoonotic disease training. For the model involving perceived training adequacy predictors, the variables assessed include access to the previously mentioned trainings and delivery methods of those trainings. Finally, the model assessing predictors of worker health outcomes focused on predictor variables of eating on the farm, facility animal

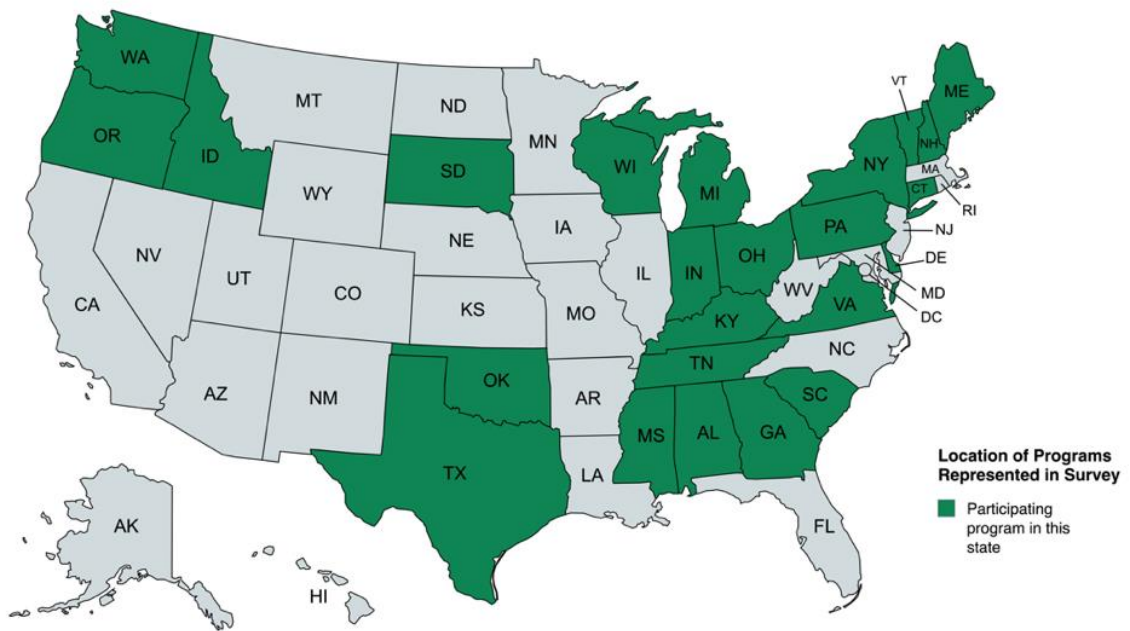
sickness levels, and hand hygiene when eating. Statistical significance was measured for these models by p values, where $p \leq .05$.

2.4. RESULTS

2.4.1. Descriptive Statistics

Responses were received from 126 students representing 27 academic institutions in 23 states (Figure 2.2; supplemental file 1) . All respondents identified the state of their institution, with X respondents identifying the specific institution in their state.

Figure 2.2.: US States where respondents identified the location of their academic institution dairy farm



Created with mapchart.net

Student farm worker respondents included undergraduate, graduate, and veterinary students. Eleven (8.9%) workers were first year undergraduate students, 16

(13%) were second year undergraduate students, 26 (21.2%) were third year undergraduate students, 42 (34.1%) were fourth year undergraduate students, 11(8.9%) were graduate level students, and 17 (13.8%) were students in Doctor of Veterinary Medicine (DVM) programs. 3 respondents omitted their academic level when taking the survey. Of these students, 74.3% of them reported having prior academic coursework outside of their farm employment programs with content related to biosafety topics such as zoonotic disease and biosecurity. Prior educational and prior work experiences varied, with the average prior work experience score being 4/10 and the average prior educational experience score being 6/10 across all respondents. Further, figures 2.3. and 2.4. show the distribution of overall educational experience and prior work experience within each academic level.

Figure 2.3. Distribution of Total Educational Experience within each respondent Academic Level

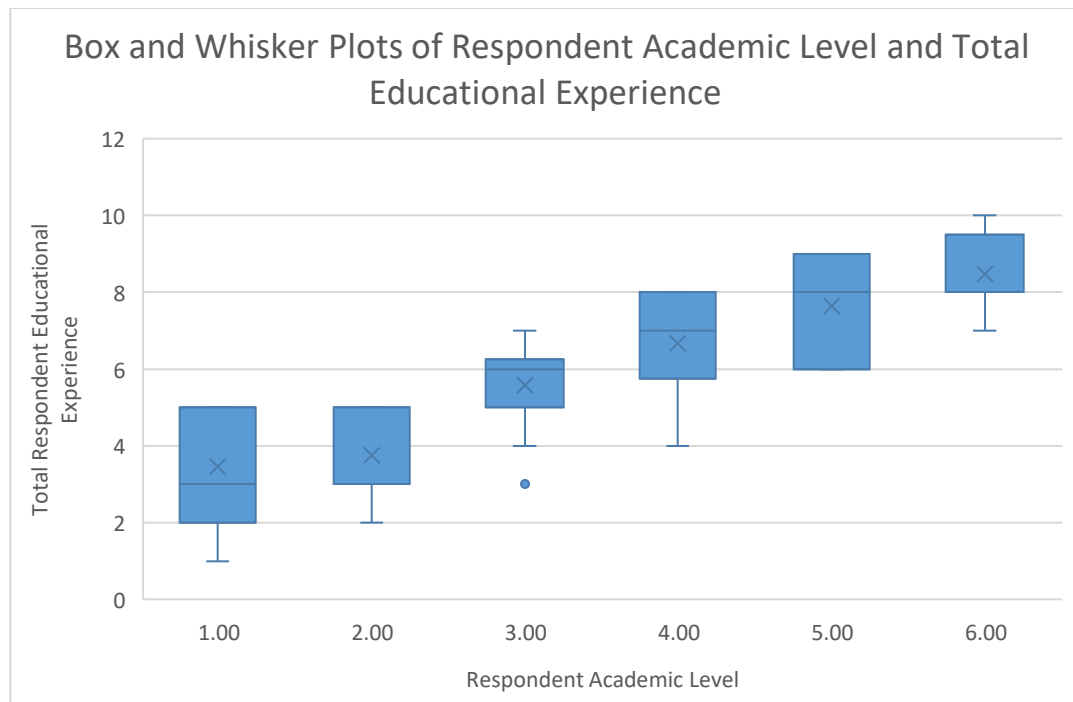
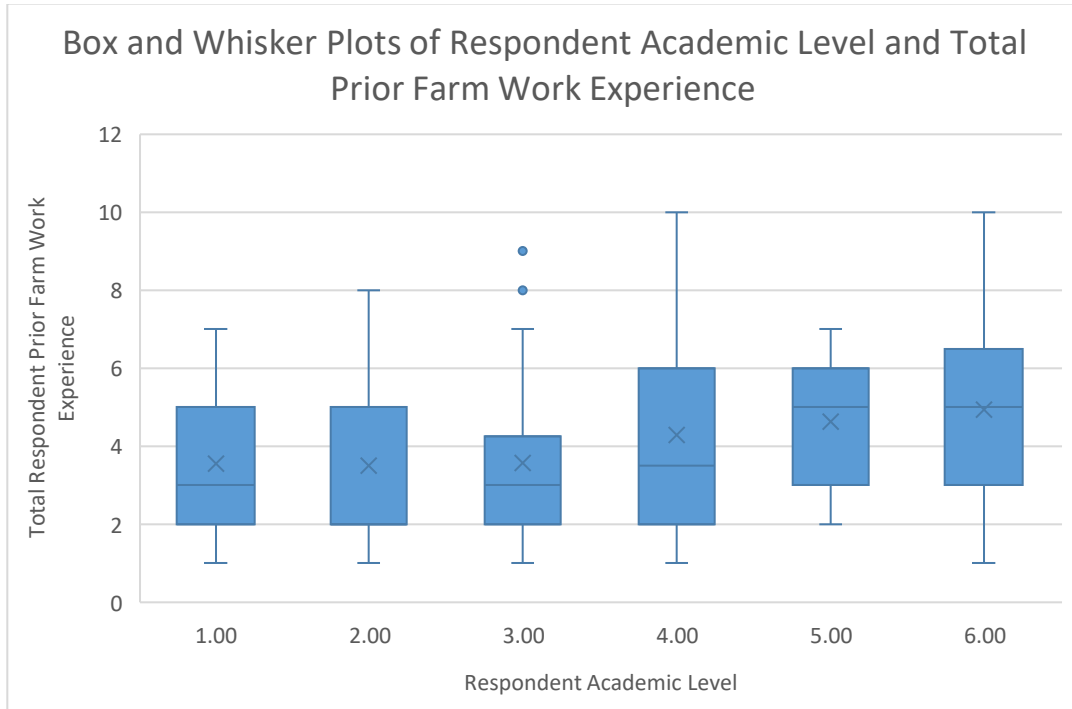
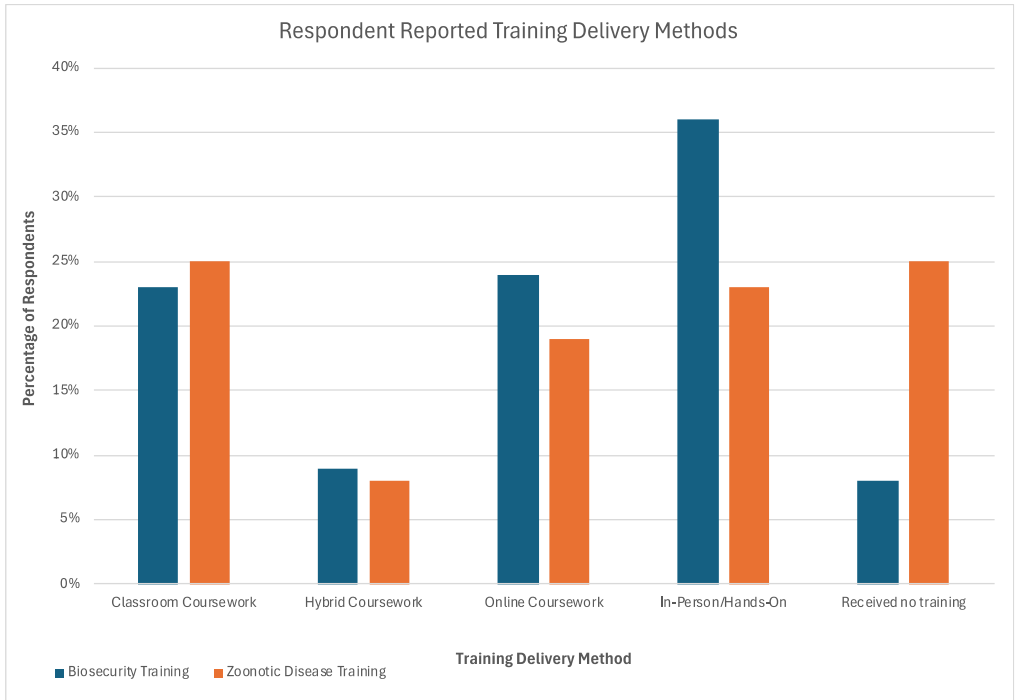


Figure 2.4. Distribution of Total Prior Farm Work Experience within each respondent Academic Level



Student farm worker biosafety training types were broken down into three categories: IACUC (Institutional Animal Care and Use Committee) training, biosecurity training, and zoonotic disease training. Assessment of training given to workers revealed 63.7% of respondents received IACUC training, 83.9% received biosecurity training, and 54.5% received zoonotic disease training. Training methods were mixed for the categories of zoonotic disease and biosecurity training, with IACUC training being solely online. The breakdown of training methods utilized in each category can be seen in Figure 2.5. below.

Figure 2.5.: Breakdown of Instructional Methods Utilized in Biosecurity and Zoonotic Disease Training



Respondents were asked to rate their overall biosafety training adequacy from 1-3, with 1 being completely inadequate, 2 being somewhat adequate but needs improvement, and 3 being completely adequate with no improvements needed. The rating breakdown among total respondents is as follows, 1: 22%, 2: 61%, 3: 17%. Further, respondents rated their perceived importance of the following issues from 0-10: educating student workers on the risks of zoonoses in agricultural settings and educating student workers on biosecurity measures and protocols in agricultural settings. The mean importance ratings biosafety education were as follows:

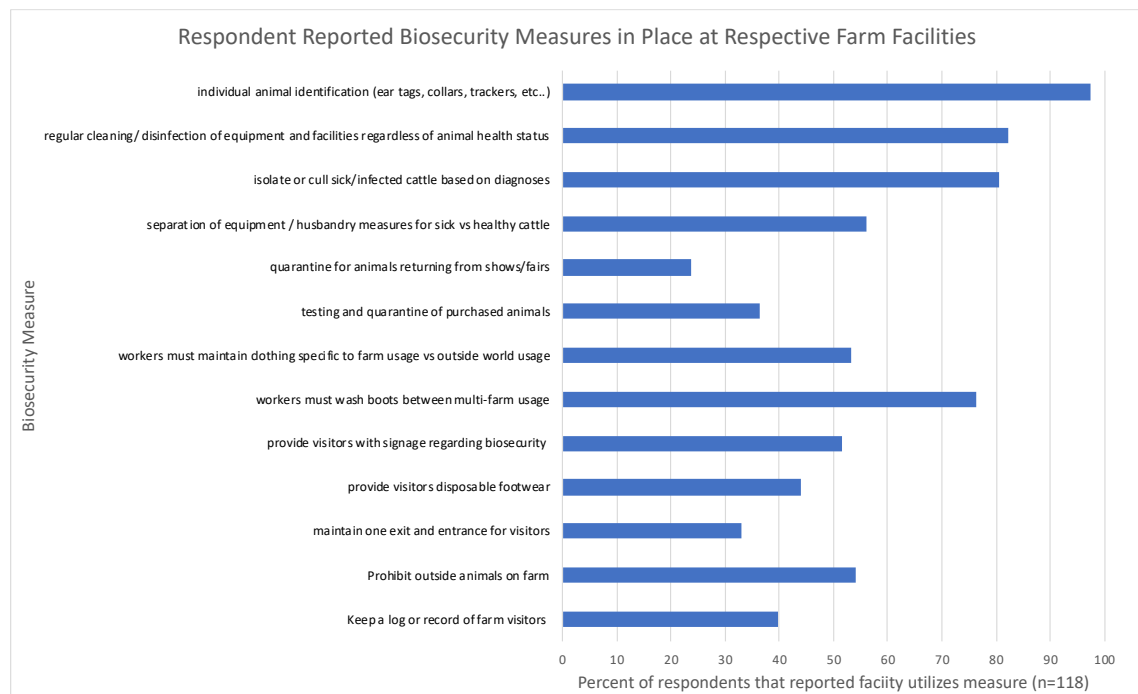
Zoonoses education for workers: Mean = 8.99 (SD = 1.41),

Biosecurity protocol education for workers= 9.32 (SD=1.19)

2.4.2. Facility Protocols, Worker Actions, and Health Outcomes

Student workers were asked to select all biosecurity measures used at their respective farm facilities from a list of 13 possible options. The average number of biosecurity protocols selected per respondent was 7.29 (SD = 2.79), indicating a moderately diverse implementation of safety practices across institutional farms. Figure 2.6 displays the frequency of each biosecurity measure. The most frequently reported measure was individual animal identification (n = 115), while the least reported was the use of quarantine protocols for animals returning from fairs or livestock shows (n = 28). A total of 118 responses were collected for this question.

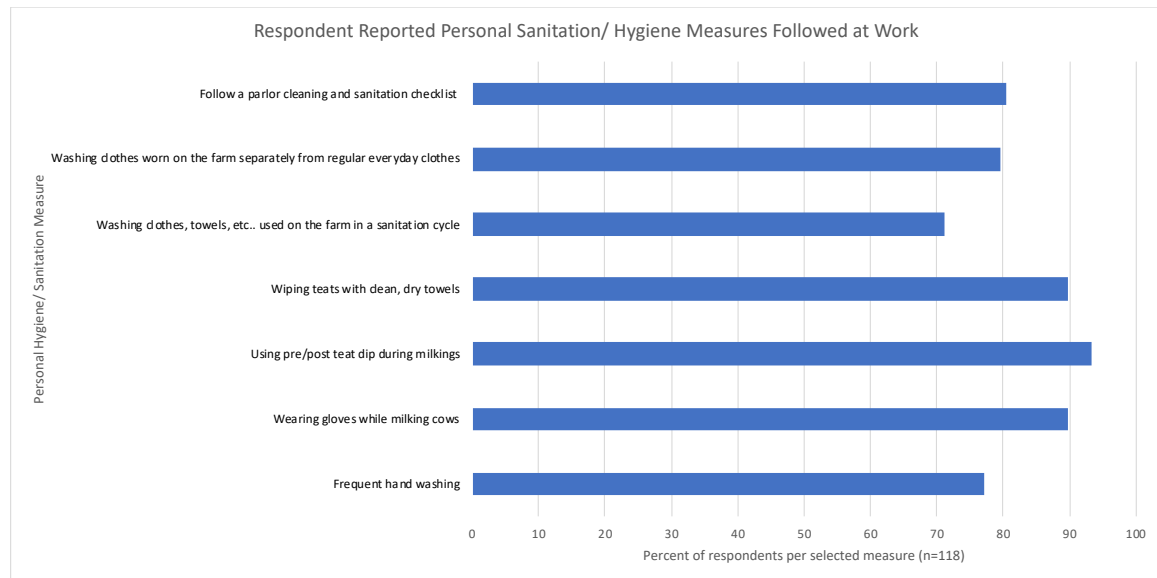
Figure 2.6.: Biosecurity Measures Chosen by Respondents that are Utilized at their Academic Farm Facility



Respondents were also asked to identify the personal hygiene and sanitation measures they practice while working. Options included seven distinct behaviors. Among the 118 respondents, the most frequently reported behavior was using pre- and post- teat dips during milking chores (n = 110), and the least reported was washing farm-specific

clothes and towels using a sanitation cycle (n = 84). Most respondents adopted at least five personal hygiene measures at work, and 43.6% reported practicing all seven listed behaviors (Figure 2.7).

Figure 2.7.: Respondent Reported Personal Hygiene and Sanitation Measures Used While Working at their Farm Facility



When asked about food-related behaviors, 55.9% of respondents (n = 66) reported that they eat on the farm premises, while 44.1% (n = 52) said they do not. Among those who reported eating on the farm, 68.11% (n = 47) said they always wash their hands before eating, whereas 31.88% (n = 22) admitted they do not always do so.

In terms of summary health outcomes, 100 respondents provided data on personal health experiences while working on their university dairy farms. Eighteen percent (n = 18) reported being diagnosed with a zoonotic disease during their employment, while 28% (n = 28) experienced symptoms consistent with zoonoses but were not formally diagnosed. Among an additional 60 respondents, 61.7% (n = 37) stated that they knew another student worker who had either been diagnosed with or presented symptoms of a zoonotic disease. Diagnoses reported in an open-response question included 20 total

cases, of which 50% were ringworm, 45% were Cryptosporidiosis, and 5% were Campylobacteriosis.

2.4.3. Impact of Experience and Education on Knowledge

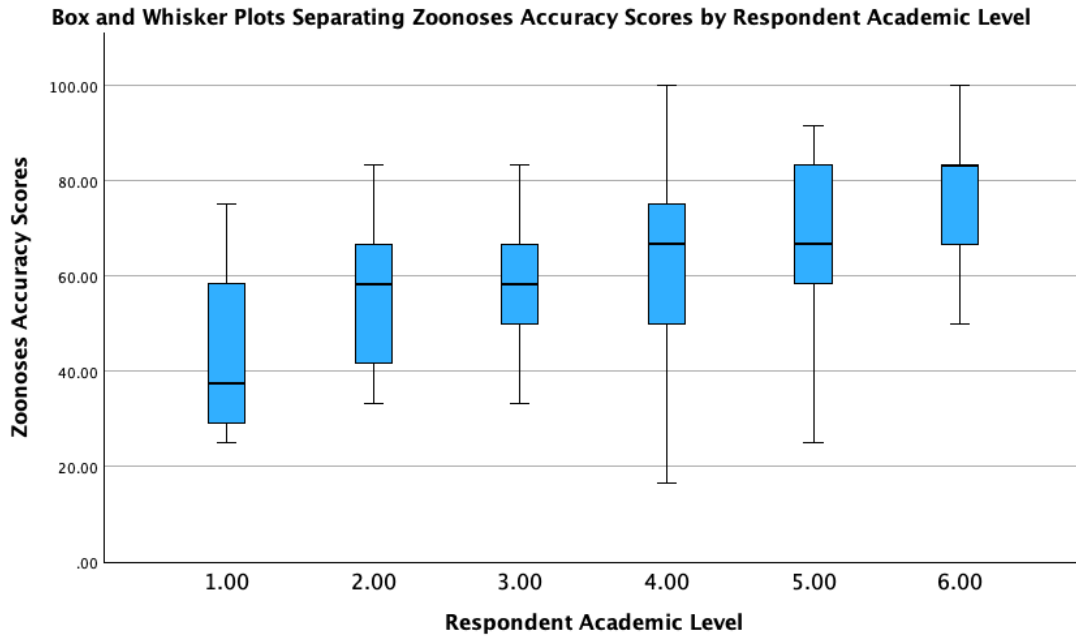
Student workers were evaluated on multiple knowledge metrics related to biosafety, and specifically zoonotic diseases and biosecurity practices. The mean percent accuracy for identifying zoonotic diseases was 62.97% (SD = 18.20), for defining zoonoses was 77.37% (SD = 20.33), for listing appropriate hygiene and sanitation practices at work was 83.76% (SD = 18.27), and for identifying a zoonotic pathogen relevant to dairy farms was 69.23% (SD = 46.41). These components were summed to yield a total knowledge score, with an average of 250.49 (SD = 96.38).

Pearson correlation analysis showed prior work experience had a weak positive correlation with educational experience ($r = .172$, $p = .057$), though this was not statistically significant. Total knowledge scores were weakly positively correlated with prior work experience ($r = .139$, $p = .135$) and positively correlated with educational experience ($r = .352$, $p < .001$). A significant correlation was also found between prior biosafety coursework taken by the respondent and total knowledge scores ($r = .273$, $p = .006$), implying that exposure to biosafety topics through formal coursework may improve knowledge retention. However, individual training programs given to respondents by their employment program did not reveal significant relationships with total knowledge scores.

A one-way ANOVA examining zoonotic disease identification accuracy across academic levels revealed a statistically significant effect ($F = 4.303$, $p = .001$), with higher academic levels associated with greater accuracy (Figure 2.8.). Post-hoc

Bonferroni tests confirmed significant differences between academic Levels 1 and 6 (mean difference = 34.58, $p = .007$), as well as between Levels 2 and 6 ($p = .027$), 3 and 6 ($p = .009$), and 4 and 6 ($p = .034$). There was no significant difference between Levels 5 and 6.

Figure 2.8.: Visualizing the comparison between zoonoses accuracy scores and respondent academic level



An additional one-way ANOVA examined differences in total knowledge scores across the four levels of biosafety training exposure (0 to 3) through IACUC training, biosecurity training, and zoonotic disease training. Level 0 is having no training, 1 is indicative of having completed one training program, 2 is indicative of having two training programs, and 3 is indicative of having completed all 3 observed programs. This analysis found a significant difference between groups ($F = 3.211$, $p = .026$). Due to the violation of the assumption of homogeneity of variances ($p < .001$), Games-Howell post-hoc testing was utilized. Group 3, the group with the most training exposure, had significantly higher knowledge scores than Group 1 (mean difference = 74.55, $p = .047$).

There were no respondents that fell into Group 0, therefore making a significant relationship with any other group impossible.

Two linear regression models were used to identify predictors of total knowledge scores. In the first model, prior work experience and educational experience were entered as predictors. The model was significant ($F = 7.960, p < .001$), accounting for 12.3% of variance in total knowledge scores ($R^2 = 0.123$). Only educational experience was a significant predictor ($p < .001, \beta = .328$), while prior work experience was not ($p = .419, \beta = .073$). A second model expanded the predictors to include sum sickness scores and prior biosafety coursework to the existing variables of prior work experience and educational experience. This model was significant ($F = 8.420, p < .001; R^2 = 0.260$) with higher explanatory power. Prior biosafety coursework ($p = .011, \beta = .256$) and sickness scores ($p < .001, \beta = .405$) emerged as significant predictors in this model.

2.4.4. Training Access and Perceived Adequacy

Pearson Correlation analysis was used to explore how access to training programs influences perceived training adequacy. It was revealed that perceived adequacy was significantly positively associated with access to IACUC training ($r = .299, p = .004$) and biosecurity training ($r = .231, p = .028$) from their employment program. No significant correlation was found between access to zoonotic disease training and perceived adequacy.

Linear regression models revealed significance when assessing predictors of respondent perceived training adequacy. The variables assessed in the model were access to IACUC, biosecurity, and zoonotic disease training. This model was significant ($F = 3.269, p = .025$) and explained 10.2% of the variance ($R^2 = 0.102$). IACUC training

emerged as the only significant predictor in this model ($p = .043$, $\beta = .239$). A second model was utilized to assess the different training delivery methods and perceived adequacy of training. When assessing the adequacy of zoonotic disease training, the predictor variables used in the model were classroom work, hybrid training, online training programs/collaborations, and in-person/hands on training. This model was statistically significant ($F = 3.163$, $p = .018$, $R^2 = 0.14$). Online programs (i.e. CITI Program) ($p = .027$, $\beta = .246$) and hands-on, in-person training ($p = .015$, $\beta = .291$) were the only significant predictors. Another model was applied to perceived adequacy of biosecurity training with the same variables but produced no significance.

2.4.5. Institutional Biosecurity Protocol Adoption

A linear regression model was used to assess how worker access to training programs influenced the number of biosecurity protocols in place at institutional dairy facilities. The model was statistically significant ($F = 20.002$, $p < .001$) and accounted for 38.2% of the variance in reported measures ($R^2 = 0.382$). Availability of IACUC training for student workers ($p < .001$, $\beta = .341$) and access to biosecurity training ($p < .001$, $\beta = .416$) were both significant predictors of the number of implemented biosecurity measures. Workers having access to zoonotic disease training did not reveal significance in predicting implementation of protocols at a respondent's institution.

2.4.6. Worker Health Outcomes and Predictors of Behavior

Pearson correlation analysis revealed higher student worker sickness scores were positively associated with eating on the farm ($r = .261$, $p = .009$) and with elevated levels of animal sickness ($r = .331$, $p < .001$). A strong negative correlation was found between

eating on the farm and hand washing before eating on the farm ($r = -.854$, $p < .001$), suggesting a significant gap in personal hygiene behavior such as frequent handwashing among those eating at the farm facility.

A final linear regression model examined potential predictors of worker health outcomes, specifically being diagnosed with a zoonoses during their employment. This model was statistically significant ($F = 4.001$, $p < .001$) and explained 23.5% of the variance in health outcomes ($R^2 = 0.235$). Eating on the farm ($p < .001$, $\beta = .640$), handwashing before eating ($p = .011$, $\beta = .450$), and facility animal sickness levels ($p = .004$, $\beta = .292$) were all significant predictors of respondents being diagnosed with a zoonotic disease during the time of their farm employment.

2.5. DISCUSSION

2.5.1. Significance and Further Implications

The significance of this study lies in its potential to inform better educational practices within agricultural programs at academic institutions, particularly those involved with dairy farm facilities that employ student workers or offer a dairy experiential learning program. By ensuring that students recognize the importance of biosafety, academic institutions can contribute to the development of a more resilient and informed agricultural workforce. Furthermore, the findings of this study could inform biosafety training priorities not only in academic settings but also in the broader agricultural industry. The significance and implications of this study are exemplified by the current novel highly pathogenic avian influenza (HPAI H5N1) outbreak in United States dairy cattle. This highlights the importance and need for comprehensive education and training on farms in biosafety, and proactive disease management in agricultural settings, rather than only reactive management in the face of an outbreak. These education and training programs could be pivotal in mitigating future disease emergence and spread throughout animal agricultural systems and inform employees on how to best protect themselves and livestock from occupational health and safety risks. This research aims to identify potential gaps and opportunities in biosafety education and training within academic dairy farming environments. By exploring the preparedness of student farm workers, we seek to contribute to safer and more effective practices in agricultural education and beyond.

2.5.2. Student Knowledge Development: Educational Experiences and Training Programs

Pearson correlations were used to provide insight into the explored relationships between training, knowledge, academics, and health outcomes among student workers at university run dairy farms. The analysis of respondent total knowledge scores revealed these scores were positively correlated with increased educational experiences. When assessed further, the educational experiences that emerged to be most impactful were academic level and prior coursework in biosafety topics. This is supported by prior research that names formal education and increased educational access as predictors of increased knowledge around various biosafety topics such as zoonotic disease and antimicrobial resistance (Subedi et al., 2025; Dhayal et al., 2023). Further, previous literature suggests that structured educational programs can significantly enhance knowledge of biosecurity among students in agriculture programs. Morris et al. (2024) showed the results of pre- and post- knowledge scores during an educational intervention on biosecurity training. The results showed increases in knowledge gain post-intervention in both a virtual delivery and in-person delivery method, highlighting the importance of diverse educational methods in preparing agricultural workers for health and safety precautions during their jobs (Morris et al., 2024).

Additionally, neither educational experiences nor total biosafety knowledge scores were associated with prior work experiences. An important consideration is that there was variation in work experience, independent of academic level or biosafety knowledge. This suggests that students working on university dairy herds receive limited knowledge of biosafety from prior work experiences, which included having previous

farm employment, having multi-farm employment at the time of their university farm employment, and growing up or currently living on a farm. The positive connections between educational experiences and total biosafety knowledge scores highlights the role that university farm employment or experiential education opportunities can play in cultivating understanding of biosafety concepts such as biosecurity measures and zoonotic disease risk mitigation. The findings regarding prior work experience suggest that these alone may not sufficiently contribute to biosafety knowledge but might be paired with comprehensive educational training for best possible outcomes. For example, current pedagogy suggests guiding undergraduate students in making connections between prior experience (e.g., in this case prior work on dairy farms) and current curricular content or learning objectives reinforces learning (Ragland et al., 2023).

The significant association and positive correlation between percent knowledge accuracy scores and academic level supports academic progression correlates with improved performance. Significant differences between levels 2 and 4, between levels 3 and 5, and between levels 1 and 6 highlights the variation in biosafety knowledge received by students at different academic levels. The results indicate a clear upward trend in accuracy scores as respondent academic level increases. Level 6 contained the least variation of scores, showing higher levels of consistency across respondents in that group. This result emphasizes the need for enhanced focus on these topics at earlier stages of education to bridge the revealed knowledge gap. It is clear through these results that students are obtaining this knowledge and information via their academic programs as they progress through their education, but it is unclear if they are receiving the necessary training and education from their university dairy herd employment programs.

Respondents' prior work experience not contributing to knowledge scores supports previous literature findings suggesting years of agricultural work experience is not necessarily an indicator of stronger knowledge of topics such as zoonoses and preventative practices (Cao Ba et al., 2020; Subedi et al., 2025). One limitation of these findings is we do not know the scope of each respondent's prior work experience, including the level and type of responsibilities these students might have had with prior agricultural operations.

Respondent educational experiences were revealed as strong predictors of higher total knowledge scores. This is supported by previous literature that has associated education level with KAP (knowledge, attitudes, and practices) of zoonoses and better food safety practices (Ahmed et al., 2025; Subedi et al., 2025). Further predictors of total knowledge scores emerged, including prior coursework in biosafety topics and sum sickness scores. Due to collinearity, respondent personal sickness scores were summed with animal sickness scores during linear regression models.

The strong association between respondent sum sickness scores and overall knowledge suggests workers may be influenced by their experiences with contracting a zoonotic disease. This may suggest a heightened sense of risk among those who have contracted a zoonotic disease and cause an increase in seeking more knowledge in biosafety. A study focused on behavioral changes due to COVID-19 risk perception founded similar results, as perceived harmfulness of infection was a major driver of preventative actions being taken (Quin et al., 2021). Therefore, we can speculate students who are seeking out more biosafety information and prevention practices may have a heightened perception of a zoonoses' harmfulness due to already having contracted one.

2.5.3. Access to Training Programs, Delivery Methods, and Perceived Gaps

The presence of biosecurity and IACUC training programs for workers at respondent facilities were positively correlated with student worker perceived training adequacy. This suggests the implementation of these programs for student workers have a positive impact on how they view their training adequacy from their university farm. Exposure to zoonotic disease training materials was not associated with perceived training adequacy, indicating that these training materials may not be positively impacting workers perception of training opportunities or breadth. This suggests there is an opportunity to bring new content and delivery for student workers to achieve comprehensive biosafety training. Further concerns are highlighted by the lack of tangible impact by training on perceived training adequacy and knowledge, suggesting that even with training programs in place, they might not be educating student workers on the right aspects of biosafety. Although, if 83% of total respondents classify their training as needing improvement or being completely inadequate, it is difficult to say whether this study has power to say what variables impact adequacy.

We further found that increased adoption of facility-level biosecurity measures was positively associated with the presence of IACUC, biosecurity, and zoonotic disease training programs. This supports the idea that universities who are providing their student workers with biosafety training are also implementing and possibly promoting facility-level practices. This broad idea of a “culture of biosecurity” is further supported by literature discussing the need to strengthen a culture in the life sciences that emphasizes biosafety, biosecurity, and responsible conduct (Perkins et al., 2019). However, our

findings of an association do not demonstrate causation, and it is equally plausible that university farms that emphasize biosafety protocols would also emphasize training opportunities. How and why facilities adopt certain protocols was not touched on in this study and should be further explored in future research. This information should be used to inform curriculum changes and suggests that perceptions of biosecurity training adequacy may come from other factors not utilized by the models within this study. Other unexamined factors may contribute to overall worker perceived training adequacy such as content, length of training, trainer adequacy, or personal worker experiences and should be explored in future projects.

2.5.4. Behaviors, Hygiene Practices, and Health Outcomes

The relationships explored during analyses revealed higher sickness scores positively correlated with eating on the farm and higher levels of animal sickness at those farm facilities. A negative relationship was also founded between eating on the farm and hand washing pre-eating, suggesting student workers are often eating at their farm without practicing hand hygiene first. These results support the established knowledge that poor hygiene practices and exposure to sick animals may lead to a higher risk of zoonotic disease transmission and contraction of a zoonotic disease (Mraz et al., 2023; Enbom et al., 2023). We also found that student workers who eat on the farm premises are less likely to wash their hands before they eat, increasing risk of zoonotic pathogen exposure and contraction of a zoonoses. These findings highlight the critical need for the promotion of personal hygiene and sanitation practices for university student farm

workers and reveal gaps between formal training and actual applied practice among respondents to this survey.

We can infer from this that workers engaging in these higher risk behaviors, such as eating without proper hand hygiene, are contracting zoonotic diseases more than their colleagues not engaging in these behaviors. We can speculate that due to the nature of reported pathogens having fecal-oral transmission, such as *Cryptosporidium*, that workers eating on the farm and not washing their hands are more likely to develop this kind of infection. This supports previous research that highlights the importance of handwashing and personal hygiene in the mitigation of zoonotic disease infections, especially those of fecal-oral transmission (Mraz et al., 2023; Enbom et al., 2023). Further, higher levels of animal sickness on the farm facility are associated with worse worker health outcomes, supporting the need for addressing both animal and human health issues with biosafety training and education. Overall, the results from this study and previous research emphasize the role of targeted educational programs and a collaborative One Health approach in enhancing both knowledge and practices of biosafety on farms (Ahmed et al., 2025). The findings suggest there are opportunities for future studies to test targeted interventions focusing on comprehensive academic coursework and high-quality targeted training initiatives to improve outcomes in worker zoonoses prevention, animal health outcomes, and biosecurity management.

2.6. CONCLUSION

2.6.1. Worker Health Outcomes and Behavioral Risks

These results suggest student workers may face significant exposure to zoonotic pathogens while working on university dairy herds. This may indicate that current biosafety training and worker hygiene practices and protocols are insufficient and need further addressing. Further concern regarding sufficiency stems from the amount of students (83%) who claim their university program's biosafety training needed significant improvement or was completely inadequate. From these results, it is clear the education and training practices need targeted improvement on addressing risky behaviors and personal worker hygiene measure adoption. Interestingly, while many respondents reported adopting five or more personal hygiene measures (61.5%), there were no statistically significant predictors among the variables in the dataset for why certain students adopted these behaviors more consistently than others. This lack of predictive factors suggests that future studies should focus on exploring qualitative insights into motivation and barriers to personal hygiene adherence in these settings.

2.6.2. Overall Educational Experience and Knowledge

Overall, it was revealed that prior biosafety coursework and academic level were influencers of knowledge. Prior research supports the ideas that education increases knowledge and positive practices, with Subedi et al. (2025) specifically reporting secondary education for farmers as a positive predictor of food safety and zoonotic disease prevention practices. Ahmed et al. (2025) also provides support for higher levels of education, and specifically science-based education, leading to more knowledge and

positive attitudes and practices related to zoonotic diseases. However, it is important that students of all academic levels are adequately prepared to address and tackle biosafety issues while working on their university farms and beyond. Students cited inconsistent training measures and protocols around all programs, supporting the need for more comprehensive education in all areas of biosafety for these dairy experiential learning programs. Though, the lack of relationship between work experience and knowledge scores shows that knowledge of biosafety does not come exclusively from experiential learning or work opportunities. This idea supports the need for a multifaceted training and educational program for student workers on university dairy farms, integrating both academic coursework and in-person, hands-on learning for an optimal and comprehensive program. All student workers at these facilities should be equipped with the tools to address issue in zoonotic disease prevention and mitigation biosecurity protocols. With these tools, they will be equipped to join the workforce as future professionals in veterinary medicine, public health, and agriculture and be able to safeguard human, animal, and environmental health.

2.6.3. HPAI H5N1 Outbreak Significance and Future Implications

The ongoing novel outbreak of highly pathogenic avian influenza (HPAI H5N1) in dairy cattle (Caserta et al., 2024) emphasizes the urgency in dairy education programs establishing strong and comprehensive biosafety training programs for their workers. As HPAI H5N1 continues to spread and begins to infect more mammals beyond cattle, it is crucial farms are establishing protocols at the facility and worker level to prepare for potential exposure events. The host-switch event that caused HPAI H5N1 to infect dairy cattle (as it never had before) heightens concern about the potential impact this outbreak

could have on both animal and human health (Caserta et al., 2024). This outbreak highlights the interconnectedness of animal, human, and environmental health as it pushes us to reevaluate how we have managed biosecurity on university farms. This study has overall revealed gaps in biosafety education and training among student dairy workers on university run farms, which, if unaddressed, could undermine control or mitigation efforts during an outbreak of HPAI H5N1.

The results of this study support the prioritization of renewed biosafety education and training for workers on university run dairy herds and the recent spillover of HPAI H5N1 into dairy cattle underscores the need for enhanced disease mitigation practices and vigilance in agricultural production systems. The correlations between increased knowledge and higher academic level highlight the gaps in knowledge for students who may be of lower academic standing or enrolled in a non-science based academic program. Ahmed et al. (2025) links a science-based educational background to higher levels of knowledge, attitudes, and practices around topics such as zoonoses. These noted gaps and lack of biosafety understanding among student workers support the need for curriculum reform to ensure student workers of all academic levels and areas are adequately prepared to address the issues of biosafety. Through tailoring the education and training programs of student workers on university dairy farms to understand the mechanisms of disease spillover, transmission, and exposure we can more effectively apply the necessary measures needed for prevention. Pinzon and Reyes of the University of Wisconsin suggest highlighting understanding each person's individual roles in implementing biosecurity and continued education is crucial to the success of human and animal disease prevention (Pinzon and Reyes). This supports the findings of this study that say work and

educational experiences do not necessarily produce safe and effective disease mitigation practices at work and will be important to emphasize within the new curriculum. Through addressing these curriculum reforms, the academic institutions that run these dairy herds can play a pivotal role in shaping a safer, more informed student agricultural work force and improving the health and wellbeing of all animals and humans at their facilities.

2.6.4. Challenges and Limitations

It is unknown how many of these academic dairy farm employment programs exist and how many students they employ at each farm facility. The outreach done to 50 universities underscores efforts to engage academic institutions with functional dairy herds that employ student workers. However, the limited response rates from both university contacts and student employees points to a limitation in data collection. Future initiatives should incorporate mechanisms for monitoring, evaluating engagement, and consider offering incentives to improve response rates and outreach success. Other speculated limitations include the length of the survey, as it should have been shortened to mitigate respondent burnout. This idea is supported by questions being left unanswered towards the end of the survey by respondents.

Overall, the sample population of student dairy workers on farms run by academic institutions is underrepresented in peer-reviewed literature and future studies should focus on broadening the examination of training and education initiatives, student worker health outcomes, and perceptions related to biosafety at these facilities. Future studies might benefit from the inclusion of focus group interviews with student workers that ask more in-depth questions regarding their education, training, and program satisfaction.

Focus group interviews would be a critical evaluation tool for assessing student perceptions and eliminate many of the limitations presented by a survey-exclusive study.

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CHAPTER 3: STUDENT FARM WORKER KNOWLEDGE AND ATTITUDES ON ANTIMICROBIAL RESISTANCE

3.1. ABSTRACT

Antimicrobial resistance (AMR) is an escalating global health crisis that can be found at the intersection of animal, human, and environmental health. Specifically antimicrobial usage (AMU) and AMR in agriculture has direct implications for our food systems and public health. This study examines the knowledge and attitudes of student farm workers employed at dairy farms affiliated with academic institutions in the United States and assesses their education and training programs regarding AMR.

The findings of this research indicate gaps in understanding and knowledge among student farm workers, and specifically students who fall in lower undergraduate education levels or those that have no prior coursework in biosafety topics such as zoonotic diseases, biosecurity, and AMR. Inconsistencies in the training and education programs across institutions further highlight this gap, with many students reporting minimal to no exposure to the topics of AMR and AMU through their institutional farm or experiential learning program.

Given the direct implications that AMR has on agricultural systems, as well as animal and human health, it is imperative that biosafety curriculums incorporate comprehensive AMR education. These changes to the education and training programs for student workers will foster a workforce knowledgeable on the importance of responsible antimicrobial usage and contribute to the mitigation of further AMR spread.

3.2. INTRODUCTION

Antimicrobial resistance (AMR) is a critical issue at the intersection of animal, human, and environmental health. According to the Centers for Disease Control and Prevention (CDC), at least 2.8 million antibiotic-resistant infections occur in the United States each year, resulting in over 35,000 deaths (CDC, 2019). As our global demand for animal products continues to rise, we subsequently see a rise in the use of antimicrobials in food animal systems (Van Boeckel et al., 2015). The continued misuse and overuse of antimicrobials in agriculture has contributed to the rise of resistant pathogens, which pose a threat to both livestock and human populations (WHO, 2015). The use of antibiotics in agriculture, particularly for growth promotion and disease prevention in healthy animals, contributes to the emergence of resistant bacteria, which can then transfer to humans through the food chain, direct contact, or environmental contamination (Van Boeckel et al., 2015). The World Health Organization cited increasing public and private sector investments in AMR through education, research, and stewardship programs as essential to mitigate this looming crisis (WHO). Farm workers occupy a vital position in this dynamic as they are in constant interaction with livestock through their employment positions. This regular contact increases the likelihood of encountering resistant organisms, either directly through animal handling or indirectly through contaminated surfaces, feed, or waste. Studies have shown that individuals working in animal farming environments are significantly more likely to develop antibiotic-resistant infections compared to the general population. For instance, a previous publication showed that U.S. poultry workers were 32 times more likely to carry antibiotic-resistant *E. coli* infections than those outside of the poultry industry (Price et al., 2007). Given these risks,

it is imperative to focus on the education and training of agricultural workers regarding AMR.

This study explores the dynamic between AMR and farm workers, focusing on student farm workers working on dairy farms at academic institutions in the United States and their knowledge and attitudes towards AMR. We assess the worker training and education programs put forth by these academic dairy farms in relation to their ability to inform their workers about AMR and its continued importance and significance within the agricultural industry. We hypothesize that students of a higher educational level and with more overall educational experience will have an increased understanding and attitude of importance towards AMR, at the cattle and human level. Education on the intricacies of AMR is essential for student farm workers, as they often will go on to join careers in agriculture, veterinary medicine, and public health. Equipping these individuals with the necessary knowledge of AMR plays a crucial role in mitigating the risk of AMR within the agricultural sector and global stage.

3.3. MATERIALS AND METHODS

The project was approved by the University of Vermont's Institutional Review Board (IRB) in compliance with all human subject protection regulations (IRB protocol [STUDY00002971](#)).

3.3.1. Study Design and Descriptive Variables

Our goal was to conduct a national survey of students employed by dairy farms or enrolled in a dairy experiential learning program run by a higher educational institution in the United States. The survey included a questionnaire administered via an online

platform (Qualtrics, Provo, UT), and distributed between February and June of 2024 (supplemental data). Recruitment materials were distributed through emails sent to the US Animal Science Department Chair Listserv, and individual university departments, faculty, and staff. Without a master list of higher education institutions with dairy farms employing student workers, programs were identified from a Hoard's Dairymen web-site resource of 4-year colleges and institutions with dairy or animal science programs (Hoard's Dairymen, 2019), internet searches conducted by the first author (MR), and word of mouth from other programs. Recruitment materials were distributed to 51 programs in 25 states (supplemental file 1). The survey was meant to target student workers with current or previous student status during their employment on academic institution-run dairy farms. It did not include responses from other farm personnel who fell outside of these parameters.

Information was collected anonymously via the survey responses and students were not asked any further identifiers such as name, email, or phone number. Students were asked to identify the academic institution they were associated with, but able to opt out of supplying that information. The survey consisted of three sections including demographic information, biosecurity, and zoonotic disease/AMR questions. This paper focuses on the sections involving demographic information and antimicrobial resistance questions. Questions ranged from multiple choice, Likert scale, to open response. Student workers were asked to complete the survey to the best of their ability and could opt out of answering any of the questions.

3.3.2. Scoring AMR Knowledge and Attitudes

A scoring system was used to assess knowledge and attitudes around AMR for responses to this survey. Survey respondents were asked to describe the definition of “antimicrobial resistance” to the best of their ability. These responses were graded utilizing a preexisting definition written by the World Health Organization, “occurs when bacteria, viruses, fungi and parasites no longer respond to antimicrobial medicines. As a result of drug resistance, antibiotics and other antimicrobial medicines become ineffective and infections become difficult or impossible to treat, increasing the risk of disease spread, severe illness, disability and death. AMR is a natural process that happens over time through genetic changes in pathogens. Its emergence and spread are accelerated by human activity, mainly the misuse and overuse of antimicrobials to treat, prevent or control infections in humans, animals and plants (WHO).” A rubric was applied to submitted definitions of antimicrobial resistance based on the inclusion of key words. Key words and phrases for this definition include organism, microbe, pathogen(s), bacteria, fungus, virus, parasite, resistance, drugs, medicine(s), treatment(s), decreased susceptibility, and reduced effectiveness. To score 3+ the definition must include the use of all antimicrobials and NOT just focus on antibiotics, which recognizes a respondent’s knowledge of the difference between an antibiotic and an antimicrobial. Even if the respondent gave a perfect definition of antibiotic resistance, their maximum score received would be a 2/4. The scoring was adapted as follows:

- **Score of 0** completely misunderstands the question or provides a fully incorrect definition

Examples: “I don’t know” or “N/A”

- **Score of 1** includes 1 key word or factor but negates others

Example: “diseases that become resistant.”

- **Score of 2** includes 2 key words/factors but shows they do not fully understand the true definition. They may only describe antibiotic resistance but not address the other microbes that experience antimicrobial resistance.

Examples: “Animals who have bacterial infections that are resistant to treatment”

OR

“Pathogens don't die from antimicrobial products”

- **Score of 3** includes key words/ideas expressed by preexisting definition and conveys a complete and correct definition.

Examples: “Microbes developing resistance to drugs normally used to treat them.”

- **Score of 4** goes above and beyond to create a definition- It is clear the respondent understands AMR and gives clear use of scientific language or supplementary examples in their answer, indicating a higher level of thinking or knowledge.

Examples involving upper-level scientific language and examples:

“My understanding of antimicrobial resistance is the ability of a pathogen to resist treatment with antimicrobial drugs such as antibiotics, antifungals, etc. for ex: MRSA. ”

Students were further scored on their ability to identify a pathogen in the farm environment with antimicrobial resistance potential. They were scored 0 for incorrect answer and 1 for correct answer. These two questions were converted to percentages out of 100 and used to build an antimicrobial resistance total knowledge score for each respondent. Total AMR knowledge scores are out of 200 points. Further, respondents were asked to rate the importance of AMR in relation to cattle illness on a Likert scale from 1-10, and additionally the same scale for AMR importance in relation to human illness. These Likert scale questions were used individually to create an AMR attitude of importance scores for further analyses.

According to their responses regarding health outcomes, respondents were given an overall sickness score correlating to their likelihood of having contracted a zoonotic disease while working for their university dairy herd. This score is on a scale of 1-4 with 1 being the least likely to have gotten sick and 4 being the most likely to have gotten sick (or certain they did). A score of 1 indicates the student reported never having been diagnosed or ever presenting with any symptoms of a zoonotic disease during their employment. A score of 2 indicates the student indicated they had presented with symptoms of a zoonotic disease at one point in their employment. A score of 3 indicates students were formally diagnosed with a zoonotic disease rather than assumptions based off symptom presentation from score 2. A total score of 4 means the student has indicated they had multiple diagnoses or presentations of a zoonotic disease. Similarly, an animal sickness score was created to gauge incidents of sickness in cattle at the respective respondents' facility. This was scored 0-7 based on the selection of seven different

possible enteric diseases found in cattle. These two sickness scores were summed for various statistical analyses due to their collinearity.

Written open response questions were collected to gauge student's overall impressions of their training that they received from their institutional dairy farm program. These responses were not used in statistical analysis and were assessed through reading and recording what students cited as being their lived experience with their employment program.

3.3.3. Data Management and Statistical Analysis

Following data collection in Qualtrics, the file was converted to .sav and exported to the IBM SPSS Statistics Program. The data was organized and analyzed primarily in IBM SPSS, but some further data manipulation and figure creation took place in Microsoft Excel. This data was analyzed with Pearson correlations, One-Way ANOVA tests, and independent t-tests.

Pearson correlation coefficients range from -1 to 1, with values closest to 1 indicating a strong positive correlation among variables. Values closest to -1 indicate a strong negative correlation among variables. Values around 0 suggest no or little correlation. Pearson correlations were used to explore relationships between variables. Relationships were assessed amongst the variables of AMR total knowledge scores and respondent academic level and respondent prior coursework. Further correlations were used at an attempt to identify a relationship between worker sickness scores and reported ratings of the importance of AMR in relation to both human and cattle illness.

Independent samples t-tests were utilized in this project in order to compare means across two groups. More specifically, we used the comparison groups of

respondents having prior coursework in the topics of biosafety or not as a means of comparing AMR knowledge scores. Significance for these tests is measured at a p value of $p \leq 0.05$.

ANOVA statistical analysis was used to compare means across multiple groups, in this case respondents having prior coursework in biosafety or not and respondent AMR knowledge. Post-hoc tests such as Games-Howell and Bonferroni were applied to those yielding significance between groups. Games-Howell is applied when homogeneity of variances is violated, and Bonferroni is applied when homogeneity of variances is assumed across the comparison groups. Statistical significance is measured by p values, where $p \leq 0.05$.

3.4. RESULTS

3.4.1. Descriptive Statistics

Responses were received from 126 students representing 27 academic institutions in 23 states (Figure 3.1; supplemental file 1).

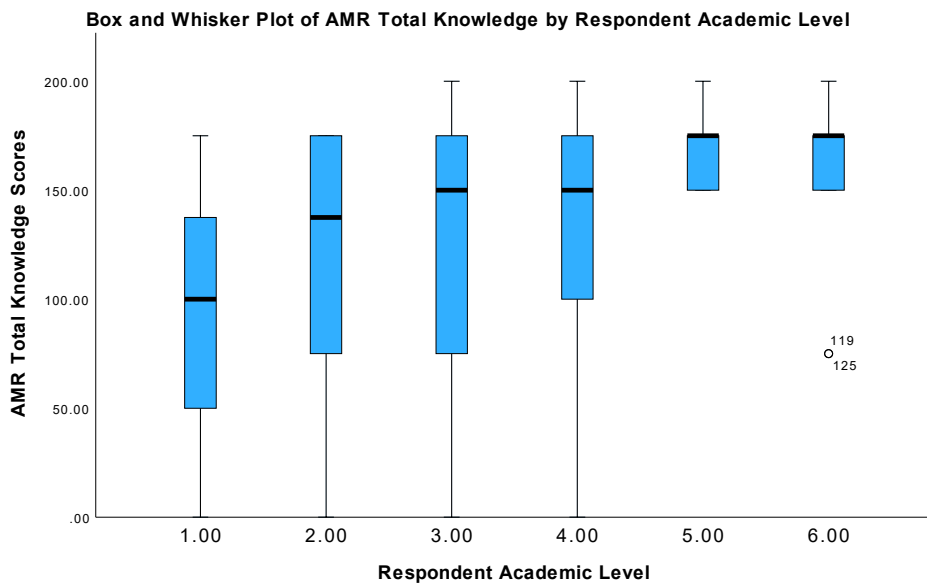
Figure 3.1.: US States where respondents identified the location of their academic institution dairy farm

context of the dairy farming environment and their employment position. The mean importance ratings for AMR were as follows:

- AMR in relation to cattle: Mean = 7.91 (SD = 2.17).
- AMR in relation to human health: Mean = 8.44 (SD = 1.78).

The mean scores for defining antimicrobial resistance were $M=60.0543$, $SD=29.89445$, and grades for identifying a pathogen in the farm environment with antimicrobial resistance potential were $M=77.6471$, $SD= 41.90826$. The variation in scores of total AMR knowledge across respondent academic level is shown below in Figure 3.2.

Figure 3.2.: Variation in AMR total knowledge scores across the different respondent academic levels



Academic levels 5 and 6 had the highest overall mean scores of $M= 167.8571$, $SD=18.8982$ and $M=161.5385$, $SD=41.6025$, respectively. Further the variation in scores for these respondents of upper academic level was the smallest, noted as having the most consistent scores when compared to the other academic levels.

Free response questions regarding AMR and its impact on agriculture revealed inconsistent results, with 28 students citing little to no knowledge of AMR or how it fits into their employment position on an academic dairy farm. These students cited recognizing its importance, but also noting the lack of attention to the topic within their farm program's training and education procedures. Examples of responses citing AMR specific deficiencies are as follows:

1. "I believe my training in college classes helped prepare me for this job, but the training for this job did not prepare me completely. I learned about AMR and diseases from classes and know they are important but otherwise, never mentioned."
2. "Student workers do not have to give antimicrobials, so it makes sense that we are not trained on how to adequately use them."
3. "My major is unrelated to agriculture, so I was not trained outside of my job through classwork. I was not aware of the existence of these topics until taking this survey, especially antibiotic resistance."
4. "I fully believe in the benefit and value of biosecurity, zoonotic disease, and antimicrobial resistance training. I see it as a way to make responsible decisions for humans, animals, and the environment. Antibiotics aren't used too frequently on the farm so there is less concern over antimicrobial resistance."

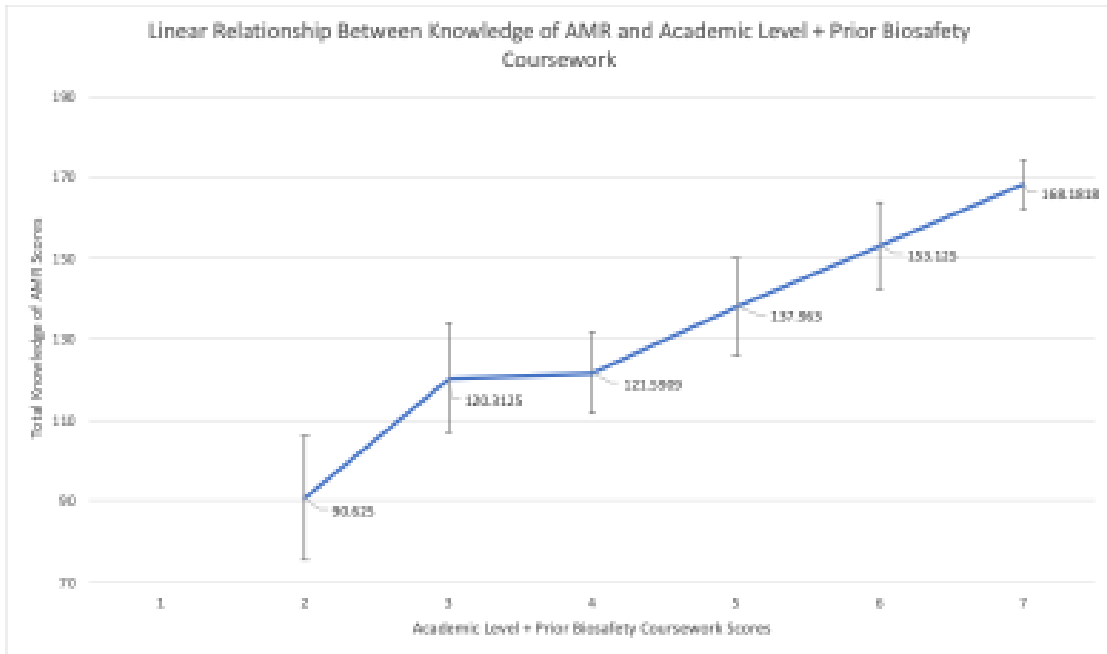
3.4.2. Impact of Education on AMR Knowledge and Attitude Scores

When assessing the possible relationship between AMR knowledge and academic level of a respondent, a positive and significant relationship was noted ($r=.285$, $p=.006$). A positive significant relationship was further found between AMR total knowledge scores and respondents having prior coursework in biosafety topics ($r=.368$, $p<.001$).

Following the assessment of the variation of AMR knowledge among respondents who have had prior coursework in biosafety topics through an independent t-test, a significant difference in scores was found between student respondents who did not have prior coursework ($M=94.3182$, $SD= 70.2597$) and those who did have prior coursework ($M=143.5714$, $SD=47.5268$), $t(27.302)= 3.074$, $p<.001$, two tailed. These results indicate students with noted prior coursework scored higher on AMR related knowledge questions than those who had no prior coursework.

Further analyses was done through a One-Way ANOVA was run between AMR-based questions and respondent education level and having taken previous coursework. AMR-based scored questions were summed, and respondent academic level and prior coursework variables were summed due to collinearity to run this ANOVA. The test was statistically significant ($F=2.433$, $p=.041$) and the homogeneity of variances was violated ($p=.008$). Games-Howell post-hoc tests were subsequently used to support the significance between higher academic levels and higher knowledge of AMR. Figure 3.3. visualizes this relationship below.

Figure 3. 3.: Linear Relationship from One-Way ANOVA Analysis Between AMR Knowledge and Academic Level and Previous Biosafety Coursework



Additionally, a negative and significant correlation was found between student sickness scores and individual respondent ratings of AMR importance in relation to human illness ($r=-.224$, $p=.025$). This suggests students who are the most likely to have gotten sick (and did) were less likely to rate AMR highly in relation to human illness.

3.5. DISCUSSION

3.5.1. Relationship Between AMR Knowledge and Education

When examining overall AMR knowledge, there were overarching positive correlations between this knowledge and respondent academic level, as well as prior coursework in the topics of biosafety including biosecurity, zoonotic diseases, and antimicrobial resistance. These findings are supported by previous literature that links access to education with farmer respondent understanding of antibiotics and AMR

(Dhayal et al., 2025). Dhayal emphasizes the need to increase farmer health literacy and responsible antibiotic use within agriculture communities. Further literature ties the association of higher education levels with correct knowledge regarding AMR and antimicrobial usage (AMU) (Hirwa et al., 2024). These relationships found between academic level and prior coursework support the need for an opportunity to introduce AMR and AMU concepts earlier in education and training programs for student farm workers. Introducing AMR and AMU at an earlier time in a student's education allows for the creation of strong foundational base in these areas for student workers to continue cultivating and building upon further into their academic journey. It would ensure these students are building a consistent and strong foundation in the areas of AMR and AMU, and hopefully working towards closing the gaps in knowledge revealed by this research.

When assessing the open written responses regarding AMR, multiple students cited never having heard of the topic or its implications in agriculture. Though, it is clear students in this sample population are being introduced to AMR as they progress in their academic journeys, but the gaps revealed by this project make it uncertain if students are receiving adequate knowledge on AMR and how it relates to their farm employment. Further evidence revealed by data analysis suggests student workers may not be making the connections between the importance of AMR and both cattle and human illness. This is exemplified by the negative Pearson correlation between the ratings of AMR importance in relation to human illness and respondent sickness scores. This relationship suggests students who are most likely to have become infected with a zoonoses during their employment are less likely to rate AMR importance highly in relation to human

illness. This correlation does not imply causation, as other factors such as extent of job duties, education, and other previous experiences with AMR could be influencing both the perception of AMR importance and exposure to zoonotic diseases.

Though our survey data did not reveal a relationship between education levels and higher perceived importance of AMR, this idea has been the focus of previous literature, with Hirwa et al. (2024) citing increased positive attitudes and practices related to AMR and Almutairi et al. (2024) showing increased perception scores relative to AMR importance following a pre- and post- educational intervention for students. Further literature has linked greater education through “class classification” (akin to our academic level classification) with perception of AMR importance (Da Silva Carvalho, 2024). Da Silva Carvalho (2024) further compares pre-health and agriculture undergraduate students, citing the need for further assessment on knowledge and attitudes of agriculture students in this area (Da Silva Carvalho, 2024). While this study makes progress on these suggestions, we suggest even further evaluation into the knowledge and perceptions of AMR and AMU in relation to student farm workers.

One limitation of this study involves the issue of autonomy over delegated farm work tasks given to these student workers. A few students cited their lack of AMR knowledge being caused by their lack of being involved in the administration and handling of any antimicrobials on their farm, insinuating they might have more knowledge if they had experience with AMU. For this reason, we cannot generalize that every student farm worker on an institutional dairy herd in the United States has handling or administrative experience with antimicrobials. Further, this poses the question of whether students should still be required to understand AMR and responsible AMU even

if they are not encountering them during their employment. We argue, yes, that the topics of AMR and AMU are crucial to the overall knowledge that a student farm worker should be required to know. This is supported by the idea that even if farm workers are not responsible for the administration of antimicrobials, their understanding of AMR is still vital in preventing its further dissemination within the agriculture industry. Previous literature and the ideas discussed in this research further highlight this importance, as continued education of farm owners and workers on AMR and AMU increase their awareness and often motivate them to adopt more responsible practices and reduce the risk of AMR spread throughout these occupational agricultural settings (Kallu et al., 2024).

Tang et al. (2017) reinforces this by emphasizing that policies to reduce antibiotic use are more effective when paired with education and training for all stakeholders in the food production chain, ensuring informed adoption of antimicrobial stewardship practices. Similarly, McEwen and Collignon (2018) stress that addressing AMR in agriculture requires a "whole system" approach that includes training all personnel in basic principles of AMU and AMR, even those not directly prescribing or administering drugs. Programs like those outlined by the WHO's Global Action Plan on Antimicrobial Resistance also emphasize the need for education at all levels of agricultural operations (WHO, 2015). Therefore, including student farm workers in this education ensures consistency in antimicrobial stewardship practices and knowledge while furthering the goals of the One Health initiative.

3.6. CONCLUSION

The overall observed gaps and lack of understanding among student workers of AMR emphasizes the need for comprehensive AMR education in these dairy employment programs. X students indicated within their definition of AMR that only bacteria and antibiotics were of concern. This poses concern that these students do not understand AMR as being different from antibiotic resistance and did not receive a comprehensive foundation of AMR knowledge. Specifically, our findings support the need for introduction to AMR for students of all academic levels and previous coursework history. We propose it is important for all student farm workers to understand and know about AMR and responsible AMU through their employment programs, regardless of their academic status. This project underscores the future opportunities to include AMR and AMU concepts and their significance to the animal agricultural industry in student worker training and educational materials as early in their employment as possible. The incorporation of AMR into comprehensive biosafety training and education for student farm workers at academic facilities will place these academic institutions in a unique place to foster responsible AMU and promote practices that mitigate the risks of AMR spread.

Without the effort to continue the spread of AMR knowledge and responsible practices, continued misuse and overuse of antimicrobials may facilitate in the acceleration of resistance spread, putting animal and human lives at risk. This integration of AMR and AMU into education and training programs is additionally important as many of these individuals may transition into more permanent and professional roles within the agricultural industries. This advanced knowledge of AMR will equip students

to enhance their careers and aid in the safeguarding of our agricultural sectors. Their comprehensive understanding of AMR will play a role in shaping the future of agriculture and reinforce the importance of the field's continued investment in AMR education.

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CHAPTER 4: LOOKING AT THE FUTURE: WHY BIOSAFETY EDUCATION FOR STUDENT DAIRY WORKERS IS IMPERATIVE FOR SAFEGUARDING PUBLIC HEALTH AND OUR FOOD SUPPLY

4.1. ABSTRACT

Biosafety education and training are a critical component of creating the most knowledgeable and prepared agricultural workforce, particularly in academic dairy farm settings where the workers are students who play major roles in the daily operations of the facilities. The significance of biosafety education is further emphasized by the novel emergence of highly pathogenic avian influenza (HPAI H5N1) in United States dairy cattle, as it highlights the critical need for increased attention to topics of biosafety such as zoonotic disease emergence and spread, as well as biosecurity mitigation procedures.

The findings of previous research reported in Chapters 2 and 3 indicate that training and education programs currently in place are inconsistent and often inadequate at impacting student knowledge and attitudes towards biosafety topics. Given the increased threats posed by the current HPAI H5N1 outbreak in dairy cattle, implementing standardized, comprehensive biosafety education and training for workers should be prioritized. By investing in proactive education and training for student workers, these institutional facilities can serve as a model for the wider agricultural industry and set a standard of prioritizing biosafety and a resilient workforce.

4.2. INTRODUCTION

Biosafety education and training are fundamental components of managing agricultural industry facilities, especially university dairy farms that employ student

workers. These educational protocols not only ensure the safety and well-being of workers and livestock but also play a crucial role in protecting the broader food system the facilities supply. Proper biosafety protocols serve as a means of safeguarding our agricultural food systems against the introduction and spread of infectious diseases. Preventing new disease introduction and further disease spread within a system can aid in mitigating significant losses economically, as well as prevent compromising public health and disrupting overall food supply chains. The recent first-of-its-kind outbreak of highly pathogenic avian influenza (HPAI H5N1) in United States dairy cattle has exposed critical vulnerabilities within our animal agricultural systems and exemplified the importance of comprehensive biosafety education and training for farm workers. The novel transmission of this virus to cattle demonstrates how infectious diseases, particularly zoonoses, continue evolving and present new threats to livestock and human populations. This development underscores the necessity for comprehensive biosafety training programs that can effectively prepare workers to identify, prevent, and respond to potential biosecurity breaches. The study found in Chapter 2 of this thesis highlights the gaps found in the biosafety education and training programs for student workers on dairy farm facilities run by an academic institution. Without workers who have a strong foundation in biosafety, farms risk becoming focal points for disease transmission and emergence, exacerbating the challenges faced by the dairy industry and all animal agriculture.

This chapter examines the significance of biosafety education in academic agricultural settings, with particular attention to the implications of the HPAI H5N1 outbreak. It also evaluates the findings from Chapters 2 and 3, which highlight existing

gaps in training resources for student farm workers at university dairy farms focused on the topics of zoonotic diseases, biosecurity, and antimicrobial resistance (AMR). These deficiencies in biosafety education pose significant risks to livestock health and production and human health, as zoonotic diseases increasingly demonstrate new host adaptations and transmission abilities. As emerging pathogens threaten both agricultural sustainability and public health, ensuring that student workers receive proper education and training in biosafety is more critical than ever. Academic institutions must address these training gaps to better equip future agricultural professionals with the knowledge and skills needed to uphold biosecurity standards, reduce the risk of disease outbreaks, and promote resilience in the agricultural industry.

4.3. BIOSAFETY EDUCATION AND TRAINING: REVEALED GAPS AND SUGGESTIONS

Biosafety in the farm environment refers to the protocols and preventative measures put in place to reduce the risk of disease transmission, ensuring the protection of livestock, farm workers, and public health. In academic dairy farm settings, biosafety education is crucial in ensuring student worker have the necessary skills and knowledge to implement these protocols effectively. Many of these procedures are known as biosecurity protocols or, according to Louisiana State University, strategic approach to analyzing and managing risks to human health, animal and plant life and the associated risks to the environment (LSU, 2024). The knowledge and understanding gaps of biosecurity measure adoption and inconsistency revealed in previous research discussed in Chapter 2 and Morris, Ehlers, and Shutske (2023) support the need for tailored

biosecurity resources and protocols for smaller-scale farming operations, as many dairy farms run by academic institutions fall into the category of having under 200 milking cattle. Morris, Ehlers, and Shutske (2023) emphasizes the need for more in depth and focused biosecurity training, as farmers and our systems are facing a greater range of biosecurity threats than ever before. When looking exclusively at the findings from Chapter 2, it is clear no comprehensive biosafety education and training exists across these programs offered at academic institutional farms, revealing the crucial need for its implementation.

It is demonstrated in Chapters 2 and 3 that training across the various dairy farm programs is inconsistent, and questionable whether it is impacting how student workers respond to questions around biosafety topics such as zoonotic disease, biosecurity, and antimicrobial resistance (AMR). Training from their respective institutional run dairy farm had no effect on student knowledge surrounding the topics, with academic level (undergraduate, graduate, doctorate) and prior coursework in related topics having the most impact on student knowledge and responses. This clearly demonstrates that even those receiving training and education from their program, may not be receiving training substantial enough to adequately educate them on the importance of biosafety in the dairy farm environment. Addressing the inconsistency of existing training should be the first step to creating a fully comprehensive biosafety education and training plan for these student workers.

Student workers overall supported the overhaul of existing biosafety education and training programs at their respective facilities, with 83% of total respondents citing their program needs improvement or was totally inadequate. Additionally, no relationship

was found to exist between knowledge or attitudes around biosafety and the training the student workers received. This suggests students are getting this vital information from other resources, or not at all, with respondent academic level and having prior biosafety related coursework emerging as possible factors. The broader implications will have an impact on the regional and national dairy industry, as many of these university farms are known to be supplying their byproducts to a wider market. Without workers who have proper education and training in biosafety, academic dairy farms become at a greater susceptibility for emerging infectious diseases, many of which are zoonotic and pose a threat to both workers and livestock at the facility. Even with the current findings of zoonotic disease transmission to workers being low, the current novel HPAI H5N1 outbreak in United States dairy cattle highlights the unpredictability of many emerging infectious zoonotic diseases. Proactive biosecurity investments rather than reacting to an outbreak is suggested by Bucini et al. (2023) and suggests delayed interventions may not successfully prevent a widespread epidemic.

Echoing Morris, Ehlers, and Shutske (2023), the threats to our agricultural systems from a biosecurity standpoint are at a high point, so the time for academic dairy farms to invest in comprehensive biosafety education and training for workers is now. By ensuring that students receive a robust biosafety education with content covering proper biosecurity measures and consistent protocol adoption, zoonotic diseases and transmission pathways, and the foundations of antimicrobial resistance and how agriculture plays a role in its mitigation, dairy farms at academic institutions can serve as models for the broader agricultural industry, promoting better disease prevention and overall preparedness strategies.

4.4. HPAI: WHAT'S NEXT?

The novel emergence of highly pathogenic avian influenza (HPAI H5N1) in dairy cattle should mark a pivotal moment for biosafety in agriculture, and especially in the dairy industry. Previous literature shows us that HPAI H5N1 was noted as a pathogen of concern, as it began to widely infect wild birds, poultry, and domestic birds before it extended beyond avian populations to other mammals, heightening its public health threat potential (Charostad et al., 2023). Following this, we saw the HPAI H5N1 persist, evolve, and eventually cross species barriers in a host-switch adaptation event to dairy cattle (Caserta et al., 2024). Now, the continued dissemination of this outbreak presents an opportunity and amplifies the necessity for a more proactive approach to biosafety across all levels of animal agriculture. While current human infection cases remain low, the previously noted behavior and transmission adaptations the virus has taken on should heighten our risk perception for the possibility of future cow-human and, further, human-human transmission. For this reason, we must ensure comprehensive biosafety education and training programs are in place for students working at these institutional dairy herds.

This outbreak serves as a reminder of the importance of investment in worker training and investment. This investment looks like a comprehensive biosafety education and training program for students that focuses on equipping student workers with the skills and knowledge to identify and mitigate threats of disease spread. As these workers interact with the livestock, it is important they can recognize and report signs of illness among the animals and adhere to the necessary reporting procedures. Further, including

lessons on outbreak cases, such as HPAI, in training and education programs would aid in worker resilience and response in the case of an active outbreak scenario.

4.5. CONCLUSION

This chapter highlighted the gaps in existing biosafety education programs, with the resulting data revealing current efforts have had little to no measurable impact on student worker knowledge and attitudes around biosafety. Rather, academic level of a respondent or having prior coursework in the areas of biosafety such as zoonotic disease, biosecurity, and antimicrobial resistance emerged as impactful. These findings reinforce the need for a more standardized, comprehensive biosafety curriculum for these student farm workers that is integrated into their employment. University farm employment programs such as these have a unique opportunity to bridge the gap between academics and agriculture, adopting a proactive approach to biosafety that prioritizes the prevention of disease emergence and spread rather than only reaction to an outbreak.

The implications of the HPAI H5N1 outbreak in United States dairy cattle should serve as a catalyst for action regarding biosafety on academic dairy farms, and within wider agriculture sectors. Through the investment in training and education now, we can work to safeguard our farm workers, livestock, and overarching public health from current and future outbreaks. Action now means protection from a future threat that could have been prevented through proactive education and training for student farm workers on institutional dairy herds.

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APPENDIX A: SURVEY MATERIALS

These materials are the survey questions utilized in the research project(s) noted in Chapters 2 and 3. These questions have been exported directly from Qualtrics, the platform utilized in the making of the survey.

Start of Block: Demographics

Q1 What is the name of the University Program that you are associated with?

Q2 What year are you currently in for your degree program?

- First Year (1)
- Second Year (2)
- Third Year (3)
- Fourth Year (4)
- Graduate Student (5)
- Other (6)

Q3 How long have you worked on **this** farm or have been in **this** program?

- Less than 6 months (1)
- 6 months to 1 year (2)
- 1 to 2 years (3)
- More than 2 years (4)

Q4 Do you have dairy farming experience prior to working on your University dairy herd?

- Yes, I grew up on a farm (1)
 - Yes, I have been employed on other farms (2)
 - No, this is my first dairy farming experience (3)
-

Q5 If you grew up on a farm, how long did you live there?

- Less than 2 years (1)
 - 2-5 years (2)
 - 5+ years (3)
 - I did not grow up on a farm (4)
-

Q6 If you have previous farm work experience, how long have you worked in this field?

- Less than 2 years (1)
 - 2-5 years (2)
 - 5+ years (3)
 - I have no previous farm work experience (4)
-

Q7 Do you currently work on more than one farm?

- No (1)
 - Yes (2)
-

Q8 How many students work on your University Dairy Herd?

- 0-15 (1)
 - 15-30 (2)
 - 30+ (3)
-

Q9 What is the typical number of **lactating** cows in the herd you work with?

- 1-50 (1)
 - 51-100 (2)
 - 101-200 (3)
 - 200+ (4)
-

Q10 Are you required to complete Institutional Animal Care and Use (IACUC) training in order to work on your University Dairy herd?

- Yes (1)
- No (2)
- I do not know (3)

End of Block: Demographics

Start of Block: Biosecurity

Q11 Following the definition of **biosecurity** by the U.S. Association of State Departments of Agriculture as “the vital work of strategy, efforts and planning to protect human, animal and environmental health against biological threats” Does your University Herd provide training on biosecurity practices?

- Yes (1)
 - No (2)
 - I do not know (3)
-

Q12 If yes, describe this training and how you received it (select all that apply):

- Classroom coursework given by University faculty or staff (1)
 - Hybrid online and classroom coursework provided by University faculty (2)
 - Online course provided by outside organization (ex: Collaborative Institutional Training Initiative (CITI Program)) (3)
 - In person / hands on training with a physical instructor (University faculty, staff, herd management) (4)
 - I received no formal training in biosecurity based on the definition provided (5)
-

Q13 If no, describe in few words how students in your program learn about farm biosecurity practices? (type n/a if this does not apply)

Q14 Select all biosecurity measures that your University herd utilizes to your own knowledge:

- Keep a log or record of farm's visitors (1)
 - Prohibit outside animals on the farm (2)
 - Maintain one exit and entrance for visitors (3)
 - Provide visitors with disposable footwear (4)
 - Provide visitors with signage regarding biosecurity (5)
 - Workers wash boots between multi farm usage (6)
 - Workers maintain clothing specific to farm usage vs outside world usage (7)
 - Testing and quarantine of purchased animals (8)
 - Quarantine for animals that return from fairs/showing (9)
 - Separation of equipment/ husbandry measures for sick vs healthy cattle (10)
 - Isolate or cull sick/infected cattle (11)
 - Regular cleaning and disinfection of equipment and facilities regardless of animal health status (12)
 - Individual animal identification (ear tags, collars, trackers, etc) (13)
-

Q15 Select all hygiene and sanitation measures that you **personally** follow while working with dairy cattle:

- Frequent hand washing (1)
 - Wearing gloves while milking cattle (2)
 - Using pre/post teat dip during milkings (3)
 - Wiping teats with clean, dry towels (4)
 - Washing clothes, towels, etc used on farm in a sanitation cycle (5)
 - Washing clothes worn on farm separately from regular everyday clothes (6)
 - Follow a parlor cleaning and sanitation checklist (7)
-

Q16 Do you eat on the farm premises?

- No (1)
 - Yes (2)
-

Q17 If yes, do you always wash your hands before eating on the farm?

- Yes (1)
 - No (2)
 - I do not eat on the farm (3)
-

Q18 Select the option(s) that most clearly describes your University herd's sick pen(s)

- Our sick pen(s) are isolated from all other animals (1)
- We have dedicated sick pen(s) that are NOT isolated from other seemingly healthy animals (2)
- We do not have dedicated sick pen(s) (3)
-

Q19 Do pregnant animals calve in a separate area/pen from other animals?

- Yes, we have separated calving pens (1)
- No, animals calve in communal pens with other animals (2)
- Both (3)
-

Q20 Do **you** come into frequent contact with youngstock/ calves while working on your University herd?

- Yes (1)
- No (2)
-

Q21 Are calves housed separately on the farm?

- Always (1)
- No (2)
- Sometimes (3)
-

Q22 Does your University herd allow visitors from the general public (i.e. people unaffiliated with the University/ not student workers)?

- Yes (1)
 - No (2)
-

Q23 If your farm allows visitors, select the following statement that best applies:

- Visitors are always supervised by a farm employee through a scheduled visit / tour (1)
- Visitors are not always supervised, but guided tours are available (2)
- Visitors are never supervised (3)
- Visitors are not allowed on the farm and no tours are available (4)

End of Block: Biosecurity

Start of Block: Zoonotic Disease and Biosafety

Q24 Does your experiential learning program or University herd provide training in zoonotic disease? (ie: special online course, dedicated coursework, graded exam etc..)

- Yes (1)
 - No (2)
 - I do not know (3)
-

Q25 If yes, describe this training and how you received it (select all that apply):

- Classroom coursework given by University faculty or staff (1)
- Hybrid online and classroom coursework provided by University faculty (2)
- Online course provided by outside organization (ex: Collaborative Institutional Training Initiative (CITI Program)) (3)
- In person / hands on training with a physical instructor (University faculty, staff, herd management) (4)
- I received no formal training in biosecurity based on the definition provided (5)

Q26 In two sentences or less describe your definition of a zoonotic disease to the best of your ability

Q27 Have you had educational instruction on zoonotic disease beyond your work on the University herd (i.e. university coursework, work experience, etc)?

- No (1)
- Yes (2)

Q28 Have you had educational instruction in other biosafety topics such as biosecurity and antimicrobial resistance beyond your work on the University herd (i.e. university coursework, work experience, etc)?

No (1)

Yes (2)

Q29 In your opinion, what is the most common pathogen responsible for sick cattle on your University herd?

Q30 Select all zoonotic diseases or pathogens below that can be found in farm environments that you know of

- E. coli (1)
 - Cryptosporidia (2)
 - Staphylococci (3)
 - Streptococci (4)
 - Bovine Viral Diarrhea (BVD) (5)
 - Ketosis (6)
 - Salmonella (7)
 - Q fever (8)
 - Antibiotic Resistance (9)
 - Digital Dermatitis (10)
 - Johnes (11)
 - Hypocalcemia (12)
 - Dermatophytosis (ringworm) (13)
-

Q31 Has any animal been diagnosed with any of the following enteric diseases during your time working on the University farm? Select all that apply.

- Campylobacter (1)
 - E. coli (2)
 - Cryptosporidium (3)
 - Shigella (4)
 - Salmonella (5)
 - Johnes (6)
 - Other (7)
 - None to my knowledge (8)
-

Q32 Does your University herd have frequent calves with scours (diarrhea)?

- Yes (1)
 - No (2)
 - I do not know (3)
-

Q33 Have you **knowingly** been infected and/or diagnosed with a zoonotic disease while working on your University herd?

- No (1)
 - Yes (2)
-

Q34 If yes, what zoonotic disease were you infected/diagnosed with? Write n/a if not applicable.

Q35 Have you ever presented with symptoms of any zoonotic disease during your time working on the University herd?

No (1)

Yes (2)

Q36 Have any other workers, to your knowledge, been diagnosed with **OR** presented with symptoms of a zoonotic disease? Select all that apply.

Yes, diagnosed (1)

Yes, presented (2)

Yes, workers have both presented with symptoms of and been diagnosed with a zoonotic disease (3)

None of the above (4)

Q37 In 2 sentences or less, define antimicrobial resistance in your own words.





Q38 Does your University herd have cases of disease that are affected by antimicrobial resistance?

- Yes (1)
- No (2)
- I do not know (3)

Q39 Name a zoonotic pathogen that, to your knowledge, has the potential for antimicrobial resistance in a farm/agriculture environment.

Q40 In your opinion, rate the importance of the following topics in relation to dairy farming, your personal educational experiences, and the educational experiences of future students in the industry. The scale is from 0-10, with 0 being unimportant and 10 being extremely important.

0 1 2 3 4 5 6 7 8 9 10

Antimicrobial resistance in relation to cattle illness ()	
Antimicrobial resistance in relation to human illness ()	
Educating student farm workers on zoonotic disease risks in agricultural settings ()	
Educating student farm workers on biosecurity measures and protocols in agricultural settings ()	

Q41 In your opinion, were you properly educated and/or trained on the topics of biosecurity, zoonotic disease, and antimicrobial resistance **prior** to your University herd student worker position?

- Training was inadequate (1)
 - Training was somewhat adequate but needs improvement (2)
 - Training was completely satisfactory (3)
-

Q42 In less than a paragraph, respond: Do you believe your education/training in biosecurity, zoonotic disease, and antimicrobial resistance was adequate? Do you see places for improvement in educating student workers on these topics who are involved in University herds or experiential learning programs?

End of Block: Zoonotic Disease and Biosafety

APPENDIX B: VARIABLE TABLE

#	Variable	SPSS Name	Type	Values
1	Name of program or school affiliation	ProgramLocation	open text	written response
2	Living/growing up on a farm	PRIOREXPER1	categorical-binary	1,2
3	Length of previous farm work	PRIOREXPER2	categorical-ordinal	1,2,3
4	Working on multiple farms	PRIOREXPER3	categorical-binary	1,2
5	Length of academic farm employment	PRIOREXPER4	categorical-ordinal	1,2,3,4
6	Currently employed on more than 1 farm	PRIOREXPER5	categorical-binary	1,2
7	Summary prior work experience	workexperience	numeric-count	0 to 10
8	Academic level of respondent	AcademicLevel	categorical-ordinal	0 to 6
9	If the respondent took prior coursework	PriorCoursework	categorical-binary	0,1
10	Required to complete IACUC training?	EDiacuc	categorical-binary	0,1
11	Required to complete zoonoses training?	Edzoonotrain	categorical-binary	0,1
12	Required to complete biosecurity training?	Edbiotrain	categorical-binary	0,1
13	Summary prior educational experience	educationalexperience	numeric-count	0 to 10
14	Personal hygiene and sanitation measures followed	Combohygienepercent	numeric-percentage	0 to 100
15	Zoonotic disease definition	zoodefpercent	numeric-percentage	0 to 100
16	Choosing zoonoses correctly from list	ZOONOaccuracyscores	numeric-percentage	0 to 100
17	Correctly providing a common zoonotic pathogen of concern for dairy cattle	commpathsickpercent	numeric-percentage	0 to 100
18	Total knowledge scores for chapter 2	TotalBIOScore	numeric-score	0 to 400
19	Cases of animal sickness on the farm	animalsickness	numeric-count	0 to 7

20	Instances of being diagnosed with a zoonoses or presenting with signs/symptoms	sicknessscore	categorical-ordinal	1 to 4
21	Summary sickness scores	sicknessSUM	numeric-count	0 to 11
22	Self-reported zoonoses diagnoses	ZOOdiagnoses	open text	written response
23	If respondent eats on the farm property	eating	categorical-binary	1,2
24	If respondent washes hands before eating on the farm	handwashing_eating	categorical-ordinal	1,2,3
25	Number of biosecurity measures in place at the facility level	bio_farm_meas	numeric-count	0 to 13
26	Antimicrobial resistance definition	antimicdefpercent	numeric-percentage	0 to 100
27	Correctly providing a pathogen with AMR potential	pathantipotentiapercent	numeric-percentage	0 to 100
28	Total knowledge scores for chapter 3	TotalAMRknowledgescore	numeric-score	0 to 200
29	Ratings of AMR importance relating to cattle illness	importantAMRcattle	numeric-Likert scale	0 to 10
30	Ratings of AMR importance relating to human illness	importantAMRhuman	numeric-Likert scale	0 to 10
31	Ratings of biosecurity education and training importance for workers on academic dairy farms	importantbiosecur_ed	numeric-Likert scale	0 to 10
32	Ratings of zoonotic disease education and training importance for workers on academic dairy farms	importantzoonotic_ed	numeric-Likert scale	0 to 10
33	Self-reported overall training adequacy	adequatetrain	categorical-ordinal	1,2,3
34	Free response question to respond to overall perceptions of personal training and education received	FREERESPONSE	open text	written response