Assessment of Animal Health Practices and Antibiotics Usage on Dairy Farms in Washington State

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Abstract

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The use of antibiotics in dairy farming plays a crucial role in maintaining animal health and productivity. However, growing concerns over antimicrobial resistance (AMR) have driven regulatory reforms and shifts in on-farm antibiotic management in recent years. This study assessed current antibiotic usage patterns, animal health management practices, and antimicrobial stewardship among Washington State dairy farms.

A structured questionnaire was emailed to 190 licensed dairy farms in Washington State (WSDA list), with reminder calls to boost participation. 24 farms (12.6%) responded, representing herd sizes from fewer than 25 animals to more than 1,000. Data were analyzed in R using descriptive statistics to quantify practices and Chi-square tests to explore associations between producer roles and antibiotic awareness.

Therapeutic use of cephalosporins (e.g., ceftiofur) and penicillins dominates, with non-therapeutic applications (medicated milk replacers, feed top-dressing) now nearly eliminated.Routine health checks (88 %), glove use (75 %), and handwashing (67 %) are widespread. One-third of farms employ daily cleaning, grooming, and footbaths; 25 % test colostrum immunoglobulins (up from 8 % in 2003).
Although 86 % screen new purchases for diseases (BVD, Johne's, etc.), only 29 % quarantine arrivals for the recommended 14–28 days. On AMR Awareness, fifty-eight percent report high knowledge of antibiotic resistance and 62.5 % correctly define it (vs. < 40 % in 2005). Seventy-five percent see resistant infections as a herd threat; 59 % recognize human-health impacts. Yet 29 % fear higher mortality without prophylactic antibiotics. Forty-five percent rely on internet resources; 33 % attend extension meetings; others use journals or newsletters, indicating a hybrid digital/traditional outreach landscape.

The findings of this study underscore a notable evolution in antibiotic management and preventive health strategies among dairy farms in Washington State. The adoption of targeted therapeutic antibiotic use—especially cephalosporins and penicillins for conditions like mastitis and respiratory disease—signals a clear departure from non-therapeutic applications such as medicated milk replacers and feed top-dressing. These results support a theoretical framework in which informed attitudes, producer roles, and farm resources collectively shape antibiotic stewardship behaviour. Notably, producers demonstrating higher awareness of antimicrobial resistance (AMR) also exhibited more rigorous hygiene practices and narrower antibiotic use, reinforcing behaviour-change models that link knowledge acquisition with practical decision-making.

In conclusion, Washington State dairy farms have made notable progress toward responsible antibiotic stewardship embracing precision therapy, strengthening hygiene, and increasing AMR awareness. Remaining gaps in quarantine practices and persistent reliance on prophylactic antibiotics highlight areas for targeted extension and research. A blended outreach model, combining digital and in-person methods, alongside practical tools (e.g. quarantine guidelines, colostrum-testing protocols), will be key to sustaining improvements in animal health, farm productivity, and public health protection.

Chapter one: Introduction

Specification of the Problem

Over the last two decades, the approach to antibiotic use in dairy farming has undergone significant transformations.The use of antibiotics in dairy farming is a critical component of herd health management. In Washington State, antibiotic administration is commonly employed to treat bacterial infections such as mastitis, respiratory diseases, and lameness[102]. Antibiotics are also utilized for meta phylaxis (the treatment of at-risk animals to prevent the spread of disease) and, in some cases, prophylaxis (preventive measures taken before disease onset). A study of dairy farms in the region indicates that β-lactams (such as penicillin and cephalosporins) and tetracyclines are among the most frequently used antibiotics due to their efficacy and broad-spectrum activity [1].

Dairy producers in Washington State follow various management strategies to ensure effective antibiotic use while maintaining milk quality and animal health. These strategies include veterinary oversight, adherence to withdrawal periods to prevent antibiotic residues in milk, and record-keeping of antibiotic treatments. Many farms have implemented protocols aligned with the Food and Drug Administration (FDA) guidelines, which restrict the use of medically important antibiotics for growth promotion and mandate veterinary prescriptions for therapeutic use [2]. Preventive health protocols in dairy farms emphasize biosecurity measures, vaccination programs, and improved housing conditions to reduce the incidence of disease and thereby limit the need for antibiotics. Some farms are also exploring alternative disease management strategies, such as probiotics, essential oils, and immunomodulatory feed additives, as potential substitutes for conventional antibiotics [3].

Historically, antibiotics were widely used not only for therapeutic purposes but also for growth promotion and disease prevention. However, growing concerns over antimicrobial resistance (AMR) have led to regulatory changes and shifts in industry practices. The introduction of the Veterinary Feed Directive (VFD) by the FDA in 2017 marked a significant turning point in antibiotic stewardship. This policy mandates veterinary oversight for medically important antibiotics and prohibits their use for growth enhancement [4]. Additionally, consumer demand for antibiotic-free dairy products has prompted many producers to adopt more stringent antibiotic use policies.

Advancements in dairy herd health management have also contributed to a decline in antibiotic dependency. Farms have increasingly adopted precision livestock farming (PLF) technologies, such as automated health monitoring systems, which enable early disease detection and targeted treatment. The integration of genetic selection for disease resistance has further contributed to improved herd health, reducing the need for antibiotic interventions [5]. Furthermore, sustainable farming practices, including enhanced nutrition and stress reduction techniques, have been widely implemented to bolster animal immune function. These efforts, coupled with ongoing research into alternative therapies such as bacteriophages and antimicrobial peptides, suggest a continued shift toward reduced antibiotic reliance in dairy farming [6].

Dairy producers' attitudes toward antimicrobial stewardship (AMS) vary depending on farm size, access to veterinary services, and familiarity with regulatory guidelines. While many farmers recognize the importance of responsible antibiotic use, practical challenges such as disease outbreaks and economic pressures can influence adherence to stewardship principles [2]. A study among Danish dairy farmers in the year 2021, reveals that a majority support AMS initiatives, particularly when they align with improved herd health and consumer expectations [103] . Farmers acknowledge the role of veterinary oversight in ensuring appropriate antibiotic use, yet some express concerns over the administrative burden and costs associated with compliance [7].

Resistance to change often stems from misconceptions regarding the effectiveness of alternative disease management strategies. However, education and outreach programs have played a crucial role in shifting perceptions. Extension services and industry-led initiatives have successfully increased awareness of AMS, emphasizing the long-term benefits of reducing antibiotic dependency. Farmers participating in stewardship programs report improved herd productivity and reduced treatment costs, further reinforcing the advantages of AMS [3].

Despite these positive trends, ongoing efforts are needed to bridge the gap between policy recommendations and practical implementation. The examination of antibiotic use in Washington State dairy farming highlights the evolving landscape of herd health management and antimicrobial stewardship. Current antibiotic usage patterns prioritize therapeutic applications while incorporating preventive health measures to minimize reliance on antimicrobial agents. Over the past two decades, regulatory changes, technological advancements, and consumer preferences have driven a shift toward reduced antibiotic use and improved disease management strategies. Dairy producers largely recognize the value of antimicrobial stewardship, yet challenges remain in aligning practical farm operations with regulatory expectations. Hence, this study seeks to assess the current antibiotic usage patterns, management practices, and preventive health protocols in Washington State dairy farms. Comparatively assess the changes in antibiotic usage, animal health management strategies, and the adoption of best practices over the past 20 years Using Dr. Wohrle's foundational research on the "Assessment and Promotion of Judicious Antibiotic Use on Dairy Farms in Washington State" as a baseline for the comparison and evaluation of dairy producers' attitudes toward antimicrobial stewardship.

Chapter two: Literature review

The usage of antibiotics in dairy farming

The usage of antibiotics in dairy farming in the United States is an issue influenced by various factors including economic viability, herd health management, and regulatory frameworks. Understanding the patterns of antibiotic use is crucial for addressing concerns about antimicrobial resistance, which has significant implications for public health. This literature review synthesizes insights from studies that quantify and analyse antibiotic use on dairy farms across the U.S.

Quantifying antibiotic use on dairy farms has proven to be a significant challenge, yet several important studies have addressed this issue. For instance, Redding et al. reported that antibiotic use on dairy farms in Wisconsin was measured at an incidence of 5.43 defined daily doses (ADD) per cow per year, which equates to about 14.8 ADD per 1,000 cow-days indicating less antibiotic use compared with 20.78 ADD/1.000 cow-day in Belgium[8]. This finding underscores the necessity for consistent methodologies in accurately capturing antibiotic consumption across diverse dairy farming systems.

Current antibiotic usage patterns in dairy farms are critical to understanding their impact on both animal and public health, particularly due to concerns over antimicrobial resistance. A notable study conducted in Pennsylvania revealed that a significant number of dairy producers routinely screened cows for antibiotic residues following treatment, which was demonstrated to be good practice in maintaining milk quality and safety [9]. Separate milking protocols for treated animals were employed as a preventive strategy against drug residues in milk, observed in most of the surveyed farms, indicating a clear preference for responsible antibiotic use amongst farmers [10]. Moreover, a report indicated that only 27% of dairy producers maintained written protocols for antibiotic administration, while many relied solely on manufacturer directions [11]. This adherence to written protocols is important for ensuring proper administration of medications and reflects management practices aimed at minimizing errors in treatment regimens. The absence of formalized protocols can lead to variabilities in antibiotic application, consequently heightening the risk of drug resistance developing on farms [11].

Alongside this empirical evidence, recent studies emphasize the importance of comprehensive management practices that transcend mere treatment, advocating for an integrated approach. Practices such as maintaining thorough treatment records and implementing biosecurity measures significantly contribute to the responsible management of antibiotic usage on dairy farms [12]. In addition, findings indicate that antibiotic use must be closely monitored and documented to assess compliance with stewardship protocols and ensure effective management of animal health [11]. Furthermore, a related study found that 24 different antibiotic types were recorded across 113 dairy herds in Pennsylvania [13]. These figures indicate significant antibiotic pressure on dairy cattle in certain environments, raising questions regarding the sustainability and safety of such practices. In terms of management practices, differences in antibiotic usage between large and small dairy farms have been noted. Moudgil et al. found that larger, organized dairy farms generally employ better management and judicious practices, leading to lower positivity rates of antibiotic residues in their milk products. In contrast, small to medium-sized farms often showed a higher prevalence of antibiotic residues due to less regulated usage practices [14]. This discrepancy can be attributed to the operational standards and educational resources accessible to larger operations, which tend to have more structured oversight of animal health and medication schedules. The data suggest that improving infrastructure and education on antibiotic use in smaller farms could provide public health benefits by reducing the incidence of antibiotic residues in milk.

The qualitative dimensions of antibiotic use also play a crucial role in the practices adopted by dairy farmers. A survey conducted by Casseri et al. revealed that many dairy farmers rely on veterinarians for guidance on alternative treatments to antibiotics. Notably, about 66% of participants sought advice on antibiotic alternatives, highlighting the veterinary community's pivotal role in promoting alternative strategies in infection management [15]. This reliance on veterinary expertise is critical, as it can steer farmers away from excessive antibiotic use, ultimately reducing the risk of resistance development. Encouraging proactive communication between farmers and veterinarians may enhance adoption rates for more responsible antibiotic use practices, potentially leading to better health outcomes for dairy herds. Concerns regarding the efficacy of antibiotic treatments used in dairy farming are rising due to the linked challenges of antibiotic resistance. Research conducted by Tufa et al. emphasizes that antibiotic effectiveness can vary significantly among different brands. This variability complicates the landscape of veterinary pharmaceutical use and may contribute to the emergence of resistance, presenting both clinical and economic implications for dairy producers [16]. Farmers' education regarding the appropriate selection and application of antibiotics is crucial to mitigate these risks and promote better health management in herds. Furthermore, systemic factors influencing antibiotic use must be considered in the context of dairy farming in the U.S. Cultural attitudes toward antibiotic use shape decision-making processes within farms. Studies have indicated that farmers often experience external pressures, such as market demands and regulatory frameworks, which can impact their antibiotic use decisions. For instance, the Farmers Assuring Responsible Management Animal Care Program (FAMRM-ACP) establishes standards that encourage careful antibiotic use, but the adoption and perceptions of these frameworks can vary significantly among farmers [17]. Engagement with such initiatives is essential for fostering a culture of responsibility concerning antibiotic practices in dairy management.

The current landscape of antibiotic usage on U.S. dairy farms reveals a pressing need for focused policies and practices aimed at reducing dependency on antimicrobials. Initiatives that promote alternative treatments, improve farmer education, and support oversight by veterinarians are vital in mitigating antimicrobial resistance. Moreover, continuous monitoring of antibiotic usage through quantifiable metrics and standards is necessary to inform better practices. As these issues are endemic to the broader discussion of livestock health management and public health, there is great urgency in advancing responsible antibiotic use within the U.S. dairy sector.

Evolution of Antibiotic Usage and Health Management Strategies in Dairy Farms

The evolution of antibiotic use and health management practices in U.S. dairy farms has undergone notable changes, driven by scientific progress, updated regulations, and increasing concerns about antibiotic resistance (AMR). With society growing more aware of the consequences of antibiotic misuse, dairy farmers have been prompted to significantly adjust their practices. This transformation can be categorized into several core areas: recognizing antibiotic usage trends, understanding the impact of regulatory frameworks, adopting management practices that enhance animal health, and addressing the continual need for education and training within the sector.

Historically, antibiotic application in U.S. dairy farming was primarily motivated by the necessity to preserve herd health and sustain productivity. Antibiotics have routinely been used to treat common ailments such as mastitis and pneumonia, conditions that substantially affect cow health and milk yield [9]. For example, a study in Pennsylvania found that the average antibiotic treatment incidence per cow per year was approximately 5.43 defined daily doses [8], highlighting the widespread use of these drugs in dairy operations. Key antibiotic classes, including beta-lactams and tetracyclines, have played a vital role in managing various bovine diseases [20]. Nevertheless, the extensive use of these medications has raised concerns regarding the development of AMR, underscoring the need to balance the medical requirements of the herds with broader public health priorities [15]. As awareness of AMR has increased, dairy farmers have begun to implement strategies to reduce their dependence on antibiotics. One such strategy is selective dry cow treatment (SDCT), which targets only cows at high risk of infection during the dry period. Research among Dutch dairy farmers has shown high adoption rates of SDCT, suggesting that U.S. producers may be following suit as they recognize the benefits of this approach [15]. Additionally, there has been a move toward evidence-based practices, such as stringent testing for antibiotic residues in milk. In one study, only 3% of surveyed farms exhibited detectable levels of residues, demonstrating the effectiveness of rigorous testing protocols [9].

Regulatory measures at both federal and state levels have increasingly promoted responsible antibiotic use in agriculture. For example, initiatives by the FDA to encourage the judicious use of medically important antibiotics in livestock have led to the development of standardized protocols for prescriptions and usage reporting [18]. This regulatory climate has spurred farmers to explore alternatives to antibiotics by investing in preventive health measures such as improving animal husbandry practices, optimizing nutrition, and enhancing biosecurity protocols [18]. Evaluations of dairy farm health management reveal a growing commitment to best practices that not only promote animal welfare but also help reduce antibiotic dependency [19]. Education and training are emerging as essential components in increasing farmers' understanding of the risks associated with antibiotic misuse and the various alternatives available. Educational programs that focus on improved animal health management and reduced antibiotic use have received favorable responses, with many producers showing readiness to embrace innovative strategies [20]. Furthermore, the formation of dairy farmer groups that advocate for antibiotic stewardship has become an invaluable resource for sharing knowledge and experiences, thereby supporting compliance with regulations and fostering a culture of responsible antibiotic use [10].

The integration of herd health monitoring systems and advanced data collection technologies has also contributed positively to dairy farm management. These systems enable farmers to monitor various health indicators and detect trends within their herds, thereby facilitating more informed decision-making regarding intervention strategies and antibiotic use [21]. Greater access to detailed data on herd health and production performance allows early identification of potential issues, helping to minimize the reliance on antibiotics [22]. Improved farm management practices that enhance cow comfort and the overall environment have gained recognition for their role in promoting herd health. Ensuring proper nutrition, providing comfortable housing, and optimizing milking procedures can reduce stress and disease incidence, thereby decreasing the need for antibiotic interventions [23]. Additionally, practices such as management-intensive grazing and organic production methods aim to improve animal welfare, which is crucial in lowering infection risks and reducing antibiotic use [24,25].

The economic impacts of adopting more sustainable practices in dairy farming are significant. Although transitioning to alternative treatments and preventive measures may require initial investments, long-term research indicates that these changes can lead to cost savings through lower veterinary expenses and enhanced productivity [26]. Moreover, investing in animal health through improved management practices can strengthen the overall sustainability of dairy operations and contribute positively to local agricultural economies [26]. Challenges posed by AMR have also spurred research into developing alternatives to conventional antibiotics. Investigations into probiotics, vaccines, and herbal treatments as potential supplements or replacements for antibiotic use are gaining momentum in both academic research and on-farm applications [21]. These alternatives not only address current health issues within herds but may also help fortify animals against diseases that traditionally require antibiotic treatment.

As the U.S. dairy industry continues to evolve, it is critical to foster collaboration among farmers, veterinarians, researchers, and policymakers. By establishing cooperative frameworks for sharing knowledge and resources, the dairy sector can better align with sustainable practices that reduce antibiotic reliance while maintaining herd health and productivity [19]. The future of health management in U.S. dairy farming is likely to involve a blend of traditional methods enhanced by innovative solutions, paving a viable path forward amid ongoing challenges related to AMR and public health policy. Ultimately, the combination of education, regulatory oversight, and the implementation of best management practices forms the foundation of a transformative approach to antibiotic use in the U.S. dairy industry. Moving toward more judicious antibiotic usage is essential to preserve their effectiveness and mitigate the public health risks associated with AMR, thereby creating a more resilient and sustainable dairy farming environment. These collective efforts will protect farmers' livelihoods and promote community health, ensuring that dairy production remains a critical component of the U.S. agricultural landscape.

Dairy Producers’ Attitudes Toward Antimicrobial Stewardship

Dairy producers in the USA increasingly face the imperative of antimicrobial stewardship (AMS), a concept aimed at promoting responsible antibiotic use to combat antimicrobial resistance (AMR). Producers’ attitudes toward AMS are influenced by various factors, including perceptions of necessity, education, management practices, and regulatory frameworks.

Research indicates that many dairy producers recognize the importance of responsible antimicrobial use. A significant percentage identify the administration of appropriate dosage and record-keeping as vital AMS practices, highlighting the need for standardized treatment protocols and antimicrobial testing for effective use [27,28]. Many farmers express confidence in their current practices, often believing they are utilizing antibiotics appropriately [29]. However, there remains a disparity between perceived necessity and the actual application of AMS principles. Farmers tend to view antibiotics as essential for animal health but may lack awareness of the long-term impacts of their use on AMR [30].

Education plays a critical role in shaping producers’ attitudes toward AMS. Ongoing training programs that leverage motivational interviewing techniques could enhance producers’ readiness to adopt AMS practices [31]. Furthermore, integrating farmers into the policy-making process can help tailor AMS strategies to their specific contexts, fostering a sense of ownership and responsibility towards AMR mitigation [31,32]. Extension and outreach efforts are crucial to bridge gaps in knowledge and promote preventive health measures, such as vaccines and proper herd management practices, which can reduce reliance on antibiotics [33,34].

The regulatory environment, exemplified by initiatives such as California’s Senate Bill 27, has motivated producers to reconsider their antimicrobials’ use. Post-implementation of such regulations, there is evidence of shifts in attitudes and practices among dairy farmers, with more emphasis on documenting antibiotic use and adhering to withdrawal periods [27,28]. Moreover, a study shows that over 95% of dairy producers emphasize the significance of judicious antibiotic use, suggesting a collective understanding of AMS principles within the context of regulatory compliance [27]. Several studies demonstrate that communication between veterinarians and farmers significantly influences AMS uptake. Farmers often view veterinarians as an authoritative source on antimicrobial use and management practices [34,35]. Therefore, improving communication strategies and aligning veterinarians' and farmers' perspectives on antibiotic treatment can help mitigate the risks of AMR and foster a culture of responsible antibiotic usage [36]. When farmers perceive veterinarians as partners in health management rather than mere regulatory enforcers, compliance with AMS recommendations can improve significantly [31,34].

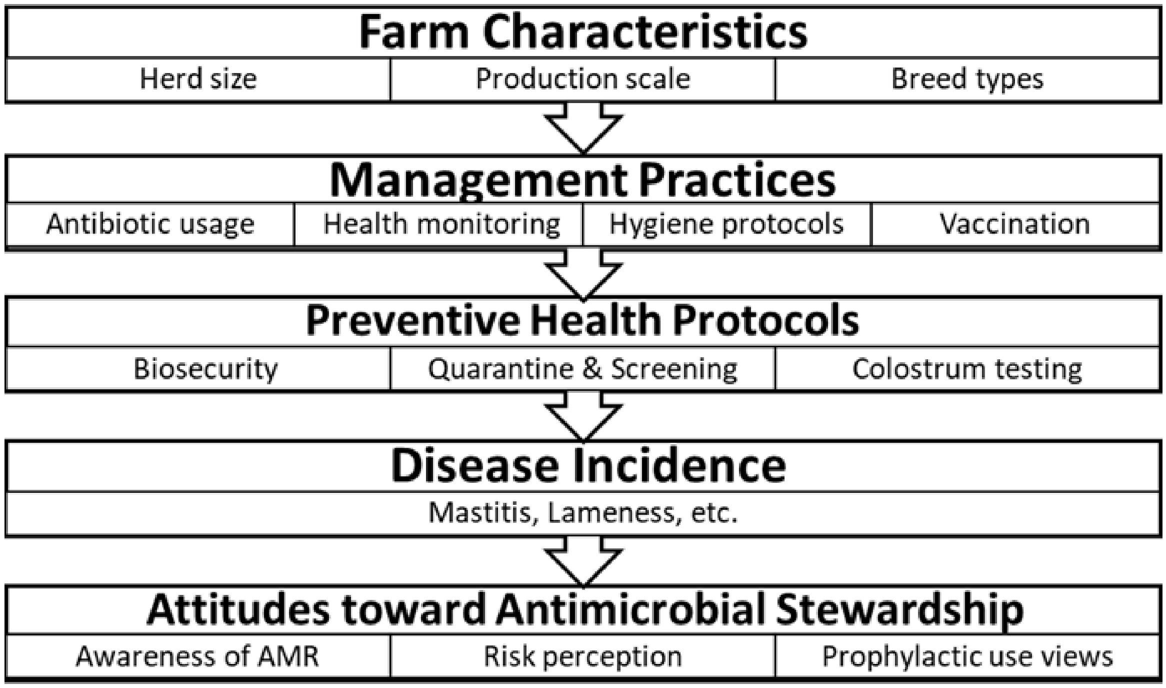
Despite the recognition of the importance of AMS, barriers exist that hinder the integration of these practices on farms. Many dairy producers may be resistant to change due to entrenched practices, potential economic concerns, or misconceptions regarding the effectiveness of non-antibiotic alternatives [29,37]. Addressing these barriers through tailored educational outreach, showcasing the economic benefits of AMS, and employing participatory learning approaches could facilitate a positive shift in producers' attitudes [31,34]. While many dairy producers display a general understanding of antimicrobial stewardship's importance, deeply ingrained practices, regulatory pressures, and effective communication with veterinary professionals are critical determinants of the successful implementation of responsible antibiotic use. Future efforts in AMS should continue to focus on education, the incorporation of farmer input in developing stewardship policies, and leveraging the veterinarian–farmer relationship to mitigate risks associated with antimicrobial resistance.

Conceptual model

The conceptual framework guiding this study is grounded in the understanding that multiple interconnected factors influence animal health outcomes and antimicrobial stewardship on farms. At the foundation of this model are the unique characteristics of individual farms, such as herd size, production type, resource availability, and management structure. These farm-level attributes significantly shape the types and scales of management strategies that are adopted. For example, larger or more resource-intensive farms may implement more structured or technologically advanced practices compared to smaller operations. The management strategies selected by producers directly impact core operational areas, most notably patterns of antibiotic use, hygiene practices, and vaccination efforts. These strategies not only reflect the farm's infrastructure but also the decision-making preferences and goals of the producers. How and when antibiotics are used, the rigor of hygiene protocols, and the extent of vaccination coverage are all critical factors that influence animal health and the risk of disease spread within a herd.

In addition to general management practices, the implementation of specific preventive protocols plays a pivotal role in mitigating health risks. Key among these are biosecurity measures such as controlling farm access and sanitation procedures and colostrum testing to ensure newborn animals receive adequate passive immunity. These proactive steps are designed to prevent the introduction and spread of infectious diseases, thereby reducing the need for reactive treatments, including antibiotics. The interplay of management strategies and preventive measures directly affects the incidence of clinical conditions observed on the farm. Farms that adopt more comprehensive and preventive approaches typically experience lower rates of disease outbreaks, leading to improved animal welfare and reduced reliance on therapeutic antibiotic interventions.

Finally, the attitudes of producers toward antimicrobial stewardship are not static; rather, they evolve based on a combination of perceived risks and firsthand experience with disease outcomes. When producers observe positive health outcomes associated with preventive practices or reduced antibiotic reliance, they may become more committed to stewardship principles. Conversely, high disease burdens or ineffective interventions may prompt reevaluation of current practices and influence future decision-making.



Evolving Antibiotic Stewardship: A 20-Year Journey of Policy Changes in Dairy Farming in Washington State

Over the last two decades, the landscape of dairy farming in Washington State has undergone significant transformations fuelled by landmark policies aimed at enhancing food safety, responsible antibiotic use, and environmental sustainability. The implementation of these policies reflects a broader national trend to optimize dairy production while minimizing public health risks associated with foodborne illnesses and antibiotic resistance. A pivotal moment in this journey was marked by the Veterinary Feed Directive (VFD) Final Rule implemented from 2015 to 2017, which mandated veterinary oversight for the use of medically important antibiotics in livestock feed. This change was intended to curb the increase in antibiotic-resistant bacteria associated with the agricultural use of such medications, effectively laying a foundation for subsequent regulations in the dairy industry [38,40].

The FDA Guidance for Industry (GFI) No. 213, released in 2017, further aligned with the VFD by outlining the responsibilities of pharmaceutical companies to voluntarily remove growth promotion claims for antibiotics used in food animals. This guidance emphasized the necessity of veterinary oversight in administering these medications, thereby fostering a more judicious approach to antibiotic usage within dairy production systems [41,43]. In conjunction with these efforts, the National Residue Monitoring Program (NRMP) has continuously monitored residues of veterinary drugs and other contaminants in milk and dairy products, illustrating a commitment to ensuring that food products meet safety standards [38,39,44].

Moreover, the Washington State Dairy Nutrient Management Act, revised in 2019, showcased a commitment to environmental stewardship within the dairy sector. This act provided frameworks for managing nutrient waste from dairy operations, thus promoting the implementation of best management practices aimed at minimizing runoff and protecting water quality, which is critically important for both environmental and public health [45,47]. In parallel, the framework of Milk Safety Regulations, implemented by both the FDA and Washington State Department of Agriculture (WSDA), established rigorous standards for the microbiological safety of milk, ensuring that dairy products consumed by the public are safe [38,44].

The adoption of the Food Safety Modernization Act (FSMA) in 2011 marked another significant milestone in food safety, shifting the focus from reactive to preventive measures in food safety management. Under FSMA, dairy farms are required to implement comprehensive food safety plans that integrate Hazard Analysis and Critical Control Points (HACCP) principles, therefore ensuring the control of food safety hazards throughout the production and processing stages [42,48]. This preventive approach is echoed in the Preventive Controls for Animal Food Rule (2015), which specifically addresses the safety of animal food products, including dairy feed, highlighting the interconnectedness of animal health and food safety [39,49].

Recent developments, including the FDA Guidance for Industry (GFI) No. 263 issued in 2023, reflect a persistence to evolve regulatory frameworks in response to the ongoing challenges faced within the dairy industry. This guidance provides recommendations for establishments involved in the production of animal food, specifically highlighting the importance of adhering to safety standards and promoting animal welfare. As antibiotic resistance remains a pressing public health concern, this evolving landscape continues to push for more stringent oversight of antibiotic practices on dairy farms [41,43]. Further efforts, such as the Washington State Veterinary Oversight and Antibiotic Use Reporting Initiatives launched in 2020, present a proactive approach to tracking antibiotic use and ensuring compliance across dairy operations. This initiative is critical in fostering transparency and accountability within the industry, thereby assisting in the reduction of antibiotic misuse and ensuring that dairy farms follow appropriate veterinary guidelines [43,48]. The convergence of these policies illustrates a comprehensive strategy aimed at safeguarding public health while maintaining the economic viability of dairy enterprises across the state.

Overarching these local initiatives is the need for continuous education and engagement with dairy farmers to ensure a collective commitment to compliance with the various regulatory frameworks. This collaborative effort between government entities, agricultural organizations, and the dairy industry itself serves as a model for how regulatory frameworks can evolve, promoting sustainable agricultural practices while addressing public health objectives [38,45,50]. Given the increasing consumer awareness regarding food safety and the antibiotic residues in dairy products, the dairy industry must sustain its efforts in enhancing transparency and adopting consumer-friendly practices. Programs such as the National Residue Monitoring Program (NRMP) provide essential data that supports the safe production of dairy products while encouraging farmers to comply with monitoring activities and engage with third-party auditing systems to assure compliance (44,50,40).

A ban on the use of cephalosporins in livestock feed complements the FDA's federal guidelines, notably the 2012 FDA rule that restricts extralabel use of cephalosporins in major food-producing animals such as cattle and poultry. This federally aligned measure directly addresses the risk of antibiotic resistance and safeguards the efficacy of essential human antibiotics like ceftriaxone. These collective actions underscore the urgent need for a coordinated approach to combat antimicrobial resistance across both human and veterinary health sectors, reflecting a trend towards more responsible antibiotic stewardship in medical practice [61].

On June 11, 2023, the U.S. Food and Drug Administration (FDA) officially transitioned all over-the-counter (OTC) medically important antimicrobial drugs used in livestock to prescription-only status. This change reflects a strategy aimed at enhancing the responsible use of antibiotics in veterinary medicine and addressing the pressing issue of antimicrobial resistance, which poses significant risks to both animal and human health [61]. Under the new policy, drugs such as injectable penicillin and oxytetracycline can no longer be purchased OTC, necessitating the involvement of licensed veterinarians in their administration. This regulatory shift aims to curtail misuse of antibiotics, recognized as a contributing factor to the development of resistant bacteria [62,63]. The past twenty years have witnessed substantial policy shifts within the dairy sector federally which has imparted in Washington State, highlighting a commitment to food safety, environmental sustainability, and responsible antibiotic use. By adhering to these complex frameworks, dairy farmers not only safeguard their businesses but also play a critical role in protecting public health and preserving the ecosystems upon which their operations rely.

Chapter Three: Methods

Methods

The study employs a structured methodology to gather data on animal health management, antibiotic usage patterns, and producers' perceptions of antimicrobial stewardship. The design of this research primarily revolves around a survey administered across a selected population of dairy farms, with specific attention to sample selection, data collection, and statistical analysis.

Study Setting

The study involves dairy farming operations across Washington State. Specifically, it revolves around a well-defined population of 190 licensed dairy farms that have been identified using a public request form provided by the Washington State Department of Agriculture (WSDA). The survey was distributed via email to 190 licensed dairy farms, thus ensuring accessibility to all identified producers. This approach allows for a comprehensive reach across diverse farm operations, facilitating a representative sample of the current practices and issues faced within the industry [48,49].

Selection of Study Materials or Subjects

The selection of study subjects is grounded in the description of eligible dairy farms based on licensing, thereby ensuring compliance with federal agricultural regulations. The recruitment method employed is systematic; the research team will utilize the WSDA's database to disseminate the survey, which grants access to a population that has been pre-qualified for participation in the study.

The criteria for eligibility include selected farms that actively engaged in dairy production in Washington State and possess a license issued by the WSDA. The sample of dairy farms covered retail raw producers, and producers of milk intended for pasteurization, including cow, sheep, and goat farms. Exclusion criteria include dairy operations that are currently under suspension or have been penalized for non-compliance with agricultural standards. Notably, the survey aims to capture a diverse demographic, including small-scale operations and larger agribusinesses, thereby providing a broader understanding of antibiotic administration practices across different farm sizes [48,49,51]. By analysing survey responses, the study aims to identify trends in antibiotic usage and attitudes towards stewardship amongst dairy producers. This elicitation of information functions as a quasi-experimental intervention, facilitating comparisons over time and highlighting changes in practice [49,51].

Data Collection

Data collection is a critical component of this study. The primary source of data was the survey distributed to licensed dairy farms. The survey was designed to encompass various aspects of antibiotic usage, including frequency and types of antibiotics used, reasons for usage, management practices, and health outcomes of dairy cattle as reported by the producers [48,52].

This survey was designed to assess animal health practices and antibiotic usage in Washington state dairy farms, following Dr. Whorle’s study on the assessment and promotion of responsible antibiotic usage conducted in 2005. The survey questionnaire's language and model were adopted from Dr. Whorle research in 2005, and the scope was broadened by capturing current animal health management practices and antimicrobial usage on dairy farms in the region. It aims to gather insights into the evolution of animal health management practice and antibiotic usage practices since Dr. Whorle study, identifying trends in animal health practices, and assessing any changes in the adoption of antimicrobial stewardship guidelines among dairy farms. The survey questionnaire and research protocol were submitted for Institutional Review Board (IRB) review and were determined to be exempt from full review in accordance with federal guidelines. This review process confirmed that the study adhered to ethical research standards, and it ensured that the rights and welfare of all participants were protected throughout the research process. The survey was disseminated on March 28th, 2025 with the response period remaining open until April 30th, 2025 to provide participants with sufficient time to complete and submit their responses. The data collection procedure was unfolded in several stages. Initially, the survey was mailed to participants, providing ample time for completion. Follow-up emails and phone calls were conducted two weeks after the initial survey distribution to remind participants, thereby enhancing response rates and ensuring more comprehensive data collection. This protocol aligns with established practices in survey research to prompt participation and counteract non-response bias [48,52]. Data was collected, handled and stored securely using RedCap from March 28th to April 30th, 2025, ensuring that sensitive information could not be traced back to individual participants, thereby safeguarding personal and proprietary details. Steps taken to assure data quality include the pre-testing of survey instruments to refine questions for clarity and relevance. Additionally, clear guidelines will inform producers on how to complete the survey, ensuring uniform understanding across diverse operator backgrounds. Each participant was provided with a detailed explanation of the study's purpose, procedures, and potential risks, ensuring that they had ample opportunity to ask questions and confirm their willingness to participate voluntarily. Confidentiality of the data was rigorously maintained. All participant and farm information were anonymized to protect the privacy of the respondents and their operations. The research team closely monitors the collection process to manage any discrepancies or erroneous data entries that may arise [53,52].

Analysis

The analysis phase employs statistical methods to explore and validate hypotheses concerning the two-decade evolution of antibiotic use and health management practices. Key analysis variables will include frequencies of antibiotic usage, classifications of management practices, and producer perceptions regarding antimicrobial stewardship [49,51].

The study utilized a quantitative approach to analyse data collected from dairy farms in Washington State. Descriptive statistics were employed to summarize key variables, including frequencies and percentages for categorical data such as types of antibiotics used and hygiene practices, as well as measures of central tendency (mean, median) and dispersion (standard deviation) for continuous variables like herd size and antibiotic usage rates. These analyses provided a comprehensive overview of current antibiotic usage patterns and farm management practices. Inferential statistical methods were applied to examine relationships between variables and test hypotheses. Chi-square tests were conducted to assess potential associations between categorical variables, such as the relationship between farm roles and awareness of antibiotic resistance. Factor analysis was performed to identify underlying dimensions in producers' attitudes toward antimicrobial resistance, revealing two primary factors: public health awareness and perceived on-farm risks. Comparative analysis was also undertaken to evaluate changes over time by benchmarking current findings against data from a 2005 baseline study. All statistical analyses were performed using R software (version 4.3.1), with specific packages employed for data management (tidyverse), visualization (ggplot2), and advanced statistical testing.

4.0 Results

This section presents the findings derived from a comprehensive analysis of antibiotic usage, management practices, preventive health protocols, and attitudes toward antimicrobial stewardship among dairy farms in Washington State. Out of the 190 survey questionnaires sent to licenced dairy farms, 24 responses were received representing 12.6% sample size. Drawing on survey data collected in 2025 and processed using the R statistical software, the analysis addresses the study's primary objectives: (1) to document the current patterns of antibiotic administration and preventive health strategies, (2) to evaluate changes in animal health management and antibiotic usage over a 20-year period, using Dr. Wohrle's foundational 2005 study as a benchmark, and (3) to explore the prevailing attitudes of dairy producers toward responsible antibiotic use.

Descriptive statistics and graphical summaries are employed to provide a nuanced understanding of present-day practices in dairy farming. Comparative insights are also incorporated where applicable to highlight progress or continuity in antibiotic stewardship. Furthermore, the study interprets producers' perceptions and beliefs concerning antimicrobial resistance and control practices. Collectively, these results aim to offer evidence-based perspectives that inform both policy and practice in the sustainable management of livestock health.

Demographics

This table outlines the distribution of roles among the 24 respondents who participated in the survey. The majority identified as Owners, comprising 79.2% of the total sample. This high representation suggests that the survey largely reflects the perspectives of primary decision-makers responsible for farm operations and policy implementation. Approximately 33.3% of the participants indicated they hold a Managerial position, highlighting the involvement of individuals who oversee daily farm activities and execute strategic decisions in collaboration with farm owners. It's possible that some individuals identified with more than one role (e.g., both owner and manager), which could explain the overlapping percentages. Notably, only 4.2% of respondents were categorized as Employees, and an additional 4.2% fell into the other category, which was clarified to represent a veterinarian. Although these groups are underrepresented numerically, their perspectives provide vital insights particularly the veterinarian's viewpoint regarding animal health and antimicrobial stewardship.

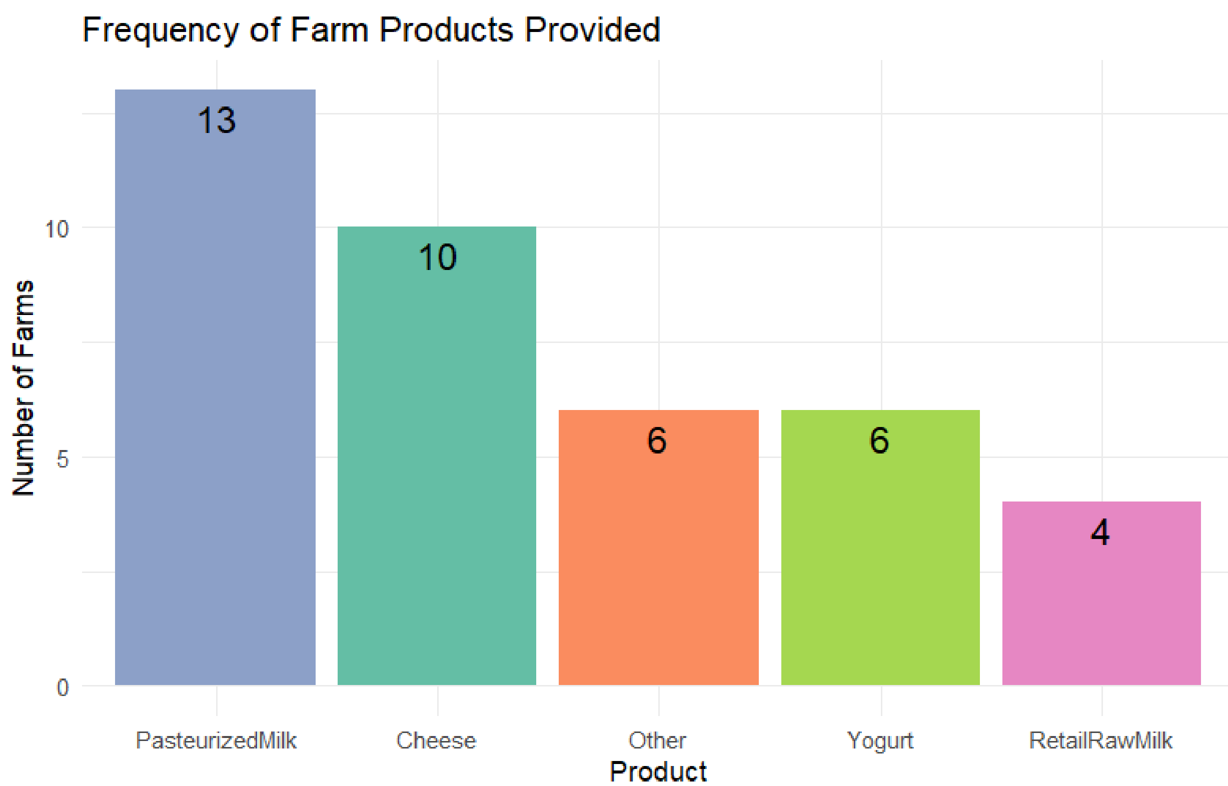
Overall, the role distribution within the survey sample demonstrates that the insights presented are primarily informed by individuals occupying decision-making and leadership roles. This enhances the credibility of the data, particularly in relation to evaluating management practices, preventive protocols, and antibiotic usage across dairy farms in Washington State.

The distribution of dairy products across the surveyed farms in Washington State reveals a notable degree of diversity in production and marketing strategies among the 19 respondents. The most frequently produced item is pasteurized milk, reported by 13 respondents, underscoring the prominence of this commodity within the region's dairy industry. The emphasis on pasteurized milk suggests a strong commitment to food safety regulations and public health guidelines, particularly as pasteurization is a standard requirement for many retail and commercial milk products. This trend also reflects widespread consumer preference for processed milk, which is generally perceived as safer and more stable in quality.

In addition to pasteurized milk, cheese production is also prevalent, with 10 farms engaging in this form of value-added processing. Cheese-making not only represents a means of diversifying farm income but also requires specialized skills and equipment, indicating a degree of operational maturity among these producers. The popularity of cheese production aligns with broader consumer interest in artisanal and specialty dairy products, offering farms an opportunity to access premium markets. Similarly, yogurt, produced by 6 farms, points to a modest but meaningful engagement in the manufacture of fermented dairy goods. Yogurt production typically aligns with consumer trends emphasizing health, nutrition, and probiotic content.

The production of retail raw milk, though limited to 4 farms, illustrates the existence of niche markets within the broader dairy sector. Raw milk sales are often heavily regulated and appeal to a specific subset of consumers who value unprocessed food. The relatively small number of farms producing raw milk may reflect the legal and logistical challenges associated with its sale, as well as heightened concerns regarding microbial safety. The "Other" product category, reported by 6 farms, reflects a wider spectrum of production outputs and marketing models. Notably, one respondent mentioned marketing bulk milk through a cooperative, which indicates participation in collective bargaining systems and commodity channels. Another respondent highlighted direct-to-consumer pasteurized milk and cream, demonstrating a focus on localized, relationship-driven marketing approaches. Additionally, the mention of diversified agricultural products including hay, butcher animals, milk goats, and miscellaneous farm items illustrates the multidimensional nature of many dairy farms, some of which operate beyond the bounds of conventional dairy production. The inclusion of pasteurized goat milk suggests attention to alternative livestock and emerging consumer segments. Lastly, one farm reported having no products for resale, possibly indicating a non-commercial or self-sustaining operation, or a farm in transition.

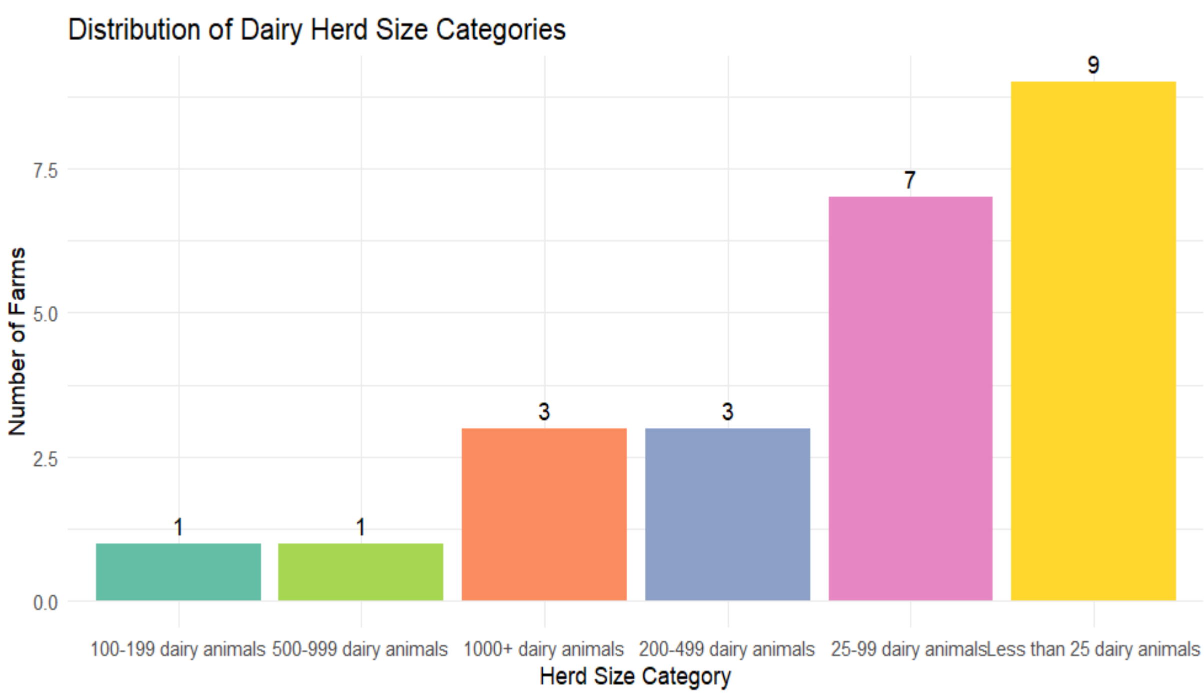
In summary, the varied range of dairy products and production strategies among Washington State dairy farms reveals a dynamic and adaptable agricultural landscape. The dominance of pasteurized milk, alongside substantial involvement in cheese and yogurt production, indicates a strong orientation toward both food safety compliance and product diversification. Simultaneously, the presence of raw milk producers and direct marketing ventures points to entrepreneurial adaptability and responsiveness to niche markets.



Herd Characteristics & Management

Nearly half of the surveyed operations (47%) maintain very small herds of fewer than 25 dairy animals, indicating that a substantial portion of Washington State dairy farms operate on a small scale or sampling bias. These small-herd producers may face unique challenges such as limited economies of scale and greater sensitivity to individual animal health events, but they also may adopt more hands-on management and rapid implementation of new practices. The next largest group (37%) falls into the 25–99 animal range, representing small-to-moderate sized farms that likely blend family-style management with some level of commercial production. Together, these two categories (under 100 animals) account for 84% of respondents, highlighting that most dairy farms in this sample are relatively small operations. Medium-sized herds (100–499 animals) are less common, comprising 21% of respondents (5% in the 100–199 category and 16% in the 200–499 category). These farms may balance the benefits of scales such as investing in more advanced equipment and biosecurity measures—with the flexibility to tailor health protocols to herd needs. Large herds (500–999 animals) are rare (5%), while the largest operations (1000+ animals) represent 16% of the sample. These larger farms likely have the infrastructure, veterinary support, and record-keeping systems necessary for robust antibiotic stewardship and herd health management. Their presence highlights a spectrum of farm sizes, from very small to very large, within Washington State's dairy sector.

Overall, the predominance of small-scale operations suggests that extension services, educational programs, and stewardship initiatives must be tailored to the resource constraints and management styles of these farms, while also addressing the needs of larger producers who may implement more structured health-management systems.



Herd Size Category	Frequency **(n)**	**Percentage (%)**
Less than 25 dairy animals	9	47
25–99 dairy animals	7	37

100–199 dairy animals	1	5
200–499 dairy animals	3	16
500–999 dairy animals	1	5
1000+ dairy animals	3	16

The distribution of the measured variable across 24 farms is highly right-skewed. The median value of 55 indicates that half of the farms report values at or below 55, suggesting that the "typical" operation falls in a relatively low range. In contrast, the mean of 778 is dramatically higher, reflecting the influence of one or more extreme outliers in this case, a maximum observation of 7,700 that pulls the average upward. The standard deviation of 1,903 further highlights the exceptional variability in the data. While most farms cluster near the lower end (as shown by the minimum of 5 and median of 55), a small subset of farms exhibit very large values, inflating both the mean and the dispersion. This pattern highlights the importance of relying on robust measures such as the median when characterizing central tendency in skewed distributions.

From a practical standpoint, these results suggest two distinct groups within the population: most farms with modest values and a minority of high-intensity operations. Any policy recommendations or management interventions should therefore be tailored accordingly: median-based benchmarks may better represent the everyday experience of most farms, while specialized strategies may be required to address the unique circumstances of the outlier operations.

Statistic	**Value**
Mean	778
Median	55
Minimum	5
Maximum	7,700

SD	1,903
N	24

Across the 24 dairy farms surveyed, the vast majority (15 farms; 62.5%) operate on a small scale, with herd sizes between 1 and 99 animals. These small operations likely rely on more hands-on management, may have tighter margins, and could face greater vulnerability to individual animal health events, but they also possess the agility to implement new health protocols rapidly.

Six farms (25.0%) fall into the medium category (100–499 animals). These mid-sized operations may balance some benefits of scale such as shared labour, greater purchasing power for veterinary supplies, and more formalized keeping with the flexibility to customize management and stewardship practices to herd needs. Only three farms (12.5%) qualify as very large operations (1,000+ animals). These outliers typically have the infrastructure, staff, and veterinary relationships needed to support comprehensive antibiotic-stewardship programs and advanced herd-health monitoring systems. Their practices can disproportionately influence aggregate antibiotic usage metrics and resistance risk, underscoring the importance of including both small and very large farms when designing statewide stewardship initiatives.

Herd Category

Herd Category	**Count (n)**	**Percentage (%)**
Small (1–99 animals)	15	62.5
Medium (100–499 animals)	6	25.0
Very Large (1,000+ animals)	3	12.5

The distribution of the measured metric (e.g. annual antibiotic doses or health-management units) varies markedly by respondent role, reflecting differences in scope of responsibility and scale of operations. The largest group farm owners comprise 19 of the 24 respondents (79.2%). Owners report a mean value of 95 and a median of 47 (range 5–400). The fact that the median is roughly half the mean, together with the modest maximum, indicates that most owners oversee relatively low levels of the activity, with only a few reaching higher intensities. This suggests that owners tend to manage on a more hands-on, limited scale, where the bulk of their workload clusters at the lower end of the spectrum.

By contrast, the eight managers (33.3% of respondents) show both a much higher average (mean = 1,206) and a median (230) that is far below the mean, with values stretching from as little as 9 up to 4,500. The wide gap between median and mean and the very large maximum reveals a heavily right-skewed distribution among managers: while many handle moderate workloads (around 230 units), a small number of managers are responsible for extremely large operations that pull the average upward. This heterogeneity highlights that managerial roles can encompass everything from oversight of modest herd-health programs to the coordination of very large, complex systems.

The single "Employee" respondent (4.2%) reported a mid-range value of 400, which sits above the owner median yet below most manager values. Although this is only one data point, it suggests that employees when directly involved in recording such metrics may operate at levels comparable to mid-sized management workloads, perhaps reflecting a focus on specific operational tasks rather than whole-farm oversight.

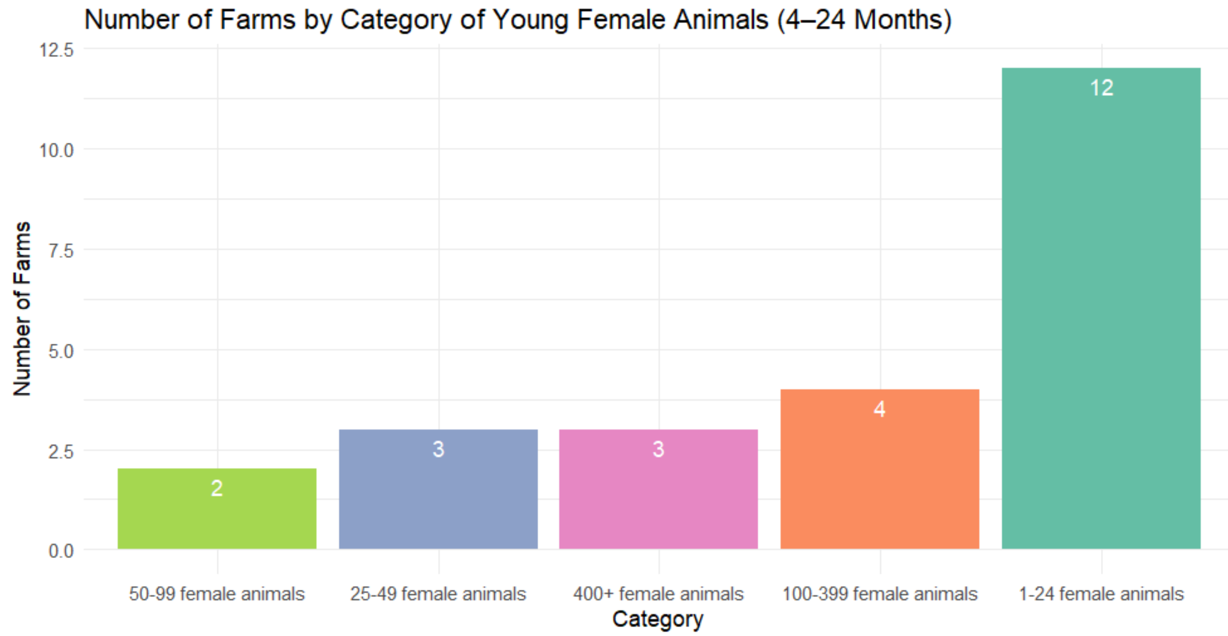
Finally, the lone "Other" respondent, a veterinarian, reported the highest value of 7,700. Representing 4.2% of the sample, this extreme outlier likely reflects aggregate responsibility across multiple farms or a distinct methodological perspective (for instance, total doses administered under veterinary supervision). Its singularity emphasizes the importance of role-based context: veterinary respondents may naturally report far larger totals because their purview spans several operations, whereas on-farm staff report only the figures for their individual farm. Together, these patterns illustrate how roles correlate with both the central tendency and variability of the measured activity. Owners generally manage at lower, more consistent levels; managers exhibit wide-ranging responsibilities with significant outliers; employees occupy an intermediate niche; and veterinarians oversee the largest aggregate volumes. Any interventions—whether training, resource allocation, or policy design should therefore be tailored to these distinct role-based profiles to ensure relevance and effectiveness.

Role	Mean	Median	Min	Max	Count (n)	Percent (%)
Employee	400	400	400	400	1	4.2
Manager	1,206	230	9	4,500	8	33.3
Other	7,700	7,700	7,700	7,700	1	4.2
Owner	95	47	5	400	19	79.2
Total	—	—	—	—	24	100

Half of the surveyed farms (50%) maintain very small pre-calving groups of 1–24 female animals, indicating that most operations in this sample employ limited numbers of heifers in the critical replacement cohort. Such small groups may allow for more individualized care, tighter biosecurity control, and easier monitoring of passive immunity transfer, but they also suggest limited capacity for herd expansion without additional investment. Medium-sized pre-calving groups (100–399 females) account for 16.7% of farms, reflecting operations that balance scale with manageability. These farms likely benefit from some economies of scale in rearing replacements such as shared facilities and labour while still retaining the flexibility to adjust protocols rapidly in response to health challenges. Smaller mid-range groups of 25–49 and 50–99 females together represent 20.8% of respondents. These categories suggest transitional herd sizes where producers may be scaling up replacement programs or experimenting with more structured heifer-rearing systems. Their intermediate position implies both opportunities and challenges: moderate resource requirements but also a need to establish robust protocols to maintain herd health as numbers grow.

Finally, 12.5% of farms maintain very large pre-calving groups (400+ females), indicative of high-throughput replacement systems. These operations must rely on standardized procedures, detailed record-keeping, and likely greater veterinary involvement to ensure uniform passive transfer, vaccination compliance, and biosecurity across large numbers of young stock. Their presence in the sample underlines the diversity of farm scales in Washington State and highlights the need for scalable health-management recommendations that accommodate both small and large replacement enterprises.

Category of Pre-Calving Female Herd Size	**Count (n)**	**Percentage (%)**
1–24 female animals	12	50
25–49 female animals	3	12.5
50–99 female animals	2	8.3
100–399 female animals	4	16.7
400+ female animals	3	12.5
Total	24	100

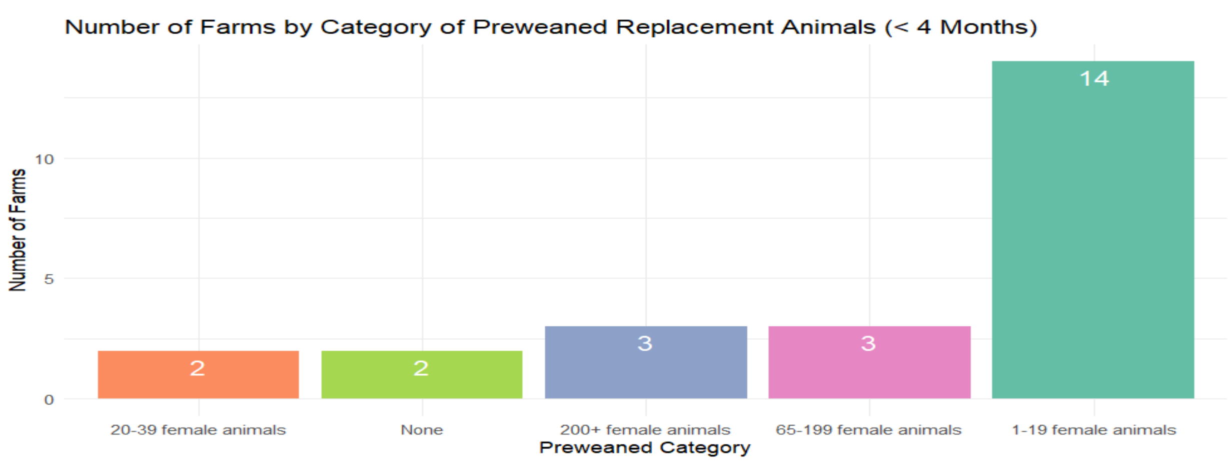


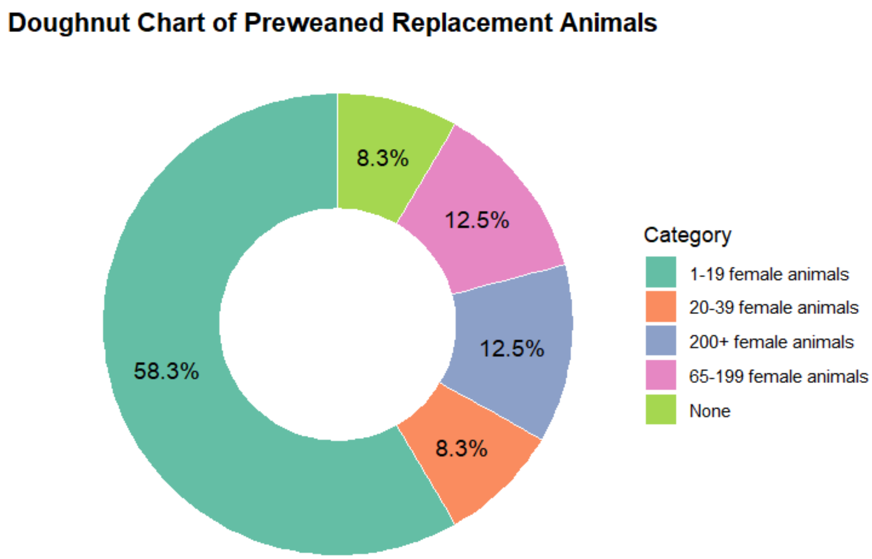
A clear majority of farms (58.3%) rear relatively small cohorts of pre-weaned replacement heifers, just 1–19 females indicating that most operations limit their immediate young-stock population to a size manageable with existing facilities and labor. This small group size likely facilitates individualized feeding and health monitoring, optimizing passive immunity transfer and early disease prevention, but may constrain rapid herd expansion. Mid-sized groups (65–199 and 200+ females) each account for 12.5% of farms. These operations have invested in larger rearing programs, reflecting a strategic emphasis on scale and throughput in their replacement pipeline. Managing such sizable cohorts demands robust protocols for colostrum delivery, sanitation, and group housing to maintain uniform health outcomes and prevent pathogen spread. Smaller intermediate groups of 20–39 females represent 8.3% of respondents, suggesting a transitional phase for some farms that are scaling up their replacement enterprises. These farms face the dual challenge of expanding capacity while establishing the biosecurity and health-management systems needed for larger populations.

Finally, 8.3% of farms reported no pre-weaned replacements, indicating reliance on external sources for heifer supply or seasonal operations without continuous young-stock rearing. These farms may focus resources on lactating herds and outsource replacement rearing to specialized facilities.

Overall, the distribution highlights the diversity of replacement-rearing strategies across Washington State dairy farms, from tightly managed small cohorts to large-scale operations. Extension and stewardship programs should therefore offer tiered recommendations ranging from hands-on protocols for small groups to system-level biosecurity and health-monitoring frameworks for larger cohorts to ensure optimal health and productivity at every scale.

Category of Pre-Weaned Female Replacement Animals	**Count (n)**	**Percentage (%)**
1–19 female animals	14	58.3
20–39 female animals	2	8.3
65–199 female animals	3	12.5
200+ female animals	3	12.5
None	2	8.3
Total	24	100

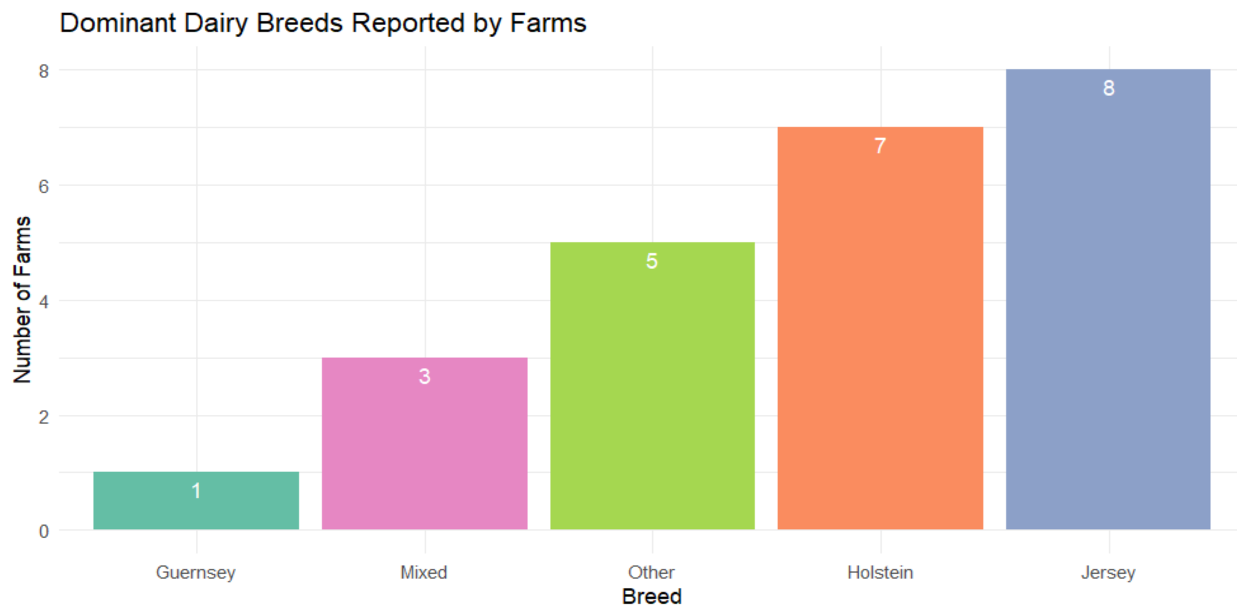




From the breed of dairy animals predominant in farms, Jersey cattle constitute the most common predominant breed among surveyed Washington State dairy farms, representing one-third of operations (33.3%). Known for the high butterfat content in milk and efficient feed conversion, Jerseys may be especially attractive to farms prioritizing product quality and economic efficiency in smaller herd settings. Holsteins follow closely at 29.2%. As the world's most prevalent dairy breed, Holsteins are valued for their high milk volume, making them a logical choice for farms focused on maximizing production. Their substantial representation suggests that many farms balance quantity with operational scale. The "Other" category accounts for 20.8% of farms, indicating a notable presence of less common or specialty breeds such as Brown Swiss, Ayrshire, or dual-purpose crosses chosen for niche market demands or adaptive traits like heat tolerance or disease resistance. In the **'Other'** category, responses indicate a notable representation of dairy goats and sheep, including **East Friesian and Lacaune, both** renowned sheep breeds for high milk production. The presence of **Nubian goats**, which produce rich, high-butterfat milk, points to a diversification into small ruminant dairying among some respondents. One farmer reported managing **goats, sheep, and Milking Shorthorn cattle**, a breed known for its dual-purpose (milk and meat) qualities. Mixed-breed herds comprise 12.5% of respondents. These operations may blend genetic advantages such as hybrid vigour from multiple breeds to optimize health, fertility, and production under local environmental conditions. Mixed herds often reflect innovative management strategies aimed at resilience and sustainability. The **‘Mixed breed’** responses exhibit a complex blend of both traditional and less conventional breeds. For instance, the combination of **Holstein, Guernsey, Jersey, Milking Shorthorn, and Brown Swiss**, including crossbreeds, reflects strategic efforts to capture the advantages of hybrid vigour and breed complementarity in terms of milk composition, disease resistance, and adaptability. The inclusion of **Fleckvieh**, a dual-purpose European breed, and **Brown Swiss**, a hardy, high-producing breed with good temperament, highlights the breadth of experimentation among progressive dairy farms. Guernsey appears least frequently (4.2%), highlighting its status as a specialty breed valued for rich, golden-coloured milk and strong protein composition. Although rare in this sample, Guernseys serve niche markets and emphasize the diversity of breed selection driven by product differentiation goals.

Overall, the distribution of breeds emphasizes the relationship between production objectives, market demands, and farm management strategies. Extension services and stewardship programs should thus tailor breed-specific health and nutrition guidelines, recognizing that Jersey and Holstein operations dominate but that a significant minority of farms work with specialty and mixed genetics requiring customized support.

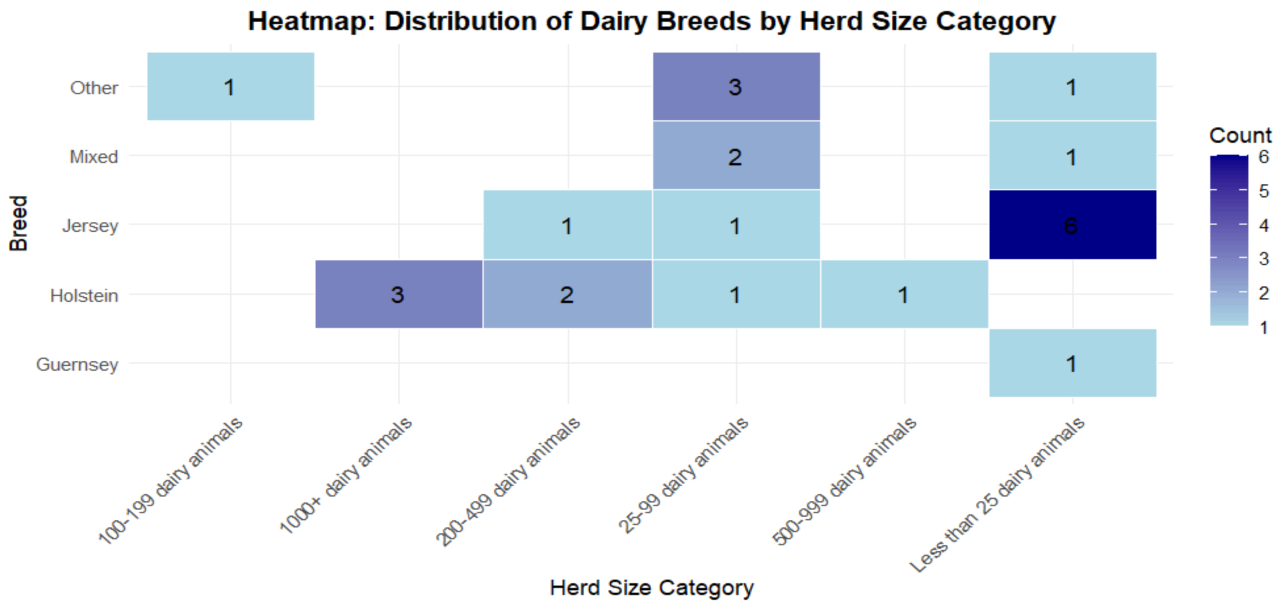
Breed	**Count (n)**	**Percentage (%)**
Jersey	8	33.3
Holstein	7	29.2
Other	5	20.8
Mixed	3	12.5
Guernsey	1	4.2
Total	24	100



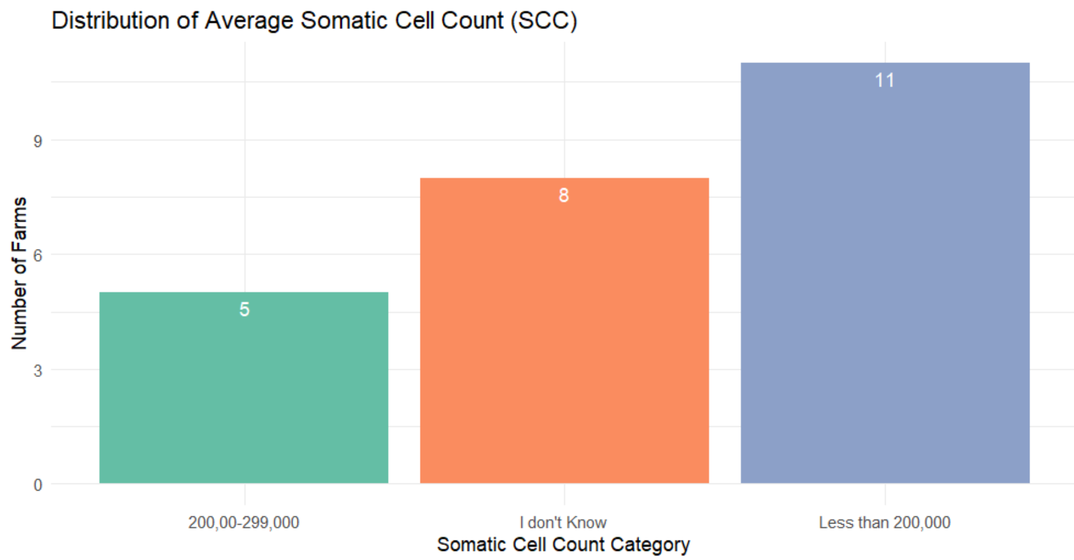
The analysis of breed distribution across different herd size categories reveals nuanced patterns in breed preference and herd management among dairy farms in Washington State. Holsteins are predominantly housed in large-scale operations, with 3 out of 7 Holstein herds (42.9%) found in the 1000+ category and another 1 in the 500–999 range. This trend aligns with the breed's reputation for high milk yield, making it suitable for intensive, production-focused enterprises.

Conversely, Jersey herds appear more concentrated in smaller-scale operations. Of the 8 Jersey farms, 6 (75%) operate with less than 25 dairy animals. This preference likely reflects the breed's suitability for smallholder and artisanal dairies, given their efficiency and higher butterfat content in milk. Only one Jersey herd is found in each of the 25–99 and 200–499 categories, indicating limited presence in medium- to large-scale systems. Mixed-breed herds show a moderate presence in small to mid-sized operations, with two herds in the 25–99 category and one in the smallest category, suggesting the adoption of hybrid vigour strategies in moderately scaled settings. The "Other" category potentially including unique or dual-purpose breeds demonstrates a diversified presence across three herd size levels, especially concentrated in the 25–99 animal range (3 herds). This may indicate a strategic use of alternative breeds to match specific farm goals, such as disease resilience or environmental adaptability. The sole Guernsey herd, a rare breed in the dataset, is operated on a small scale with fewer than 25 animals. This supports the inference that niche breeds are typically kept in low-volume, specialty dairies catering to differentiated product markets.

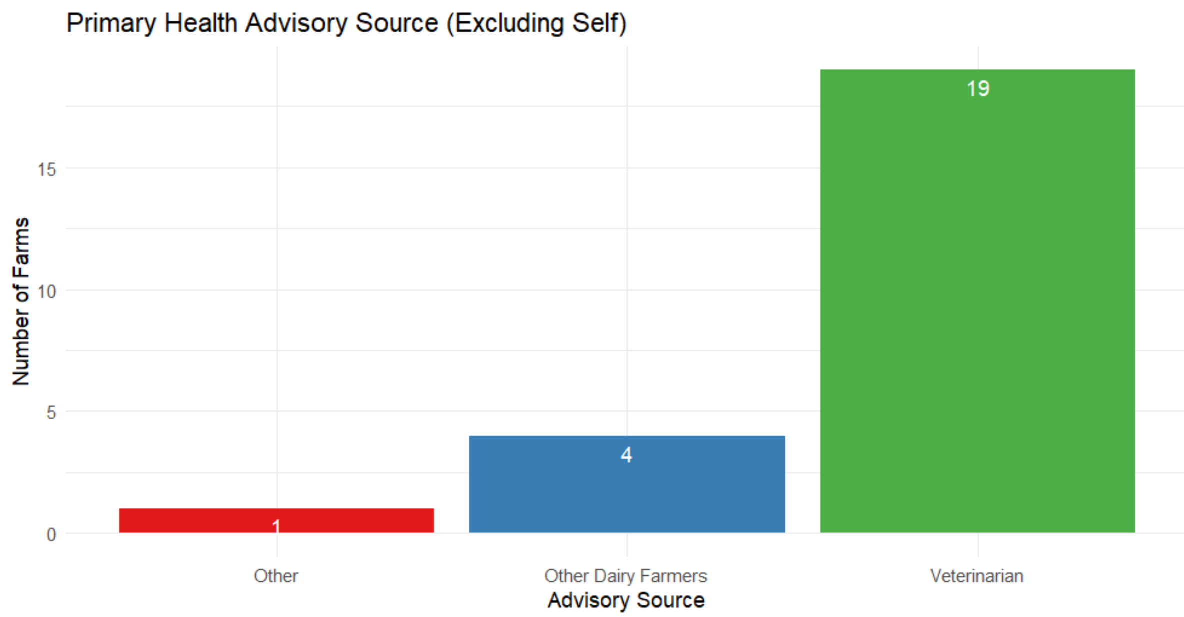
These findings illustrate a clear association between breed type and operational scale, which may have implications for tailored veterinary care, breeding programs, and antimicrobial stewardship.



Nearly half of respondents 11(45.8%) report maintaining herd average somatic cell counts below 200,000 mL, indicating strong udder health and milk quality control on those farms. Keeping SCC under this threshold aligns with industry best practices to minimize mastitis incidence and meet premium milk‑price standards. About one‑fifth of farms 8(20.8%) recorded SCC in the 200,000–299,000 range. While still within many regulatory and quality limits, this intermediate band signals room for improvement in milking hygiene or mastitis prevention protocols to push counts downward and reduce the risk of subclinical infections. Notably, one‑third of respondents 5 (33.3%) did not know their herd's average SCC. This knowledge gap highlights an opportunity for extension outreach: encouraging routine SCC monitoring and record‑keeping will empower these producers to detect udder‑health issues earlier, refine management practices, and optimize milk quality.



When managing herd health challenges, most respondents 19 out of 24 farms (79.2%) identify their veterinarian as the primary source of guidance and support. This reliance underlines the central role of veterinary expertise in diagnosing illnesses, prescribing treatments, and advising on preventive protocols such as vaccination schedules and biosecurity measures. Veterinarian-led oversight is a key pillar of antimicrobial stewardship, ensuring that antibiotic use is both medically justified and aligned with best-practice guidelines. A smaller segment of 4 farms (16.7%) turn to other dairy farmers for advice. Peer-to-peer consultation can be valuable for sharing practical, experience-based insights into farm-level interventions, creative management hacks, and locally adapted solutions. While farmer networks provide accessible support, these respondents may benefit from complementary veterinary input to validate and refine peer-recommended strategies, particularly around antibiotic decision-making. Only 1 farm (4.2%) indicated "Other" as their primary health-support source, suggesting a reliance on non-traditional advisors (such as feed suppliers, extension agents, or online resources). This minority highlights the importance of ensuring that all advisory channels maintain accurate, evidence-based information especially when it comes to antibiotic stewardship and disease prevention so that even non-veterinary sources reinforce sound animal-health practices.

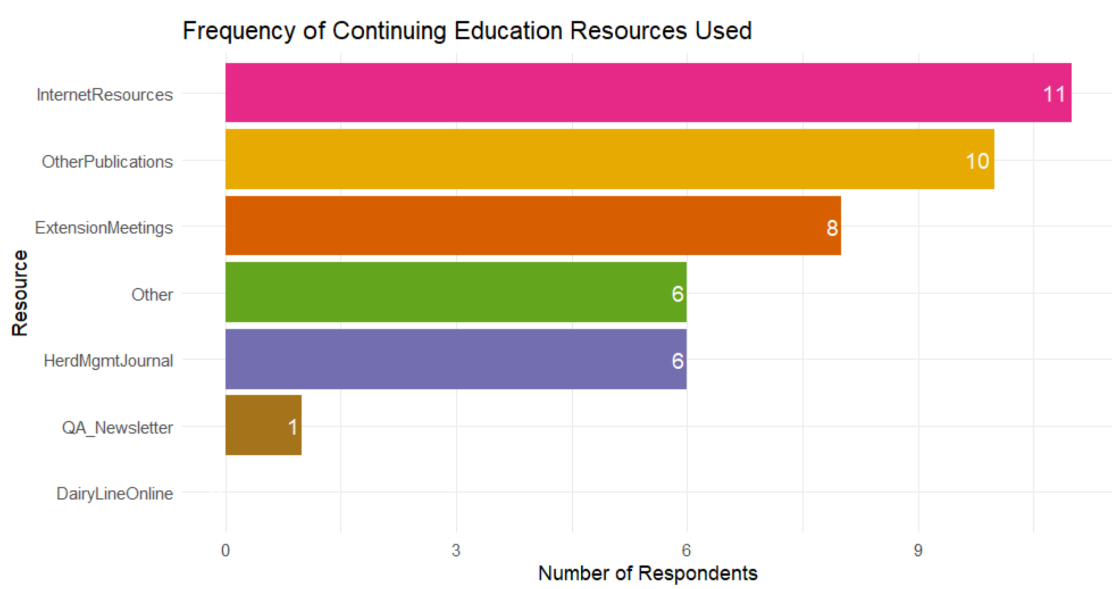


A plurality of producers—11 farms (45.8%)—report using general internet resources for continuing education. This high reliance on online materials likely reflects the convenience and breadth of information available digitally, enabling farmers to quickly access articles, webinars, and discussion forums on herd health and antibiotic stewardship.

"Other Publications" (41.7%, n = 10) and "Herd Management Journal" (25.0%, n = 6) are also key print or subscription-based sources. Their continued use indicates that many producers value peer-reviewed articles and industry-specific newsletters for in-depth, curated content on best practices and emerging research. The relatively lower uptake of the QA Newsletter (4.2%, n = 1) suggests that quality-assurance bulletins may have niche appeal or limited distribution among this group.

Extension meetings and conferences attract one-third of respondents (33.3%, n = 8), demonstrating the importance of in-person workshops and networking events. These forums provide direct access to experts, hands-on demonstrations, and peer exchange, which can be critical for adopting complex practices such as antimicrobial stewardship protocols. A quarter of producers (25.0%, n = 6) indicated "Other" resources—potentially including veterinarian-led trainings, farm-consultant visits, or specialized trade shows—highlighting that customized or locally organized educational offerings play a meaningful role alongside mainstream channels. Notably, no respondents reported using Dairy Line Online, suggesting either limited awareness or perceived relevance of that platform within this cohort. Overall, the diversity of resources emphasizes the need for multi-modal extension strategies, combining digital, print, and face-to-face formats to effectively reach and engage dairy producers in ongoing education about animal health and antibiotic stewardship.

Continuing Education Resource	**Count (n)**	**Percentage (%)**
Herd Management Journal	6	25.0
QA Newsletter	1	4.2
Other Publications	10	41.7
Internet Resources	11	45.8
Extension Meetings & Conferences	8	33.3
Other	6	25.0
Total respondents	**24**	**100**



Animal Health Management and Hygiene Practices

From the Animal Health Management and Hygiene Practices, routine health checks top the list, with 21 of 24 farms (87.5%) conducting regular examinations of their animals. This near-universal practice highlights producers' focus on early disease detection catching problems before they require antibiotic intervention. Personal hygiene measures are also widely adopted: 18 farms (75.0%) require glove use, and 16 farms (66.7%) enforce handwashing. These steps form a frontline defense against pathogen transmission between stock and staff, reducing infection pressure in the herd.

Environmental and animal-care protocols show moderate uptake. Daily cleaning is performed by 8 farms (33.3%), matching the use of regular grooming and footbath treatments (each 8 farms, 33.3%). Such measures target barn hygiene and hoof/skin health, helping to prevent mastitis and lameness common triggers for antibiotic therapy.

Colostrum testing is carried out by 6 farms (25.0%), indicating that one-quarter of producers actively monitor passive immunity in calves. While this practice can significantly reduce neonatal illness, its lower adoption suggests an opportunity for extension programs to promote its benefits more broadly. No farms (0.0%) reported mask usage, reflecting that airborne biosecurity via masks is not considered a priority in these dairy settings compared to contact-based controls.

Overall, the data reveal a layered preventive strategy: a strong emphasis on health monitoring and personal hygiene, complemented by targeted environmental and animal-care practices, with room to expand colostrum testing for improved calf health and reduced antibiotic reliance.

Preventive Measure	**Frequency (n)**	**Percentage (%)**
Colostrum Testing	6	25.0
Daily Cleaning	8	33.3
Handwashing Enforced	16	66.7
Gloves Usage	18	75.0
Masks Usage	0	0.0
Regular Grooming	8	33.3
Footbath Treatments	8	33.3

Routine Health Checks	21	87.5
Total respondents	**24**	**100%**

Purchasing Practices & Disease Screening

Among the seven farms that purchased replacement animals in the past two years, quarantine practices showed considerable variation. One farm (14.3%) did not separate new arrivals at all, immediately introducing them into the main herd. This approach poses the highest biosecurity risk, as latent infections may go undetected and spread rapidly. Two farms (28.6%) isolated newcomers for only 24 hours, a minimal separation that may allow for observation of overt clinical signs but is unlikely to capture diseases with longer incubation periods. Another two farms (28.6%) implemented a moderate quarantine of 1–13 days, striking a balance between operational constraints and disease detection; this duration can reveal many acute infections but may still miss subacute or chronic pathogens. One farm (14.3%) extended quarantine to 14–27 days, aligning more closely with veterinary recommendations by covering the typical incubation windows for a broader range of diseases. Finally, one farm (14.3%) practiced the most stringent biosecurity, maintaining separation for four weeks or more, thereby maximizing the likelihood of identifying both acute and delayed-onset illnesses before herd integration.
Disease screening was nearly universal among these operations: six out of seven farms (85.7%) conducted pre-entry testing on purchased animals. The scope of diagnostics was comprehensive, encompassing routine veterinary health panels, brucellosis and tuberculosis assays, and targeted screenings for bovine viral diarrhea (BVD), ovine progressive pneumonia (OPP), caseous lymphadenitis (CL), and Johne's disease. One respondent specifically mentioned using the Washington Animal Disease Diagnostic Laboratory (WADDL) for goat biosecurity screening, illustrating tailored protocols for mixed-species operations. Even the farm that had not purchased animals in over two years maintained its screening regimen, indicating institutionalization of biosecurity measures irrespective of purchase frequency.

Together, these findings highlight both strengths and opportunities in current quarantine and screening practices on Washington State dairy farms. While the high rate of disease testing demonstrates strong awareness of pathogen risks, the variability in quarantine durations suggests inconsistent application of best‑practice guidelines. Farms employing only brief separations remain vulnerable to introducing infections with longer incubation times, potentially leading to disease outbreaks that necessitate antibiotic interventions. Encouraging all farms to adopt a minimum quarantine period of 14–28 days, in conjunction with broad‑spectrum disease screening, would bolster herd immunity, reduce the reliance on antibiotics, and strengthen overall antimicrobial stewardship across the region.

Animal Purchase, Quarantine, and Disease Screening Practices on Dairy Farms

Quarantine Practice for Purchased Animals	**Frequency (n)**	**Percentage (%)**
Not separated	1	14.3
Separated ≤ 24 hours	2	28.6
Separated 1–13 days	2	28.6
Separated 14–27 days	1	14.3
Separated ≥ 4 weeks	1	14.3
Total purchased animals	**7**	**100.0**
Disease Screening Conducted?	**Frequency (n)**	**Percentage (%)**
Yes	6	85.7
No	1	14.3
Total purchased animals	**7**	**100.0**

Diseases Screened (n = 6 farms)

Vet screens; brucellosis; tuberculosis; biosecurity screen for goats through WADDL; BVD; OPP; CL; Johne's disease (JD)

Objective 1: What are the current antibiotic usage patterns, management practices, and preventive health protocols in Washington State dairy farms?

Types of Antibiotics Used

The predominance of "NA" responses for lameness treatment 23 out of 24 farms suggests that antibiotics are rarely the first line of defense against lameness. Instead, producers appear to favour non-antibiotic interventions such as hoof trimming, corrective shoeing, or topical therapies. The single report of Polyflex use, a topical anti-inflammatory and analgesic, highlights this focus on supportive care rather than systemic antimicrobial therapy for hoof and limb conditions. For respiratory infections, 21 farms again left antibiotic fields blank, indicating limited reliance on antibiotics or a standardized protocol that respondents assumed need not be detailed. Among the three farms specifying drugs, the use of long-acting cephalosporins Excede for adult cows and Resflor for calves reflects age-specific strategies to manage bovine respiratory disease complex. Additional mentions of tulathromycin (a macrolide), florfenicol (a phenicol), and ampicillin (an aminopenicillin) demonstrate that when antibiotics are employed, farmers choose broad-spectrum agents recommended for respiratory pathogens. The lone Polyflex entry may indicate occasional off-label use for inflammation control in respiratory cases. Mastitis therapy appears more uniformly recognized: 19 respondents left the antibiotic field blank, likely relying on well-established intramammary protocols. The five detailed responses reinforce cephalosporins' central role Spectramast and Spectramast LC (both ceftiofur formulations) accounted for three entries while penicillin G ("ToDay or Pen G") represented a narrow-spectrum choice aligned with pathogen susceptibility profiles. This pattern suggests that, for mastitis, dairy producers adhere closely to recommended intramammary antibiotic regimens, reserving broad-spectrum agents for more severe or refractory cases.

Overall, the data reveals a judicious, condition-specific approach to antibiotic use on Washington State dairy farms. Lameness is largely managed without systemic antibiotics, respiratory treatments employ targeted broad-spectrum drugs only when needed, and mastitis care follows standard intramammary antibiotic protocols. The high frequency of blank entries may reflect farmer confidence in established, routine practices that were not elaborated in the survey, indicating that antibiotics are reserved for clearly defined clinical scenarios rather than used prophylactically or indiscriminately.

Frequency of Antibiotic Use by Condition

Condition	**Antibiotics (Individual Responses)**	**Frequency**

Lameness Treatment	NA (no antibiotic specified)	23
	Polyflex	1
Respiratory Treatment	NA (no antibiotic specified)	21
	Excede (cows), Resflor (calves)	1
	Tulathromycin, Florfenicol, Ampicillin	1
	Polyflex	1
Mastitis Treatment	NA (no antibiotic specified)	19
	Ceftiofur intramammary suspension (Spectramast)	1
	ToDay or Pen G (penicillin)	1
	Spectramast LC (Ceftiofur)	1
		1

The analysis of the reported antibiotic use on dairy farms reveals a varied but patterned distribution of antimicrobial agents, reflecting prevailing practices in veterinary care, prioritization of specific conditions, and potentially antimicrobial stewardship awareness.

A total of 24 responses were analyzed under the variable "Antibiotics_Used." The most mentioned antibiotic classes were **cephalosporins** and **penicillins/aminopenicillins**, each recorded in 33.3% of the reports. Cephalosporins such as ceftiofur (marketed under names like Excede, Excenel, and Spectramast) were often cited in the treatment of mastitis. These agents are known for their efficacy against Gram-negative and Gram-positive organisms and are approved for use in food-producing animals under specific withdrawal times. Their frequency suggests a reliance on intramammary and systemic cephalosporin therapies, particularly for treating udder infections, one of the most common health issues in dairy herds.

Similarly, **penicillins** and **aminopenicillins** (penicillin G, ampicillin, and those in Clavamox) were cited with equal frequency, underscoring their continued use as broad-spectrum antibiotics for conditions such as mastitis, respiratory infections, and general systemic infections. The combination of cephalosporins and penicillins as first-line antibiotics reflects their favorable safety profile, effectiveness, and longstanding role in veterinary medicine. The **macrolide** class, including tulathromycin and draxxin, was reported less frequently (12.5%). Macrolides are often used for respiratory conditions due to their ability to concentrate in lung tissue. Their relatively low frequency might reflect prudent use or specific targeting for respiratory cases, rather than routine application. A similar pattern was observed with **tetracyclines**, such as oxytetracycline and tetracycline, also reported in 12.5% of responses. These antibiotics are used for a variety of infections, including foot rot and respiratory conditions, but their reduced usage could be indicative of a shift toward more targeted antimicrobial strategies.

The **phenicol** class, particularly florfenicol found in Resflor and Nuflor, appeared in 12.5% of reports. Phenicols are broad-spectrum and reserved for respiratory diseases, and their use typically suggests a more severe or resistant case profile. Interestingly, one respondent listed **sulfamethoxazole–trimethoprim (Bactrim)**, a sulfonamide combination rarely used in dairy due to residue concerns, possibly indicating off-label or anecdotal application.

Additionally, **fluoroquinolone** use (specifically enrofloxacin) was cited only once (4.2%), reflecting strict regulatory controls surrounding its use in food animals due to concerns over antimicrobial resistance and public health. Such rare usage aligns with global efforts to restrict fluoroquinolones in livestock settings.

A significant proportion of respondents (16.7%) selected "NA" for antibiotic use, while 20.8% provided responses like "none," "not relevant," or "don't use." This suggests that either no antibiotic treatments were administered during the reporting period or there was reluctance or uncertainty in reporting. This could reflect effective herd health management practices, seasonal factors, or a possible underreporting bias. Furthermore, a few responses (e.g., "Why?") indicated possible confusion or skepticism toward the survey question, underscoring the need for clearer communication in data collection instruments. There were also instances of combination therapies reported, such as polyflex with banamine or "Pen one + tetracycline," which suggest integrated approaches combining antibiotics with anti-inflammatory agents or using synergistic combinations to broaden antimicrobial coverage.

In summary, the data reflects a predominant reliance on cephalosporins and penicillins for managing common dairy cattle diseases, particularly mastitis and respiratory ailments. The relatively limited mention of higher-tier or critically important antibiotics for human medicine, such as fluoroquinolones and sulfonamides, may indicate compliance with antimicrobial stewardship principles. However, the presence of vague or non-responses signals the need for improved antibiotic usage tracking systems on farms to ensure both transparency and responsible antibiotic administration. These findings are crucial in informing policy, training, and regulatory oversight on dairy antibiotic practices, as well as in guiding future interventions aimed at reducing antimicrobial resistance.

Antibiotic Class	**Specific Agents**	**Frequency (n)**	**% of 24 farms**
No response / NA	NA	4	16.7%
Cephalosporins	Ceftiofur; Spectramast (ceftiofur); Spectramast LC (ceftiofur); Cephipirin	8	33.3%
Penicillins/Aminopenicillins	Penicillin G; Ampicillin; Amoxicillin (in Clavamox)	8	33.3%
Macrolides	Tulathromycin; Draxxin	3	12.5%
Tetracyclines	Oxytetracycline ("oxytetrac"); Tetracycline	3	12.5%
Phenicols	Florfenicol (Resflor/Nuflor); Chloramphenicol (in Bactrim)	3	12.5%
Sulfonamides/Trimethoprim	Sulfamethoxazole–trimethoprim (Bactrim)	1	4.2%
Fluoroquinolones	Enrofloxacin	1	4.2%
Combination / Multiple classes	Excenel (ceftiofur); Polyflex+Banamine (β-lactam + NSAID); "Pen one + Tetracycline" (penicillin + tetracycline)	3	12.5%
"None" / Not relevant	"Don't use," "None," "None thus far," "Not relevant," "Why?"	5	20.8%

Antibiotic usage across various herd size categories

The summary table detailing antibiotic usage across various herd size categories provides valuable insights into the distribution and application of antimicrobial agents in dairy operations of differing scales. Four distinct herd size categories were reported: 25–99, 100–199, 500–999, and 1000+

dairy animals. Each category had at least one farm that reported the use of antibiotics, though the overall frequency of reporting was relatively low, which may indicate limited antibiotic use or underreporting. **Small-scale operations (25–99 dairy animals)** accounted for two farms using antibiotics. The antibiotics reported within this category were *Spectramast* and *Spectramast LC (Ceftiofur)*, both of which are third-generation cephalosporins widely used in the treatment of mastitis in dairy cattle. Their use in smaller herds suggests that even modest-scale dairy farms rely on advanced intramammary antibiotic formulations to manage udder health, perhaps reflecting either the prevalence of mastitis or a proactive therapeutic approach.

Medium-scale operations (100–199 dairy animals) reported the use of *ToDay* or *penicillin*. *ToDay* is the brand name for cephapirin sodium, another intramammary antibiotic approved for lactating dairy cows. Penicillin, a β-lactam antibiotic, is often used systemically or intramammarily for infections like mastitis or metritis. This indicates a continued reliance on classic, broad-spectrum antibiotics among mid-sized farms, potentially due to cost-effectiveness and familiarity. In **larger herd categories**, antibiotic use appeared more targeted. Among farms with **500–999 dairy animals**, *Spectramast* was reported. Its usage at this scale aligns with the routine protocols implemented in larger herds to control mastitis in high-producing animals. For farms with **1000 or more dairy animals**, a single respondent reported the use of *Ceftiofur intramammary suspension*, another third-generation cephalosporin. The use of such advanced antibiotics in large operations might reflect both the scale of disease management challenges and adherence to standardized treatment protocols under veterinary oversight.

Overall, the data indicate that **mastitis-related antibiotic therapies dominate across all herd sizes**, particularly involving **cephalosporins such as ceftiofur and cephapirin**. While the sample size is small, the pattern suggests consistent treatment strategies regardless of herd size, though the specific brands or formulations may vary. This uniformity might be driven by common industry recommendations and the need for effective, fast-acting agents that ensure milk quality and udder health. Importantly, the data also highlights the necessity of promoting responsible antibiotic use practices uniformly across farm sizes to combat antimicrobial resistance, especially concerning the use of critically important antibiotics in food-producing animals.

Herd Size Category	**Farms Using Antibiotics**	**Antibiotics Used**
25–99 dairy animals	2	Spectramast, Spectramast LC (Ceftiofur)
100–199 dairy animals	1	ToDay or Penicillin
500–999 dairy animals	1	Spectramast
1000+ dairy animals	1	Ceftiofur Intramammary Suspension

Frequency of Antibiotic Use

The table reports that, on average, only about 9.6 percent of farms top-dress feed with antibiotics and even then, only "never" or "during outbreaks of disease" (i.e. no routine or preventive use). Crucially, zero farms indicated they ever top-dress any age group, calves under four months, weaned heifers, older juveniles, lactating cows or dry cows.

Such uniformly nil usage across all animal categories suggests that Washington State dairy producers have almost entirely abandoned feed-based antibiotic administration except in the most acute situations. This pattern aligns closely with modern antimicrobial stewardship principles, which discourage non-therapeutic antibiotic applications (e.g. for growth promotion or routine disease prevention) and reserve them for bona fide disease events under veterinary oversight.

By eschewing prophylactic (top-dressing) in all herd segments, producers demonstrate a high level of compliance with both regulatory expectations (e.g. FDA's Veterinary Feed Directive) and consumer demands for judicious antibiotic use. Moreover, this restraint likely reflects broader management changes enhanced biosecurity, vaccination, nutrition and housing improvements that reduce reliance on antibiotics overall.

In sum, the data indicate that dairy farms in this study are practicing conservative, targeted antibiotic use consistent with national and international calls to curb antimicrobial resistance, deploying feed-based antibiotics only as an emergency response rather than as a routine health-management too

Average Annual Percentage	Conditions for Top-Dressing	Animals < 4 Months	Weaned Animals < 12 Months	Animals 12–24 Months	Lactating Animals	Dry Animals
9.56%	Never, During outbreaks of disease	0	0	0	0	0

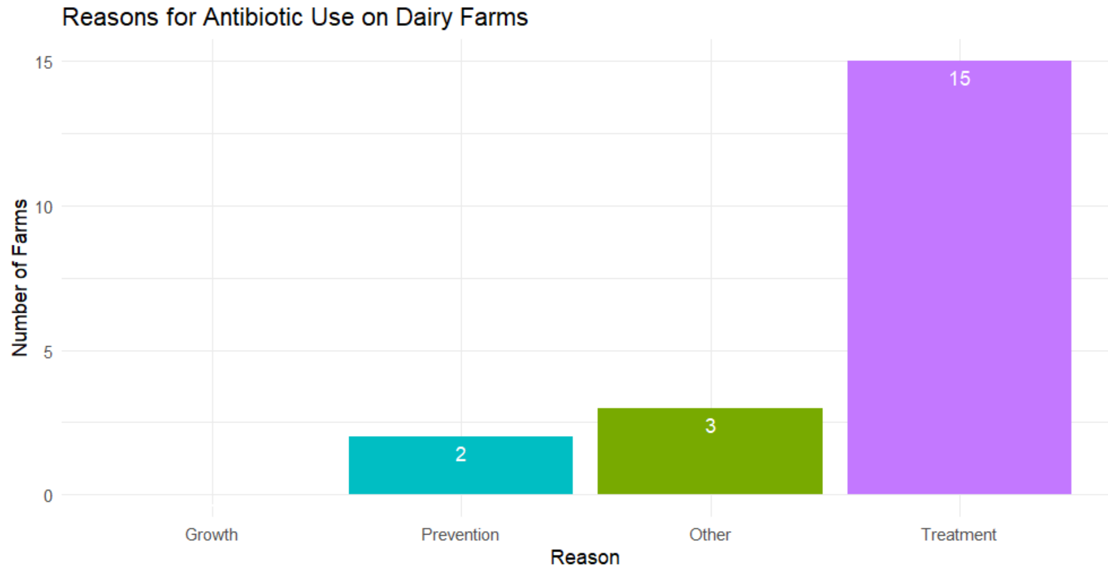
Reasons for Antibiotic Administration

Most respondents 15 farms (75.0%) use antibiotics primarily for the treatment of clinical illness, highlighting that antibiotic administration is being reserved largely for therapeutic purposes rather than routine application. This pattern aligns with antimicrobial stewardship goals that emphasize treating sick animals rather than using antibiotics indiscriminately.

A small proportion of 2 farms (10.0%) reported antibiotic use for prevention. While prophylactic applications can help control potential outbreaks within a herd, the relatively low frequency suggests most producers prefer to rely on targeted therapeutic interventions, biosecurity measures, or vaccination protocols to manage disease risk rather than routine preventive antibiotic dosing.

No respondents (0.0%) indicated using antibiotics for growth promotion, reflecting adherence to regulatory restrictions and industry best practices that discourage subtherapeutic antibiotic use for productivity enhancement. This absence confirms that growth-promotion through antibiotics is no longer practiced among these Washington State dairy operations.

Three farms (15.0%) selected “Other” as their reason for antibiotic use. This category likely captures less common or situational practices such as metaphylactic treatment of groups following an initial case or emergency herd-level interventions that fall outside the standard treatment/prevention dichotomy. Further qualitative follow-up would help clarify these "Other" uses to ensure they are consistent with stewardship principles and to guide any needed education on judicious antibiotic application.

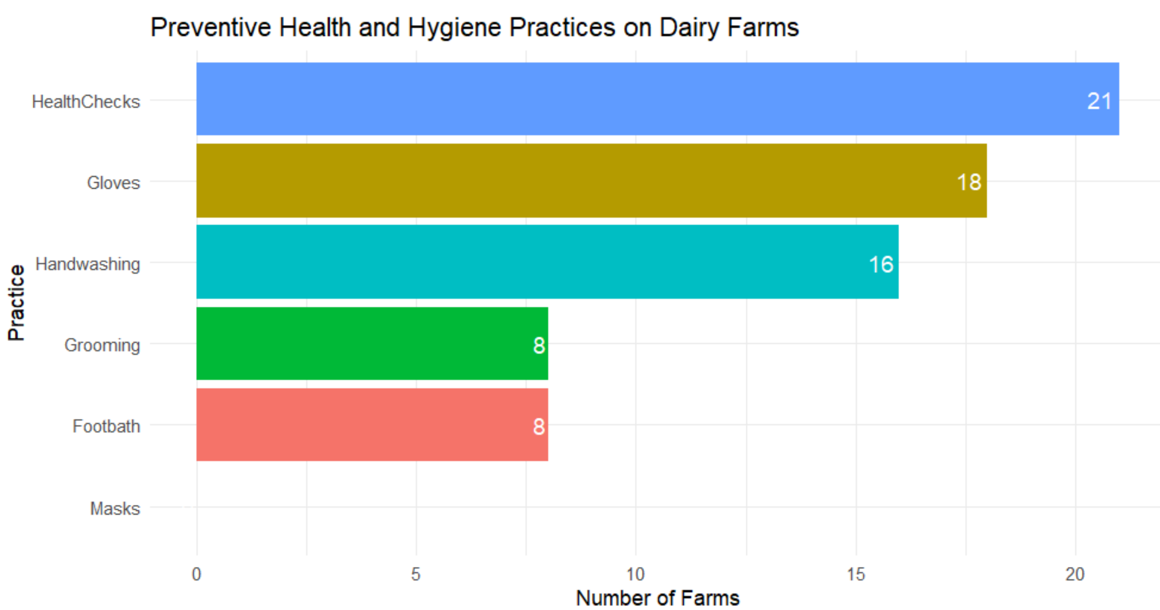


Reason for Antibiotic Use	**Count (n) (Percentage)**
Treatment	15 (75.0%)
Prevention	2 (10.0%)
Growth	0 (0.0%)
Other	3 (15.0%)
Total	**20 (100%)**

Producers consistently implement routine health checks, with 21 farms (87.5%) reporting regular monitoring of animal health indicators. This high rate of health checks demonstrates a proactive approach to disease detection, enabling early intervention that can reduce the need for antibiotic treatments.

Wearing gloves is practiced on 18 farms (75.0%), and handwashing is enforced on 16 farms (66.7%). Together, these personal-hygiene measures form the first line of defense against disease transmission between animals and caretakers, helping to maintain herd health and limit infection spread. Regular grooming and footbath treatments are each used by 8 farms (33.3%). These practices contribute to skin and hoof health, lowering the incidence of lameness and mastitis common conditions that often necessitate antibiotic therapy. Although less widespread than basic hygiene measures, grooming and footbaths remain important components of a comprehensive preventive health protocol. Notably, no farms (0.0%) reported mask-wearing as a preventive measure. This likely reflects the focus on preventing disease transfer via direct contact or fomites rather than airborne pathogens in typical dairy settings. Overall, the combination of high adoption rates for health checks, glove use, and handwashing indicates that Washington State dairy producers prioritize practical, evidence-based measures to prevent disease and reduce reliance on antibiotics.

Preventive Practice	Count (n) (Percentage)
Handwashing	16 (66.7%)
Wearing Gloves	18 (75.0%)
Wearing Masks	0 (0.0%)
Regular Grooming	8 (33.3%)
Footbath Treatments	8 (33.3%)
Routine Health Checks	21 (87.5%)
Total respondents	**24 (100%)**



The vaccination data reveal a striking lack of consensus among Washington State dairy producers regarding three key viral threats Bovine Respiratory Syncytial Virus (BRSV), Bovine Viral Diarrhoea (BVD), and Infectious Bovine Rhinotracheitis (IBR). For each disease, roughly half of the surveyed farms choose to vaccinate while the other half do not, indicating divergent perceptions of risk, cost–benefit trade-offs, and alternative management strategies.

For BRSV, 8.9 percent of farms vaccinate compared to 8.1 percent that do not. This near-parity suggests that although many producers recognize the respiratory and performance losses BRSV can inflict especially in young stock an almost equal number remain unconvinced of vaccine value or instead rely on environmental controls (improved ventilation, reduced stocking density) or metaphylactic antibiotic use to mitigate outbreaks.

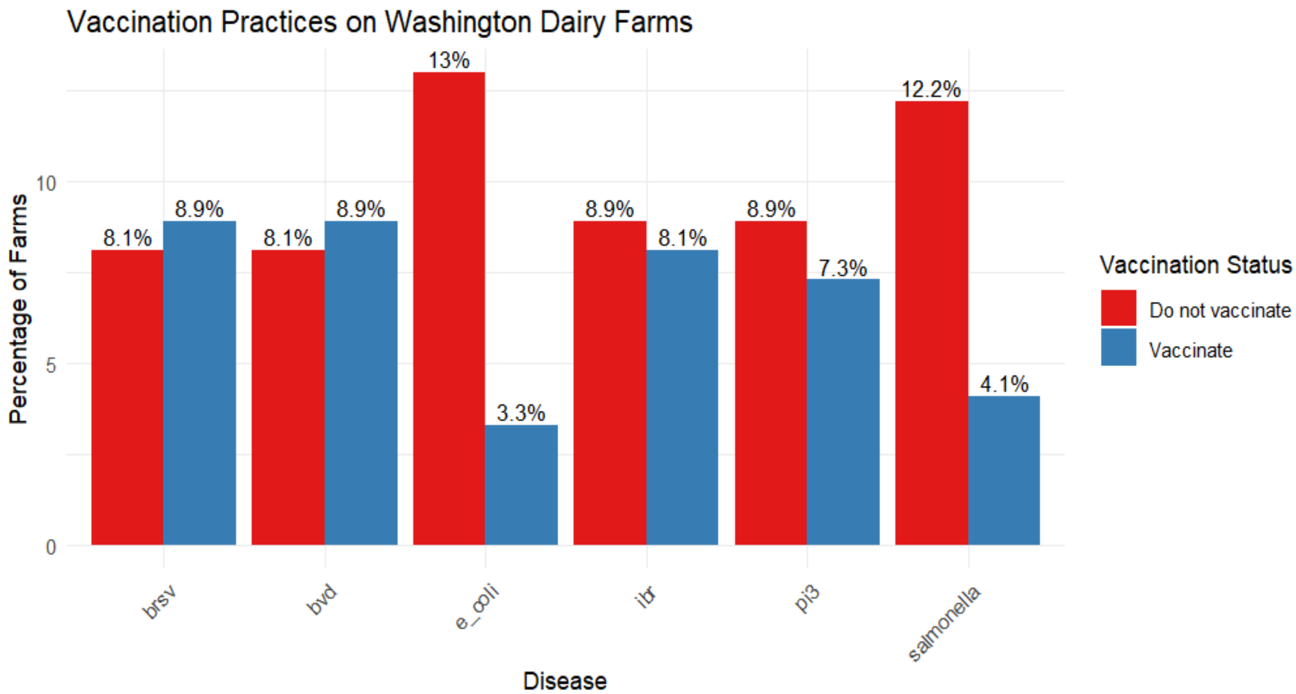
Similarly, BVD vaccination is practiced by 8.9 percent of respondents and declined by 8.1 percent. BVD's well-documented impacts on reproduction and immune function would favour universal vaccination, yet the split implies that some farms perceive their biosecurity measures (closed herd, testing of incoming stock) as sufficient protection. Others may defer vaccination due to cost concerns or skepticism about vaccine strain coverage versus circulating viral variants. For IBR, slightly more farms opt out (8.9 percent) than vaccinate (8.1 percent). This suggests a modest lean toward controlling IBR via non-vaccinal tactics such as stringent animal movement controls, herd certification programs, or reliance on natural immunity perhaps reflecting doubts about vaccine efficacy across diverse field strains.

In contrast to the roughly even split seen for BRSV, BVD and IBR, vaccination against Parainfluenza-3 (PI3) and Salmonella shows a clear skew toward non-vaccination, suggesting that producers perceive different risk–benefit profiles for these pathogens.

For PI3, 8.9 percent of farms reported that they do not vaccinate, while only 7.3 percent do. Although the gap is modest, it indicates that a slight majority of producers rely on non-vaccine measures such as enhanced ventilation, all-in/all-out grouping or metaphylactic antibiotic protocols to manage PI3's contribution to bovine respiratory disease complexes. The lower uptake may reflect doubts about the incremental benefit of PI3 vaccines in herds where other respiratory vaccines are already in use or concerns that maternal antibody interference reduces vaccine efficacy in young calves.

Salmonella vaccination exhibits the largest disparity of all six diseases surveyed: 12.2 percent of farms do not vaccinate, compared with just 4.1 percent that do. This nearly three-to-one ratio suggests that many producers question the cost-effectiveness or field performance of Salmonella vaccines, perhaps relying instead on rigorous hygiene, feed management, and biosecurity to control enteric infections. The relatively low vaccination rate may also reflect the diversity of Salmonella serotypes in the environment and uncertainty as to whether the available vaccines cover the most prevalent strains on a given farm. Vaccination against *Escherichia coli* mastitis is by far the least-adopted of the six disease targets surveyed. While 13 percent of Washington dairy farms reported that they do not vaccinate against *E. coli*, only 3.3 percent actually do. This wide gap indicates that most producers rely entirely on non-vaccine measures, improved hygiene at milking, stringent environmental management in the calving and housing areas, and prompt treatment protocols to control *E. coli* mastitis rather than on immunization.

Together, these patterns reveal that Washington dairy producers make nuanced decisions on viral versus bacterial vaccine use embracing immunization where perceived return on investment is high yet favoring alternative controls when vaccine efficacy or economics are less certain. Targeted education on vaccine performance under local conditions, combined with economic modeling of disease losses versus vaccination costs, could help farms refine their protocols potentially increasing uptake where it will yield the greatest herd-health and antimicrobial-stewardship benefits.



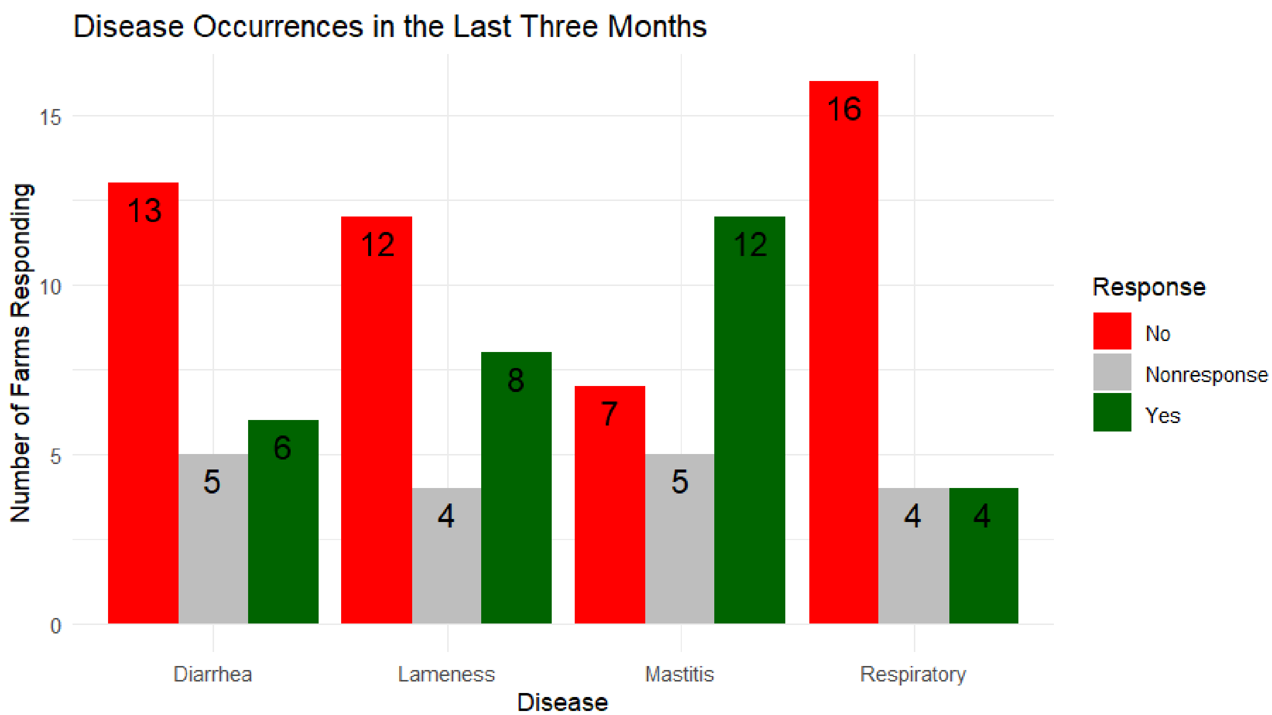
Clinical Condition Occurrence on Dairy Farms (Last 3 Months)

The survey results from 24 respondents indicate varying levels of recent disease occurrence within dairy herds. The four primary clinical conditions assessed were mastitis (udder inflammation or abnormal milk), respiratory infections, diarrhea, and lameness.

Mastitis was the most frequently reported condition, with exactly half (12/24; 50.0%) of the respondents confirming its occurrence within the past three months. This highlights its prevalence in dairy operations and the continued importance of udder health management. A non-negligible portion of farms (29.2%) did not experience clinical mastitis recently, while 20.8% of the responses were missing—likely due to either non-occurrence or survey non-completion. **Respiratory infections** were relatively uncommon during the reporting period. Only 4 farms (16.7%) indicated recent cases, whereas two-thirds (66.7%) reported no such health issues. This may reflect good ventilation, vaccination protocols, or low seasonal incidence at the time of data collection. **Diarrhea**, another critical health concern especially in younger stock, was reported by a quarter of farms (25.0%). The majority (54.2%) indicated no recent occurrence, suggesting that most farms may have effective calf management and feeding protocols in place. However, the 20.8% nonresponse rate might hide unreported or overlooked cases. **Lameness** was reported by one-third of farms (33.3%), making it the second most common issue after mastitis. This condition impacts both welfare and productivity and often reflects management factors such as housing, flooring, and hoof care. Half of the respondents (50.0%) stated no recent cases of lameness, which could indicate successful preventive programs in place. The remaining 16.7% did not provide a response.

These results suggest that mastitis and lameness remain significant animal health concerns in Washington dairy herds. In contrast, respiratory disease and diarrhea appear less frequent during the observed period, though both still affect a minority of farms. These patterns offer useful direction for targeted interventions and continued refinement of herd health protocols.

Condition	**Yes (Occurrence)**	**No (No Occurrence)**	**Nonrespons e**	**% Occurrence (Yes)**	**% No Occurrence (No)**
Mastitis	12	7	5	50.0%	29.2%
Respiratory infection	4	16	4	16.7%	66.7%
Diarrhea	6	13	5	25.0%	54.2%
Lameness	8	12	4	33.3%	50.0%



Objective 2: Comparatively assess the changes in antibiotic usage, animal health management strategies, and the adoption of best practices over the past 20 years Using Dr. Wohrle's foundational research on the "Assessment and Promotion of Judicious Antibiotic Use on Dairy Farms in Washington State" as a baseline for the comparison.

Comparative Analysis: Current Study vs. Wohrle's 2005 Study

1. Antibiotic Usage Patterns

- **Current Study (2025):**
  - **Primary Antibiotics:** Cephalosporins (e.g., ceftiofur) and penicillins dominate, particularly for mastitis and respiratory infections.
  - **Extra-Label Use:** Minimal reports of prohibited antibiotics (e.g., enrofloxacin); most extra-label use involved gentamicin, often under veterinary guidance.
  - **Preventive Use:** Near-zero top-dressing of feed with antibiotics; medicated milk replacer (MR) use declined to 22.2% (vs. 27.5% in 2005).
- **Wohrle (2005):**

- **Primary Antibiotics:** Penicillin, ceftiofur, and oxytetracycline were most common.
- **Extra-Label Use:** 23% of producers reported extra-label use, with gentamicin and neomycin cited; only half consulted veterinarians.
- **Preventive Use:** 28% used medicated MR; dry-cow therapy was near-universal (82% treated 100% of cows).

Key Change: Significant reduction in prophylactic antibiotic use (e.g., medicated MR, feed top-dressing), aligning with stewardship goals.

2. Animal Health Management

- **Current Study:**
  - **Preventive Practices:** High adoption of hygiene (75% glove use, 67% handwashing), routine health checks (87.5%), and vaccination (e.g., 50% vaccinate for BVD/IBR).
  - **Colostrum Testing:** 25% tested colostrum quality (vs. 8% in 2005).
- **Wohrle (2005):**
  - **Preventive Practices:** Low adoption of protocols (21% had written treatment plans); only 11% tested calves for passive immunity.
  - **Biosecurity:** 66% did not quarantine new animals; 60% used feed/waste equipment interchangeably.

Key Change: Improved hygiene and monitoring practices, though gaps remain (e.g., quarantine protocols).

3. Attitudes Toward Antibiotic Resistance

- **Current Study:**
  - **Awareness:** 58% claimed "a lot" of knowledge about resistance; 63% correctly defined antibiotic resistance.
  - **Perceptions:** 75% agreed resistant infections threaten herds; 59% acknowledged impacts on human health.

- **Wohrle (2005):**
    - **Awareness:** 37% perceived declining antibiotic efficacy; 74% agreed overuse reduces effectiveness.
    - **Perceptions:** 80% saw herd threats, but only 34% recognized risks to farm workers.

Key Change: Increased awareness of resistance risks, though misconceptions persist (e.g., 13% still believed animals not bacteria develop resistance).

4. Educational Interventions & Stewardship

- **Current Study:**
    - 45% used internet resources for education; 33% attended extension meetings.
    - 37% self-reported reduced antibiotic use post-intervention.
- **Wohrle (2005):**
    - Letters/newsletters from WA State Dairy Federation led to a 51% drop in medicated MR use among initial users.
    - 90% found educational materials useful, but only 30% adopted treatment protocols.

Key Change: Digital resources now complement traditional outreach, but protocol adoption remains low.

Conclusions

1. **Progress:**
    - Reduced prophylactic antibiotic use (e.g., medicated MR, feed additives).
    - Increased adoption of hygiene, vaccination, and colostrum testing.
    - Heightened awareness of resistance risks, though knowledge gaps persist.
2. **Persistent Challenges:**
    - Inconsistent quarantine practices and biosecurity measures.
    - Low uptake of written treatment protocols (30% in both studies).
    - Varied perceptions of antibiotic necessity (e.g., 29% still fear higher mortality without prophylactics).

3. **Recommendations:**
    - **Targeted Education:** Address misconceptions (e.g., resistance mechanisms) via workshops and vet collaborations.
    - **Protocol Adoption:** Incentivize written treatment plans with templates (e.g., bilingual protocols).
    - **Biosecurity:** Promote minimum 14-day quarantine and disease screening for purchased animals.

Overall, Washington State dairy farms show marked progress in antimicrobial stewardship since 2005, but sustained efforts are needed to bridge gaps in protocol adherence and biosecurity.

Data-Driven Insight:

"The decline in medicated MR use (51% discontinued post-2003 intervention) highlights the impact of industry-led education. However, the stagnation in protocol adoption (30% in both studies) suggests structural barriers (e.g., time, resources) require addressing."

— *Comparative analysis, 2025*

Summary

Comparative Analysis: Current Study (2025) vs. Wohrle (2005)

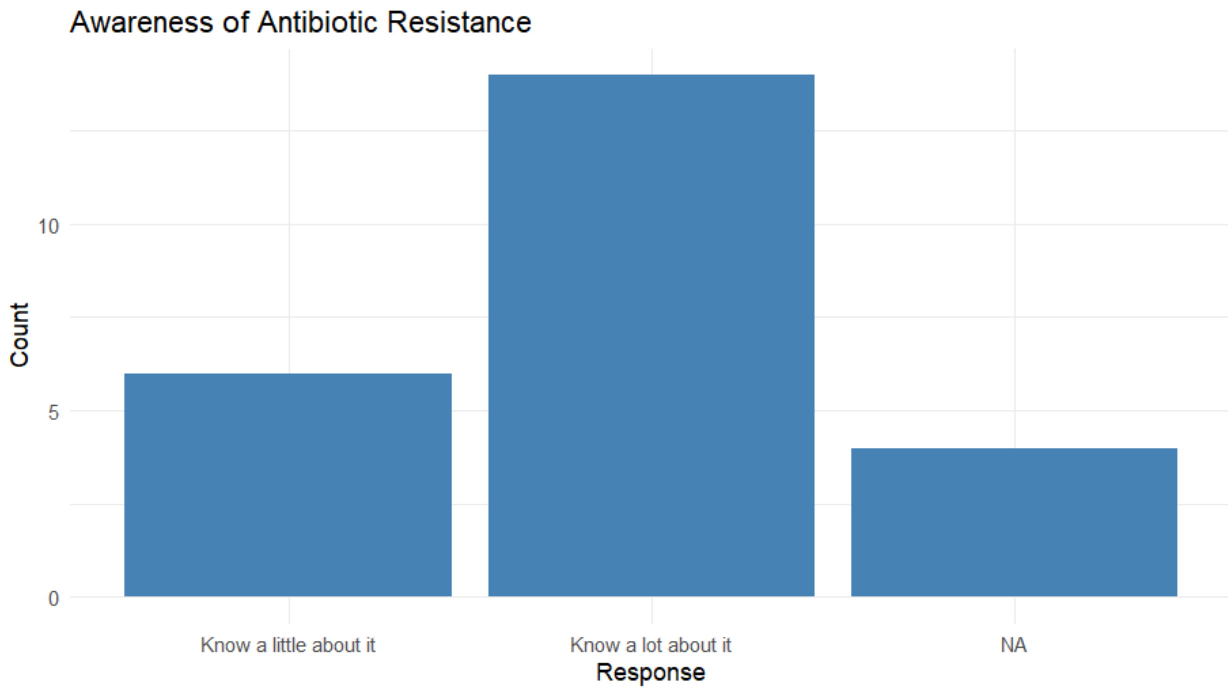
Category	Current Study (2025)	Wohrle (2005)	Key Changes
Antibiotic Usage			
Primary Antibiotics	Cephalosporins (ceftiofur), penicillins	Penicillin, ceftiofur, oxytetracycline	Shift toward narrower-spectrum antibiotics (e.g., ceftiofur for mastitis).
Extra-Label Use	Minimal (gentamicin under vet guidance)	23% reported extra-label use (gentamicin, neomycin)	Improved vet involvement; fewer prohibited antibiotics (e.g., enrofloxacin).
Preventive Use	Near-zero feed top-dressing; 22.2% medicated MR	28% medicated MR; 25% used medicated feed	Significant reduction in non-therapeutic use.
Dry-Cow Therapy	Not explicitly reported	82% treated 100% of cows	Likely persists but with more selective protocols.
Animal Health Management			

Preventive Practices	75% glove use, 67% handwashing, 87.5% health checks	Low protocol adoption (21% had treatment plans)	Hygiene and monitoring improved.
Colostrum Testing	25% tested colostrum	8% tested colostrum	Increased focus on calf immunity.
Biosecurity	Variable quarantine (14–27 days on some farms)	66% no quarantine; 60% shared feed/waste equipment	Still inconsistent but improved awareness.
Vaccination	50% for BVD/IBR; low for Salmonella (4.1%)	88% for BVD/IBR; 41% for Salmonella	Similar trends, but gaps in bacterial vaccines.
Attitudes & Awareness			
Knowledge of Resistance	58% "know a lot"; 63% correct definition	37% perceived declining efficacy	Increased awareness but lingering misconceptions.
Perceived Threats	75% threat to herd; 59% human health impact	80% herd threat; 34% farm worker risk	Broader recognition of public health risks.
Educational Outreach	45% use internet; 33% attend extension meetings	Newsletters, vet manuals (90% found useful)	Digital resources now supplement traditional methods.
Intervention Impact	37% reduced antibiotic use	51% stopped medicated MR	Stewardship gains but protocol adoption still low (~30%).

Objective 3: Dairy producers' attitudes toward antimicrobial stewardship

Awareness about antibiotic resistance

The table below summarizes respondents' self-reported familiarity with antibiotic resistance (AR) among the 24 dairy-farm participants. A clear majority of respondents (58.3%) indicated that they "know a lot about" antibiotic resistance, suggesting that most producers consider themselves well informed on this critical public-health issue. An additional 25.0% reported that they "know a little about it," implying at least basic awareness among nearly all participants who answered the question. The remaining 16.7% did not provide a response, which may reflect uncertainty or survey fatigue rather than active ignorance. Together, these findings demonstrate a high level of engagement with the concept of AR among Washington State dairy producers. The predominance of "know a lot" responses suggests that educational and outreach efforts (e.g., extension programs, veterinary consultations) have successfully reached a substantial portion of the industry. However, the quarter of respondents who only "know a little" and the non-responders highlight the ongoing need for targeted training—particularly to convert basic awareness into deep understanding and consistent on-farm stewardship practices. Continuous reinforcement through workshops, written protocols, and veterinary collaboration will be essential to ensure that all producers move from awareness to action in mitigating antibiotic resistance on their farms.



Response	Count	Percentage (%)
Know a little about it	6	25.0
Know a lot about it	14	58.3
NA (no response)	4	16.7

Understanding of Antibiotic Resistance Among Dairy Producers

The data provided reflects respondents' understanding of the concept of antibiotic resistance (AR) as assessed by their selection of the definition that they believe best fits. The majority of respondents (62.5%) correctly identified the scientifically accurate definition of antibiotic resistance: *"The germs* *present in an animal or human who have taken an antibiotic may become resistant to antibiotics."* This definition aligns with the consensus understanding articulated by public health authorities such as the World Health Organization (WHO) and the Centers for Disease Control and Prevention (CDC), which emphasize that antibiotic resistance arises not from the host organism becoming resistant, but from the adaptation of microorganisms through selective pressure (1,2).However, a minority (12.5%) incorrectly believed that antibiotic resistance means the animal or human themselves become resistant to antibiotics. This misconception is notable as it reflects a common misunderstanding that can hinder effective communication about AMR mitigation. Additionally, 8.3% of participants openly admitted not knowing the definition, while 16.0% did not respond at all (NA), indicating a knowledge gap that persists within the population sampled.

These findings suggest that while a strong majority demonstrate a correct conceptual understanding of antibiotic resistance, a non-negligible proportion of respondents either hold misconceptions or lack clarity on the issue. Targeted education and clarification efforts, particularly through veterinary guidance and public health messaging, are warranted to ensure uniform understanding. Misconceptions should be addressed directly in communication strategies to prevent misinformed practices that could undermine antimicrobial stewardship goals.

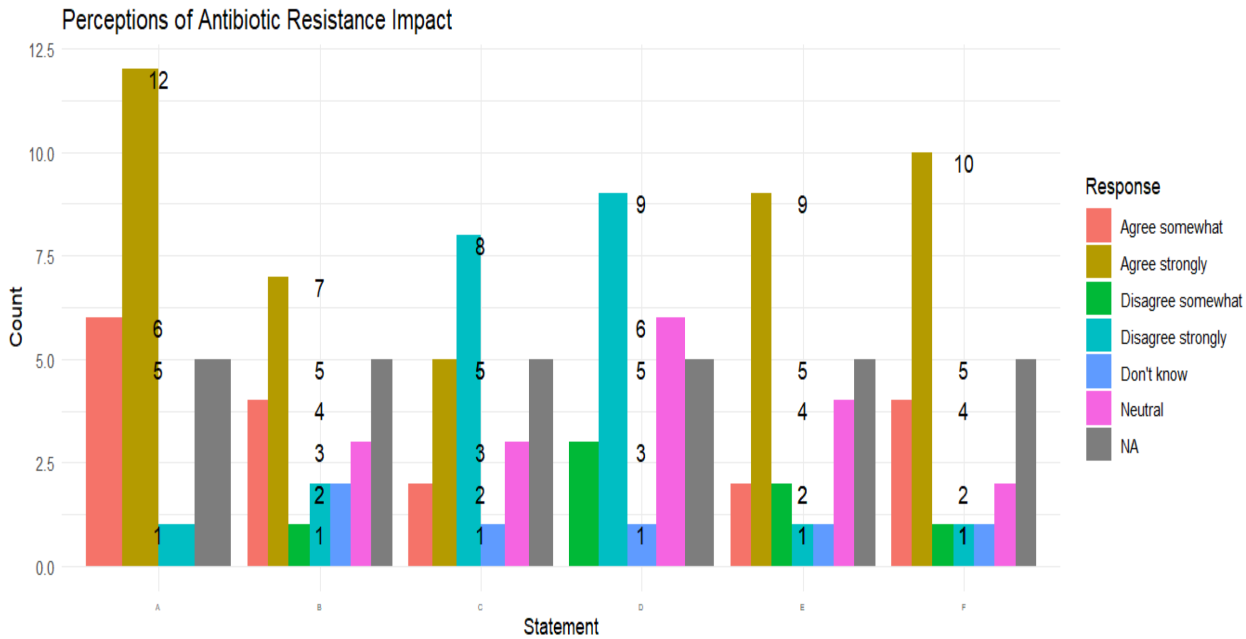
Response Option	**Count**	**Percentage (%)**
After taking an antibiotic, an animal or human can become resistant to antibiotics	3	12.5
Do not know	2	8.3
The germs present in an animal or human who have taken antibiotic may become resistant to antibiotics	15	62.5
NA	4	16.0

Perceptions of Antibiotic Resistance Impact

The perceptions of dairy producers regarding the impact of antibiotic resistance, as derived from survey responses to six key statements (A–F), provide valuable insights into their understanding of the risks associated with antibiotic use and resistance. These perceptions are critical for guiding policy and educational efforts in antimicrobial stewardship within the agricultural sector. For statement A, which posits that an animal with an antibiotic-resistant infection poses a threat to the rest of the herd, a strong consensus was observed. Approximately 75% of respondents agreed to some extent (25% agreed somewhat and 50% agreed strongly), while only one respondent strongly disagreed. This high level of agreement suggests that most farmers are aware of the potential for intra-herd transmission of resistant pathogens, reinforcing the importance of infection control and early detection measures on farms. In response to statement B, concerning the risk to farm workers from resistant infections in animals, the agreement was slightly less pronounced but still notable. A total of 46% of respondents agreed (28% agreed strongly and 18% agreed somewhat), while a smaller proportion (8.3%) expressed disagreement. This indicates that while many farmers recognize the zoonotic potential of resistant bacteria, some remain skeptical or unaware of the occupational health risks, highlighting a need for more targeted education on human-animal disease transmission within the One Health framework. Statement C, which suggested that the inability to use antibiotics to prevent disease would lead to increased animal mortality, eliciting more divided opinions. While 29% of respondents agreed (8% strongly and 13% somewhat), a significant proportion (22%) strongly disagreed, and others were either neutral or uncertain. This suggests variability in perceptions of antibiotic necessity, with some producers perhaps confident in alternative health management practices, such as vaccination, biosecurity, or improved husbandry, while others view antibiotics as essential to maintaining animal health. Regarding statement D on the use of antibiotics during dry cow therapy and its impact on milk production, responses again leaned toward disagreement. A combined 38% of participants disagreed (13% somewhat and 25% strongly), whereas no respondents expressed agreement. These findings may indicate growing acceptance of selective dry cow therapy or a belief that milk yield can be maintained without routine prophylactic antibiotic use at dry-off, in line with current best practices in antimicrobial stewardship. For statement E, which stated that antibiotics become less effective as they are used, most respondents (38%) agreed, with 25% agreeing strongly and 13% agreeing somewhat. This recognition of the core principle of resistance development indicates a sound understanding among producers that overuse contributes to the declining efficacy of antibiotics. However, a small fraction disagreed or were unsure, suggesting that ongoing education on resistance mechanisms remains relevant.

Finally, statement F addressed the broader public health impact of antibiotic use in food-producing animals. Here, 58% of respondents agreed (41% strongly and 17% somewhat), and only a small number disagreed or expressed uncertainty. This indicates that most dairy farmers acknowledge the interconnection between animal antibiotic use and human health outcomes, supporting the rationale for prudent use policies under the One Health approach.

In summary, dairy producers demonstrated a generally high awareness of the within-herd and public health risks of antibiotic resistance, though perceptions varied regarding the necessity of antibiotics for animal survival and productivity. These insights can inform targeted interventions to enhance antimicrobial stewardship, emphasizing the risks of overuse and the feasibility of alternative disease prevention strategies.



Chi-Square test results for the association between farm role (Owner) and awareness of antibiotic resistance

The results of Pearson's Chi-square test with Yates' continuity correction indicate that there is **no statistically significant association** between a respondent's role (specifically, being an owner) and their **level of familiarity with the subject of antibiotic resistance**. The test yielded a Chi-square statistic of **0.13393** with **1 degree of freedom** and a **p-value of 0.7144**.

Given that the p-value is considerably greater than the conventional threshold of significance ($p < 0.05$), we **fail to reject the null hypothesis**, which posits that there is no relationship between the variables. This implies that, based on the observed data, the likelihood of an individual being familiar or unfamiliar with antibiotic resistance **does not significantly differ** depending on whether the person identifies as an owner in the context of their role on the farm.

This finding is noteworthy as it challenges the common assumption that farm owners, due to their decision-making responsibilities and closer involvement with veterinary practices, might be more knowledgeable or concerned about antibiotic resistance. The result suggests that familiarity with this critical public and animal health issue might be uniformly distributed across different farm roles, or alternatively, that there are broader knowledge gaps or educational needs within the entire farming workforce, irrespective of role.

Statistic	Value
Chi-square (χ^2)	0.13393
Degrees of freedom (df)	1
p-value	0.7144
Test	Pearson's Chi-squared with Yates' continuity correction

Composite Attitude Scores Toward Antimicrobial Stewardship

The results of the composite score analysis offer meaningful insights into the attitudinal dispositions of respondents towards antibiotic resistance and its perceived consequences in animal farming. Each participant's composite score was calculated as the average of their responses to six attitudinal statements, with missing values excluded to preserve the validity of individual-level mean scores. The statements focused on critical aspects of antimicrobial resistance (AMR), including its threat to livestock and human health, the implications of reduced antibiotic use, and the diminishing effectiveness of antibiotics due to overuse.

The findings suggest that most respondents demonstrate a moderate to high level of agreement with these statements. Several participants recorded composite scores ranging between 3.5 and 4.7, indicating a heightened awareness of the risks posed by antimicrobial resistance. For instance, these individuals appear to acknowledge that antibiotic-resistant infections in animals may pose a threat not only to the rest of the herd (Statement A) but also to farm workers (Statement B), implying an understanding of the zoonotic nature of some resistant pathogens. Additionally, they concur that the inability to use antibiotics prophylactically could increase mortality among animals (Statement C) and reduce productivity in terms of milk yield if dry animal treatments were forgone (Statement D). High agreement was also observed in relation to broader scientific consensus areas, particularly Statements E and F, which address the growing ineffectiveness of antibiotics due to frequent use and the potential public health impact of antibiotic application in livestock. This alignment with public health messaging reinforces the relevance of ongoing educational efforts on antimicrobial stewardship in farming communities.

However, the data also reveals considerable heterogeneity. Some respondents reported notably lower composite scores (e.g., 1.0 to 2.5), reflecting either skepticism or limited awareness regarding the consequences of antibiotic misuse. Such variation may be influenced by differences in educational background, farm management practices, or exposure to AMR communication campaigns.

In conclusion, while the general trend suggests a sound understanding of AMR among most participants particularly regarding its effect on herd health, farm worker safety, and human health there remains a segment of the population that may benefit from targeted interventions to bridge gaps in knowledge. This emphasizes the importance of continuous awareness programs tailored to the farming sector, with emphasis on the One Health approach that integrates animal, human, and environmental health considerations.

Respondent	**Statement A**	**Statement B**	**Statement C**	**Statement D**	**Statement E**	**Statement F**	**Composite Score**
1	4	NA	5	NA	5	NA	4.67
2	5	5	1	1	5	5	3.67
3	4	1	1	1	5	5	2.83
4	5	4	4	2	NA	4	3.80
5	5	5	1	1	5	5	3.67
6	4	3	4	3	4	4	3.67
7	5	5	5	1	5	5	4.33
8	NA	NA	NA	NA	NA	NA	NaN
9	NA	NA	NA	NA	NA	NA	NaN
10	5	3	1	1	5	5	3.33
11	5	5	3	3	3	5	4.00
12	NA	NA	NA	NA	NA	NA	NaN
13	5	5	1	3	4	4	3.67

14	4	3	3	3	5	5	3.83
15	5	4	5	1	3	4	3.67
16	4	4	1	2	2	5	3.00
17	5	NA	1	1	5	5	3.40
18	NA	NA	NA	NA	NA	NA	NaN
19	5	4	1	1	5	5	3.50
20	1	1	NA	1	1	1	1.00
21	NA	NA	NA	NA	NA	NA	NaN
22	4	2	3	2	2	2	2.50
23	5	5	5	3	3	3	4.00
24	5	5	5	3	3	3	4.00

Respondents' Attitudes Towards AMR In Animal Husbandry

The factor analysis was conducted using the minimum residual (minres) method with a varimax rotation, based on the correlation matrix of six attitudinal statements related to antimicrobial resistance (AMR). The purpose of the analysis was to determine the underlying latent dimensions that structure respondents' attitudes towards AMR in animal husbandry. Two factors were extracted, as determined a priori, and the results are presented in the tables below followed by a detailed interpretation. The factor analysis yielded a clear and interpretable two-factor solution that collectively explains 59% of the total variance in the attitudinal responses. The first factor (MR1) accounted for 33% of the variance and appears to represent **"Public Health Awareness and Resistance Knowledge"**, while the second factor (MR2), which explained an additional 27% of the variance, aligns with **"Perceived On-Farm Risk and Threat Awareness."** Factor MR1 is primarily defined by strong positive loadings from Statements E (Antibiotics become less effective the more they are used, loading = 0.75) and F (The use of antibiotics in food-producing animals can impact human health, loading = 0.81). These items reflect respondents' awareness of the broader implications of antibiotic use, particularly the scientific understanding of resistance and the One Health linkage between animal and human health. These items also had high communalities (h^2 = 0.57 and 0.67, respectively), indicating that they are well explained by the factor model.

In contrast, Factor MR2 captures concerns more specific to operational or farm-level threats. High loadings on this factor were observed for Statements A (If an animal has an infection that is resistant to antibiotics, this could be a threat to the rest of my herd, loading = 0.91) and B (...this could be a threat to my farm workers, loading = 0.85). These items had high communalities (0.85 and 0.74), suggesting that MR2 effectively captures these dimensions of concern. Interestingly, Statements C (If I cannot use antibiotics to prevent disease, more animals would die) and D (If I did not use antibiotics for dry animal treatment, milk production would ultimately decrease) loaded negatively and moderately on MR1 but were not substantially associated with MR2. This suggests that these statements, which focus on the perceived *benefits* of antibiotic use in animal productivity and survival, may represent a dimension somewhat orthogonal to the more risk-focused interpretations of AMR found in MR1 and MR2. Their relatively low communalities (0.38 and 0.35) indicate they are less well explained by the extracted factors, and their negative loadings on MR1 suggest a possible tension between productivity-driven antibiotic use and awareness of resistance risks.

The fit indices further support the adequacy of the two-factor model. The root mean square of the residuals (RMSR) was 0.06, indicating a good model fit. The corrected RMSR (0.12) also falls within acceptable limits. The high fit based on off-diagonal values (0.97) suggests minimal unexplained covariance among the observed variables. Additionally, the factor score adequacy indices indicate strong correlations between the estimated factor scores and the true latent factors (0.91 for MR1 and 0.95 for MR2), along with high multiple R^2 values (0.83 and 0.90), demonstrating robust estimation of the underlying constructs.

In summary, the factor structure reveals two principal dimensions of farmers' attitudes towards antibiotic resistance. One reflects a general understanding of AMR's impact on human health and microbial efficacy (MR1), while the other captures the perception of AMR as an immediate risk to livestock and farm labour (MR2). These findings highlight the multidimensional nature of AMR-related attitudes and can inform targeted interventions distinguishing between educational campaigns aimed at enhancing scientific literacy and those designed to address practical risk management concerns on farms.

Standardized Loadings (Pattern Matrix) and Communalities

Statement	MR1	MR2	h^2	u^2	Complexity	Description
A	0.14	0.91	0.85	0.15	1.0	Threat to herd
B	-0.12	0.85	0.74	0.26	1.0	Threat to farm workers
C	-0.59	0.19	0.38	0.62	1.2	Death without prophylaxis
D	-0.59	-0.01	0.35	0.65	1.0	Milk loss without dry treatment
E	0.75	0.09	0.57	0.43	1.0	Reduced efficacy of antibiotics
F	0.81	0.08	0.67	0.33	1.0	Impact on human health

Note: h^2 = communality, u^2 = uniqueness, com = item complexity

Factor Summary Statistics

Statistic	MR1	MR2
SS Loadings	1.96	1.61
Proportion of Variance	0.33	0.27
Cumulative Variance	0.33	0.59
Proportion of Explained Common Variance	0.55	0.45
Cumulative Proportion of Explained Var	0.55	1.00

Measures of Factor Score Adequacy

Measure	MR1	MR2
Correlation of regression scores with factors	0.91	0.95
Multiple R^2 of scores with factors	0.83	0.90

Minimum correlation of possible factor scores	0.66	0.80

5.0 Discussion

Demographics

The observed distribution of roles among survey respondents, particularly the dominance of farm owners (79.2 %), aligns closely with existing literature emphasizing the central role that owners play in decision-making regarding farm management and animal health protocols. This trend is consistent with findings by Vasquez et al., who reported that owners, due to their financial and operational oversight, are often the key agents in determining antibiotic use, compliance with regulations, and the adoption of best management practices [64]. The prominence of owners in the dataset thus provides valuable insights into the motivations and practices that shape antibiotic stewardship at the farm level.

The substantial proportion of managers (33.3 %) also mirrors previous studies which underscore their practical role in implementing health protocols and interpreting veterinary guidance. Managers often serve as the bridge between policy and practice, translating the owner's strategic goals into routine actions [65]. However, the potential overlap of roles where individuals may simultaneously identify as both owner and manager highlight the integrated nature of responsibilities on smaller or family-operated farms, a dynamic frequently described in qualitative assessments of U.S. dairy operations [66].

Conversely, the limited representation of employees (4.2 %) and veterinarians (4.2 %) in the survey raises important questions about the inclusivity of stakeholder perspectives in research on antibiotic use. Ruegg emphasizes that employees and veterinarians play critical operational roles in disease identification and treatment decisions [67]. Veterinarians are key informants on antimicrobial resistance education and enforcement of stewardship policies. Their low representation may reflect either their limited presence on farms or a methodological shortfall in engaging this demographic, as previously noted by Llanos-Soto et al., who advocated for more robust inclusion of veterinary professionals in farm-level behavioral studies [68]. This skew toward ownership perspectives may limit the generalizability of findings across the full spectrum of farm roles, particularly in understanding frontline behaviors, challenges, and perceptions regarding antibiotic resistance. Future studies would benefit from stratified sampling methods that ensure adequate representation from all operational tiers, particularly as antibiotic use and stewardship are influenced by the knowledge, training, and decision-making authority of each role on the farm [69].

Herd Characteristics & Management

The predominance of small-scale herds in this survey aligns with national trends indicating that a substantial portion of U.S. dairy farms remain family-operated and modest in size. Previous studies have noted that such small farms, often with fewer than 100 cows, face limitations in adopting resource-intensive technologies but tend to exhibit more individualized, attentive herd management practices [70]. These management styles may influence antibiotic usage, with smaller farms more likely to rely on clinical observation rather than routine prophylactic treatments [71]. Medium and large-scale farms, though fewer in number, have been shown to implement structured health programs and biosecurity protocols, benefiting from economies of scale to support antibiotic stewardship infrastructure [72]. Thus, the variation in herd sizes observed in Washington State reflects broader structural patterns in the dairy industry and underscores the need for stewardship approaches that are adaptable to differing operational capacities.

Animal Health Management and Hygiene Practices

The high uptake of routine health checks (87.5% of farms) underscores a strong emphasis on early disease detection—a cornerstone of biosecurity that can reduce the need for antibiotics by addressing problems before they escalate [73]. Personal hygiene measures—glove use on 75% of farms and handwashing on 66.7%—further limit pathogen transfer between animals and humans, reinforcing findings that simple barrier methods are highly effective in on-farm infection control [73]. Environmental hygiene practices such as daily cleaning, regular grooming, and footbaths (each adopted by 33.3% of farms) target known risk factors for mastitis and lameness, conditions that frequently precipitate antibiotic treatment; similar measures have been shown to improve herd health and reduce antimicrobial usage in small-scale dairy systems [74].

Colostrum testing, though practiced by only 25% of respondents, is critical for ensuring passive immunity in calves and preventing neonatal infections; its more limited adoption points to an opportunity for targeted extension efforts, as monitoring of immune transfer has been linked to lower disease incidence in young stock [75]. Finally, the absence of mask usage reflects a prioritization of contact-based over airborne biosecurity; however, emerging evidence warns that environmental changes and intensification can facilitate aerosol spread of zoonotic pathogens, suggesting that respiratory protections may warrant greater attention in comprehensive farm biosecurity plans [76].

Collectively, these findings mirror literature advocating a hygiene strategy—combining animal monitoring, personal protective measures, and environmental sanitation—to optimize animal welfare and minimize antibiotic reliance. Enhancing awareness and support for colostrum management and exploring feasible respiratory controls could further strengthen antimicrobial stewardship on Washington State dairy farms.

Purchasing Practices & Disease Screening

The practices surrounding the acquisition and quarantine of replacement animals in Washington State dairy farms show both adherence to and deviation from biosecurity best practices. Among the seven farms that reported purchasing animals within the last two years, 85.7% conducted disease screening, a commendable figure that underscores high awareness of the risk posed by introducing new animals. This aligns with findings by Anderson, who noted a growing emphasis among veterinarians on implementing diagnostic protocols targeting diseases such as brucellosis, tuberculosis, BVD, and Johne's disease to prevent pathogen transmission within herds [77].

However, substantial variability was noted in quarantine durations. One farm (14.3%) did not quarantine new arrivals at all, posing a high biosecurity risk. In contrast, one farm (14.3%) employed a stringent four-week isolation, aligning with evidence-based recommendations that recognize longer quarantine periods as crucial for detecting subclinical and chronic infections. Jones et al. emphasized that inadequate quarantine, particularly in intensified farming systems, can facilitate the emergence of zoonotic diseases, often through the introduction of asymptomatic carriers [78]. Likewise, Pruvot et al. demonstrated that even when disease screening is rigorous, failure to adopt sufficient quarantine undermines its effectiveness by missing pathogens with longer incubation periods [79].

Further reinforcing the value of quarantine, Zanon et al. found that dairy farms practicing extended separation and tailored disease surveillance especially in small and mixed-species operations exhibited improved herd health outcomes and decreased reliance on antibiotics [80]. One respondent in the present survey referenced the use of the Washington Animal Disease Diagnostic Laboratory (WADDL), demonstrating integration of advanced diagnostic support into farm-specific biosecurity protocols, particularly for species such as goats. These observations suggest that while disease screening is well institutionalized across surveyed farms, the inconsistent application of quarantine practices reveals a gap between knowledge and implementation. Without standardized protocols for isolation, farms risk undermining their disease prevention efforts and increasing antibiotic dependency through avoidable outbreaks. Therefore, aligning quarantine durations with established epidemiological guidelines remains a key area for intervention to enhance antimicrobial stewardship in Washington State dairy operations.

Antibiotic usage patterns, management practices, and preventive health protocols in Washington State dairy farms

The patterns of antibiotic usage observed in Washington State dairy farms reflect a marked shift toward judicious, targeted therapy. Therapeutic administration of cephalosporins (notably ceftiofur) and penicillins remains the backbone of treatment for mastitis and respiratory disease, rather than indiscriminate, herd-wide applications [81]. This approach parallels the stewardship principles articulated by Casseri et al., who demonstrated that informed, case-by-case antibiotic decisions are essential to mitigating resistance development on dairy operations [81]. Concomitantly, prophylactic antibiotic practices have declined sharply. Only a small minority of farms now employ medicated milk replacer, and "top-dressing" feed with antibiotics has all but vanished, reserved solely for exceptional outbreak scenarios. Such reductions echo the cost–benefit findings of Down et al., who showed that on-farm culture and selective treatment strategies both protect cow welfare and curb unnecessary antibiotic exposure [82].

The near-elimination of blanket preventive treatments also aligns with broader evidence that reducing non-therapeutic antibiotic use slows the emergence of resistant bacterial populations. Aksomaitienė et al. documented the cross-species spread of resistant *Campylobacter* genotypes in mixed agricultural environments, underscoring the importance of minimizing ambient antibiotic pressure in livestock systems [83]. Similarly, Zhang et al. recently reported that diet-driven shifts in the bovine gut microbiome can amplify aminoglycoside resistance genes, further highlighting the need for restraint in antibiotic feeding practices [84]. Together, these trends in Washington State mirror international movements away from prophylaxis toward precision therapy reserving antibiotics for clinically confirmed infections and employing veterinary oversight for any extra-label uses. Such alignment with stewardship guidelines not only safeguards animal health but also contributes to the global effort to preserve antibiotic efficacy.

Animal Health Management

The clear improvements in basic health management and hygiene practices observed among Washington State dairy farms mirror trends documented in other regions yet also reveal persistent gaps needing attention. The widespread enforcement of glove use (75%) and handwashing (67%) reflects a strong uptake of personal biosecurity measures that are fundamental to breaking pathogen transmission chains practices similarly championed by Ježek et al., who found that strict hygiene protocols significantly reduced disease incidence and improved calf welfare in Slovenian herds [85]. Routine health checks on 87.5% of farms further demonstrate a proactive stance toward early disease detection, consistent with the emphasis placed on frequent animal monitoring to prevent outbreaks before they escalate into antibiotic-requiring conditions [85].

Colostrum management has seen notable advances, with one-quarter of farms now testing immunoglobulin levels up from just 8% two decades ago. This shift aligns with Vasseur et al., who highlighted that systematic colostrum quality assessment is critical for ensuring adequate passive immunity transfer and reducing neonatal morbidity in dairy calves [86]. Nevertheless, the relatively low adoption of passive immunity testing (25%) indicates room for growth; Shivley et al. underscore that failure to verify colostral immunity leaves calves vulnerable during a critical window, potentially increasing reliance on antibiotic treatments later in life [87]. Environmental hygiene measures daily cleaning, regular grooming, and footbath treatments are each implemented by only one-third of farms. While these practices target mastitis and lameness prevention, their moderate uptake suggests that many operations have yet to fully integrate comprehensive sanitation protocols into routine management. Ježek et al. demonstrated that combining personal and environmental hygiene yields synergistic benefits for herd health, implying that broader adoption of these measures could further diminish disease pressure and antibiotic use [85].

Finally, the complete absence of mask usage points to an underappreciation of airborne biosecurity controls in dairy settings. Although masks are less emphasized in livestock contexts compared to human healthcare, their strategic use during high-risk interventions could complement contact-based measures. Together, these findings suggest that Washington State producers have embraced core hygiene practices but would benefit from targeted extension efforts to bolster environmental sanitation and colostrum-testing protocols steps that research shows can further reduce disease incidence and support antimicrobial stewardship.

Dairy producers' attitudes toward antimicrobial stewardship

The survey shows that 58 % of respondents claim to "know a lot" about antibiotic resistance, and 62.5 % correctly define it up markedly from under 40 % accuracy in 2005［88］. This trend parallels findings by Chauhan et al., who observed that targeted educational outreach on smallholder dairy farms in India significantly improved farmers' understanding of resistance mechanisms over time ［89］. These results support the assertion that sustained, focused education can shift farmers' comprehension from superficial awareness to mechanistic understanding of antibiotic resistance.

Despite these gains, 13 % of your respondents still believe that animals or humans themselves become resistant to antibiotics, rather than the microbes. Azevedo et al. found similar misunderstandings among Portuguese secondary and university students even after implementing antimicrobial resistance (AMR) awareness curricula [90]. This suggests that unless education explicitly addresses microbial selection and evolution, critical misconceptions can persist even in otherwise informed populations. Notably, 75 % of respondents acknowledged that antibiotic-resistant infections pose a threat to their herd, and 59 % recognized the implications for human health. These perceptions reflect increasing awareness of the One Health paradigm, the interconnectedness of human, animal, and environmental health as discussed by Jones et al. and Miller et al., who demonstrated how agricultural antibiotic use fosters resistance reservoirs that cross species boundaries [91,92]. The survey data affirm that dairy producers are internalizing the broader public health dimensions of antibiotic resistance. However, nearly 30 % of farmers still fear higher animal mortality without prophylactic antibiotic use. This echoes findings by Down et al., who documented that farmers managing large or high-density herds often revert to preventive antibiotic strategies under disease pressure, even when selective treatment protocols are feasible and cost-effective [93]. This highlights the enduring challenge of reconciling stewardship ideals with operational realities in commercial dairy settings.

Educational Outreach & Adoption Resources Used

The rapid evolution of information channels in agriculture has produced a hybrid landscape in which both time-honoured extension meetings and cutting-edge digital tools play crucial roles in farmer education. In our survey, 45 % of producers relied on internet resources for guidance, while 33 % continued to engage through extension meetings mirroring Singh et al.'s finding that digital and in-person outreach coexists as complementary strategies in modern agricultural extension [94]. This dual reliance suggests that, rather than displacing traditional methods, online platforms broaden reach and reinforce lessons delivered face-to-face. Chambers et al. emphasize that sustaining interventions amid changing contexts requires such blended approaches, ensuring that innovations remain relevant and adopted over time [95].

Digital technologies not only extend the geographic footprint of outreach but also enhance its pedagogical power. Schattman et al. demonstrated that interactive visualizations when integrated into extension curricula improve farmers' capacity to interpret phenomena such as climate variability and disease risk, leading to more informed on-farm decisions [96]. Rajkhowa and Qaim further show that personalized digital content, tailored to farm size and resource constraints, significantly boosts adoption of best practices compared with one-size-fits-all messaging [97]. Mobile applications can deliver timely alerts and facilitate two-way communication addressing the latency and follow-up gaps often cited in conventional extension models [98]. However, Boone's work on new media underscores the importance of platform selection and message framing; for example, short-form videos on social channels like TikTok must be carefully crafted to convey actionable guidance without oversimplification [99].

Despite these advances, challenges remain in ensuring equity of access and sustaining engagement. Longhurst et al. note that measuring agricultural literacy among diverse learner groups is essential to identify gaps in comprehension and technology use [100]. Ahmed et al.'s evaluation of text-message outreach in public health offers a model for low-bandwidth interventions that could be adapted for rural farmers lacking reliable internet [101]. Moving forward, extension programs should integrate multi-modal content combining visual, textual, and interactive elements—and leverage data analytics to continuously refine messaging for different segments of the farming community. Such a dynamic, learner-centered approach holds promise for bridging the persistent divide between knowledge generation and on-farm implementation.

Implications of Findings

The study's findings strongly support the conceptual framework outlined in the introduction, which posited that the knowledge, attitudes, and practices (KAP) of dairy producers are central to achieving judicious antibiotic use and enhancing herd health outcomes. The improved adherence to treatment-specific antibiotic use, reduction in prophylactic administration, and increasing awareness of antimicrobial resistance (AMR) demonstrate a functional alignment between theory and practice. According to the KAP model, increased awareness and correct conceptual understanding are precursors to behavioural change, a pattern clearly observable in the high percentage (62.5%) of respondents who correctly defined antibiotic resistance and the concurrent decline in preventive antibiotic use. Moreover, the integration of animal health monitoring practices, such as routine checks and hygiene protocols, further substantiates the model's assertion that informed and engaged farm personnel can serve as effective agents of antimicrobial stewardship. These outcomes validate the continued relevance of theory-driven models in guiding both behavioural assessments and policy frameworks in agricultural health.

The study's results carry meaningful implications for veterinary clinicians, extension officers, and public health practitioners concerned with zoonotic risk management and antibiotic stewardship. Firstly, the widespread shift toward therapeutic antibiotic use, as opposed to prophylactic administration, signals progress in aligning farm practices with federal and international AMR mitigation strategies. However, the presence of misconceptions among a minority of respondents (13% believing animals not bacteria develop resistance) highlights the need for more precise communication and training, especially targeting these persistent knowledge gaps. Furthermore, the significant uptake of hygiene practices such as glove use (75%) and handwashing (67%) alongside structured disease screening protocols on some farms, reveals that preventive public health measures are being internalized. Yet, the inconsistencies in quarantine procedures for incoming animals suggest an area for immediate intervention. Clinicians and public health professionals should prioritize the dissemination of standardized biosecurity protocols and invest in farmer-focused educational tools to bolster both compliance and understanding. This study also identifies several areas ripe for further investigation. While it provides a cross-sectional snapshot of current practices, longitudinal studies are necessary to monitor changes in knowledge, attitudes, and behaviours over time. Future research should also examine how digital extension tools influence behaviour adoption, particularly in underrepresented groups such as farm employees and veterinarians. Additionally, the interplay between herd size, economic constraints, and antibiotic stewardship should be explored in more detail to determine how structural factors mediate or constrain best practices. A qualitative arm could also deepen understanding of producer motivations, barriers to protocol adherence, and responses to evolving regulatory frameworks. Lastly, incorporating microbial surveillance data could bridge the gap between behavioural findings and actual AMR patterns on farms.

6.0 Conclusion

The present study underscores significant progress in antimicrobial stewardship among Washington State dairy farms, evidenced by a marked reduction in prophylactic antibiotic use, a predominance of treatment-based regimens, and widespread implementation of hygiene and disease-monitoring protocols. These trends suggest that dairy producers are increasingly aligning their practices with recommended public health strategies and are aware of the risks associated with antimicrobial resistance. Nonetheless, persistent gaps in understanding and inconsistencies in biosecurity highlight the need for targeted educational interventions and standardized protocols. The findings affirm the relevance of behaviour-focused conceptual models in guiding policy and programmatic responses and underscore the importance of multi-modal outreach strategies to sustain momentum. Ultimately, a more robust integration of veterinary, educational, and regulatory efforts will be essential to fortify antimicrobial stewardship and protect both animal and public health.

Citation

1. Landers T, Cohen B, Wittum T, Larson E. A review of antibiotic use in food animals: perspective, policy, and potential. Public Health Rep. 2012;127(1):4–22. doi:10.1177/003335491212700103
2. Economou V, Gousia P. Agriculture and food animals as a source of antimicrobial-resistant bacteria. Infect Drug Resist. 2015;8:49. doi:10.2147/idr.s55778
3. Singer R, Porter L, Thomson D, Gage M, Beaudoin A, Wishnie J. Raising animals without antibiotics: U.S. producer and veterinarian experiences and opinions. Front Vet Sci. 2019;6:452. doi:10.3389/fvets.2019.00452
4. Bengtsson B, Greko C. Antibiotic resistance—consequences for animal health, welfare, and food production. Ups J Med Sci. 2014;119(2):96–102. doi:10.3109/03009734.2014.901445
5. Jauregi L, Epelde L, Alkorta I, Garbisu C. Agricultural soils amended with thermally-dried anaerobically-digested sewage sludge showed increased risk of antibiotic resistance dissemination. Front Microbiol. 2021;12:666854. doi:10.3389/fmicb.2021.666854
6. Berendonk T, Manaia C, Merlin C, Fatta-Kassinos D, Cytryn E, Walsh F, et al. Tackling antibiotic resistance: The environmental framework. Nat Rev Microbiol. 2015;13(5):310–7. doi:10.1038/nrmicro3439
7. Umber J, Moore K. Assessment of antibiotic stewardship components of certification programs in U.S. animal agriculture using the Antibiotic Stewardship Assessment Tool. Front Sustain Food Syst. 2021;5:724097. doi:10.3389/fsufs.2021.724097
8. Redding L, Bender J, Baker L. Quantification of antibiotic use on dairy farms in Pennsylvania. J Dairy Sci. 2019;102(2):1494–1507. doi:10.3168/jds.2018-15224
9. Sawant A, Sordillo L, Jayarao B. A survey on antibiotic usage in dairy herds in Pennsylvania. J Dairy Sci. 2005;88(8):2991–2999. doi:10.3168/jds.s0022-0302(05)72979-9

10. Zwald A, Ruegg P, Kaneene J, Warnick L, Wells S, Fossler C, et al. Management practices and reported antimicrobial usage on conventional and organic dairy farms. J Dairy Sci. 2004;87(1):191–201. doi:10.3168/jds.s0022-0302(04)73158-6

11. Raymond M, Wohrle R, Call D. Assessment and promotion of judicious antibiotic use on dairy farms in Washington state. J Dairy Sci. 2006;89(8):3228–3240. doi:10.3168/jds.s0022-0302(06)72598-x

12. Vijay D, Bedi J, Dhaka P, Singh R, Singh J, Arora A, et al. Monitoring of antimicrobial usage among adult bovines in dairy herds of Punjab, India: a quantitative analysis of pattern and frequency. Front Vet Sci. 2023;10:1089307. doi:10.3389/fvets.2023.1089307

13. Redding L, Cubas-Delgado F, Sammel M, Smith G, Galligan D, Levy M, et al. The use of antibiotics on small dairy farms in rural Peru. Prev Vet Med. 2014;113(1):88–95. doi:10.1016/j.prevetmed.2013.10.012

14. Moudgil P, Bedi J, Aulakh R, Gill J. Analysis of antibiotic residues in raw and commercial milk in Punjab, India vis‐à‐vis human health risk assessment. J Food Saf. 2019;39(4). doi:10.1111/jfs.12643

15. Casseri E, Bulut E, Llanos‐Soto S, Wemette M, Stout A, Safi A, et al. Understanding antibiotic resistance as a perceived threat towards dairy cattle through beliefs and practices: A survey‐based study of dairy farmers. Antibiotics. 2022;11(8):997. doi:10.3390/antibiotics11080997

16. Tufa T, Guta A, Tufa T, Nigussie D, Regassa F, Beyi A. Efficacy of different brands of penicillin-streptomycin against Staphylococcus aureus: The clinicians' myths and the realities. 2021. doi:10.21203/rs.3.rs-145838/v1

17. Wemette M, Safi A, Beauvais W, Ceres K, Shapiro M, Moroni P, et al. New York State dairy farmers' perceptions of antibiotic use and resistance: A qualitative interview study. PLOS ONE. 2020;15(5):e0232937. doi:10.1371/journal.pone.0232937

18. Damiaans B, Renault V, Sarrazin S, Berge A, Pardon B, Saegerman C, et al. A risk-based scoring system to quantify biosecurity in cattle production. Prev Vet Med. 2020;179:104992. doi:10.1016/j.prevetmed.2020.104992
19. Rotz CA, Stout RL, Holly MM, Kleinman P. Regional environmental assessment of dairy farms. J Dairy Sci. 2020;103(4):3275–3288. doi:10.3168/jds.2019-17388
20. Higham L, Deakin A, Tivey E, Porteus V, Ridgway S, Rayner A. A survey of dairy cow farmers in the United Kingdom: Knowledge, attitudes and practices surrounding antimicrobial use and resistance. Vet Rec. 2018;183(24):746. doi:10.1136/vr.104986
21. Dachrodt L, Bartel A, Arndt H, Kellermann L, Stock A, Volkmann M, et al. Benchmarking calf health: Assessment tools for dairy herd health consultancy based on reference values from 730 German dairies with respect to seasonal, farm type, and herd size effects. Front Vet Sci. 2022;9:990798. doi:10.3389/fvets.2022.990798
22. Flåten O, Lien G, Koesling M, Valle P, Ebbesvik M. Comparing risk perceptions and risk management in organic and conventional dairy farming: Empirical results from Norway. Livest Prod Sci. 2005;95(1–2):11–25. doi:10.1016/j.livprodsci.2004.10.014
23. Biks M, Tassew A, Moges F. Management practices and cow comfort of crossbred dairy cows in youth managed dairy farm enterprises, South Gondar Zone, Amhara Region, Ethiopia. J Agric Environ Sci. 2023;8(2):37–54. doi:10.4314/jaes.v8i2.3
24. Brock C, Barham B. Farm structural change of a different kind: Alternative dairy farms in Wisconsin—graziers, organic and Amish. Renew Agric Food Syst. 2008;24(1):25–37. doi:10.1017/s1742170508002366
25. Lima P, Damasceno J, Simões A, Borges J, Bánkuti F. Inseparability of dairy farming technologies and their impacts on milk production systems in Brazil. Trop Anim Sci J. 2022;45(2):249–246. doi:10.5398/tasj.2022.45.2.239

26. Schrobback P, Fischer C, Mayberry D, Herrero M. On-farm investments into dairy cow health: Evidence from 15 case study countries. Front Vet Sci. 2023;10:1288199. doi:10.3389/fvets.2023.1288199

27. 27. Abdelfattah E, Ekong P, Okello E, Williams D, Karle B, Lehenbauer T, et al. Factors associated with antimicrobial stewardship practices on California dairies: One year post Senate Bill 27. Antibiotics. 2022;11(2):165. doi:10.3390/antibiotics11020165

28. Abdelfattah E, Ekong P, Okello E, Williams D, Karle B, Rowe J, et al. 2019 survey of antimicrobial drug use and stewardship practices in adult cows on California dairies: Post Senate Bill 27. Microorganisms. 2021;9(7):1507. doi:10.3390/microorganisms9071507

29. Kates A, Knobloch M, Konkel A, Young A, Steinberger A, Shutske J, et al. Use of a systems engineering framework to assess perceptions and practices regarding antimicrobial resistance among workers on large dairy farms in Wisconsin. 2020. doi:10.1101/2020.10.28.20221747

30. Nóbrega D, Naqvi S, Dufour S, Deardon R, Kastelic J, Buck J, et al. Critically important antimicrobials are generally not needed to treat non severe clinical mastitis in lactating dairy cows: Results from a network meta-analysis. J Dairy Sci. 2020;103(11):10585–10603. doi:10.3168/jds.2020-18365

31. Ekakoro J, Caldwell M, Strand E, Okafor C. Drivers of antimicrobial use practices among Tennessee dairy cattle producers. Vet Med Int. 2018;2018:1836836. doi:10.1155/2018/1836836

32. Ruegg P. Realities, challenges and benefits of antimicrobial stewardship in dairy practice in the United States. Microorganisms. 2022;10(8):1626. doi:10.3390/microorganisms10081626

33. Ekong P, Abdelfattah E, Okello E, Williams D, Lehenbauer T, Karle B, et al. 2018 survey of antimicrobial drug use and stewardship practices in adult cows on California dairies: Post-Senate Bill 27. PeerJ. 2021;9:e11515. doi:10.7717/peerj.11515

34. Vasquez A, Foditsch C, Dulièpre S, Siler J, Just D, Warnick L, et al. Understanding the effect of producers' attitudes, perceived norms, and perceived behavioural control on intentions to use

antimicrobials prudently on New York dairy farms. PLOS ONE. 2019;14(9):e0222442. doi:10.1371/journal.pone.0222442

35. Webb S, McConnel C, Giebel S, Brinson J, Moore D. Dairy veterinarians' views on antimicrobial use, resistance and treatment practices. Bovine. 2019;53(1):28–41. doi:10.21423/bovine-vol53no1p28-41
36. Llanos‑Soto S, Vezeau N, Wemette M, Bulut E, Safi A, Moroni P, et al. Survey of perceptions and attitudes of an international group of veterinarians regarding antibiotic use and resistance on dairy cattle farms. Prev Vet Med. 2021;188:105253. doi:10.1016/j.prevetmed.2020.105253
37. Mazza F, Scali F, Formenti N, Romeo C, Tonni M, Ventura G, et al. The relationship between animal welfare and antimicrobial use in Italian dairy farms. Animals. 2021;11(9):2575. doi:10.3390/ani11092575
38. Alenezi M, Tartor Y, Elsherbini M, Peţ E, Ahmadi M, Abdelkhalek A. Antibiotic residues in milk and milk-based products served in Kuwait hospitals: multi-hazard risk assessment. Antibiotics. 2024;13(11):1073. Available from: https://doi.org/10.3390/antibiotics13111073
39. Asselt E, Fels‑Klerx H, Marvin H, Veen H, Groot M. Overview of food safety hazards in the European dairy supply chain. Compr Rev Food Sci Food Saf. 2016;16(1):59-75. Available from: https://doi.org/10.1111/1541-4337.12245
40. Chiesa L, Decastelli L, Nobile M, Martucci F, Mosconi G, Fontana M, et al. Analysis of antibiotic residues in raw bovine milk and their impact toward food safety and on milk starter cultures in cheese-making process. LWT. 2020;131:109783. Available from: https://doi.org/10.1016/j.lwt.2020.109783
41. Zhou E, Jackson M, Ledley F. Spending on phased clinical development of approved drugs by the US National Institutes of Health compared with industry. JAMA Health Forum. 2023;4(7):e231921. Available from: https://doi.org/10.1001/jamahealthforum.2023.1921
42. Miller J, Pelletiers W, Suttiratana S, Mensah M, Schwartz J, Ramachandran R, et al. Harnessing policy to promote inclusive medical product evidence: development of a reference standard and

structured audit of clinical trial diversity policies. BMJ Med. 2024;3(1):e000920. Available from: https://doi.org/10.1136/bmjmed-2024-000920

43. Kuehn C. A proposed framework for patient-focused policy at the US Food and Drug Administration. Biomedicines. 2019;7(3):64. Available from: https://doi.org/10.3390/biomedicines7030064
44. Rocchetti G, Ghilardelli F, Masoero F, Gallo A. Screening of regulated and emerging mycotoxins in bulk milk samples by high-resolution mass spectrometry. Foods. 2021;10(9):2025. Available from: https://doi.org/10.3390/foods10092025
45. Klerk J, Robinson P. Drivers and hazards of consumption of unpasteurised bovine milk and milk products in high-income countries. PeerJ. 2022;10:e13426. Available from: https://doi.org/10.7717/peerj.13426
46. Nyokabi N, Lindahl J, Phelan L, Berg S, Gemechu G, Mihret A, et al. Exploring the composition and structure of milk and meat value chains, food safety risks and governance in the Addis Ababa and Oromia regions of Ethiopia. Front Sustain Food Syst. 2023;7. Available from: https://doi.org/10.3389/fsufs.2023.1085390
47. Bukari N, Kwofie M, Adeboye O. Aflatoxin M1 (Aspergillus parasiticus, flavus) occurrences in milk and milk products and its possible health effects. Adv Microbiol. 2020;10(10):509-24. Available from: https://doi.org/10.4236/aim.2020.1010038
48. Landers T, Cohen B, Wittum T, Larson E. A review of antibiotic use in food animals: perspective, policy, and potential. Public Health Rep. 2012;127(1):4-22. doi:10.1177/003335491212700103
49. Abdelfattah E, Ekong P, Okello E, Williams D, Karle B, Lehenbauer T, et al. Factors associated with antimicrobial stewardship practices on California dairies: one year post Senate Bill 27. Antibiotics. 2022;11(2):165. doi:10.3390/antibiotics11020165
50. Abdelfattah E, Ekong P, Okello E, Williams D, Karle B, Rowe J, et al. 2019 survey of antimicrobial drug use and stewardship practices in adult cows on California dairies: post Senate Bill 27. Microorganisms. 2021;9(7):1507. doi:10.3390/microorganisms9071507

51. Vasquez A, Foditsch C, Dulièpre S, Siler J, Just D, Warnick L, et al. Understanding the effect of producers' attitudes, perceived norms, and perceived behavioral control on intentions to use antimicrobials prudently on New York dairy farms. PLoS One. 2019;14(9):e0222442. doi:10.1371/journal.pone.0222442
52. Ramirez C, Dumas S, Schlist K, French D, Bichi E, Correa-Rivero B, et al. Evidence in support of veterinary involvement in antimicrobial stewardship training programs in the dairy industry. Bov Pract. 2017;51(2):200-204. doi:10.21423/bovine-vol51no2p200-204
53. Sami R, Sadegh R, Fani F, Atashi V, Solgi H. Assessing the knowledge, attitudes and practices of physicians on antibiotic use and antimicrobial resistance in Iran: a cross-sectional survey. J Pharm Policy Pract. 2022;15(1):[page numbers]. doi:10.1186/s40545-022-00484-2
54. Redding L, Bender J, Baker L. Quantification of antibiotic use on dairy farms in Pennsylvania. J Dairy Sci. 2019;102(2):1494–1507. doi:10.3168/jds.2018-15224
55. Sawant A, Sordillo L, Jayarao B. A survey on antibiotic usage in dairy herds in Pennsylvania. J Dairy Sci. 2005;88(8):2991–2999. doi:10.3168/jds.s0022-0302(05)72979-9
56. Higham L, Deakin A, Tivey E, Porteus V, Ridgway S, Rayner A. A survey of dairy cow farmers in the United Kingdom: knowledge, attitudes and practices surrounding antimicrobial use and resistance. Vet Rec. 2018;183(24):746. doi:10.1136/vr.104986
57. Casseri E, Bulut E, Llanos-Soto S, Wemette M, Stout A, Safi A, et al. Understanding antibiotic resistance as a perceived threat towards dairy cattle through beliefs and practices: a survey-based study of dairy farmers. Antibiotics. 2022;11(8):997. doi:10.3390/antibiotics11080997
58. Damiaans B, Renault V, Sarrazin S, Berge A, Pardon B, Saegerman C, et al. A risk-based scoring system to quantify biosecurity in cattle production. Prev Vet Med. 2020;179:104992. doi:10.1016/j.prevetmed.2020.104992
59. Rotz CA, Stout RL, Holly MK, Kleinman PJ. Regional environmental assessment of dairy farms. J Dairy Sci. 2020;103(4):3275–3288. doi:10.3168/jds.2019-17388

60. Nóbrega D, Naqvi S, Dufour S, Deardon R, Kastelic J, Buck J, et al. Critically important antimicrobials are generally not needed to treat no severe clinical mastitis in lactating dairy cows: results from a network meta-analysis. J Dairy Sci. 2020;103(11):10585–10603. doi:10.3168/jds.2020-18365

61. Schmidt CW. FDA proposes to ban cephalosporins from livestock feed. Environ Health Perspect. 2012 Mar;120(3):a106. Available from: https://doi.org/10.1289/ehp.120-a106

62. Ekong PS, Abdelfattah EM, Okello E, Williams DR, Lehenbauer TW, Karle BM, Rowe JD, Aly SS. 2018 Survey of factors associated with antimicrobial drug use and stewardship practices in adult cows on conventional California dairies: immediate post-Senate Bill 27 impact. PeerJ. 2021 Jul 13;9:e11596. Available from: https://doi.org/10.7717/peerj.11596

63. U.S. Food and Drug Administration. FDA announces transition of over-the-counter medically important antimicrobials for animals to prescription status. [Internet]. 2023 Jun 12 [cited 2025 Mar 28]. Available from: https://www.fda.gov/animal-veterinary/cvm-updates/fda-announces-transition-over-counter-medically-important-antimicrobials-animals-prescription-status

64. Vasquez A, Foditsch C, Dulièpre S, et al. Understanding the effect of producers' attitudes, perceived norms, and perceived behavioral control on intentions to use antimicrobials prudently on New York dairy farms. PLoS One. 2019;14(9):e0222442. https://doi.org/10.1371/journal.pone.0222442

65. Abdelfattah E, Ekong P, Okello E, et al. Factors associated with antimicrobial stewardship practices on California dairies: One year post Senate Bill 27. Antibiotics. 2022;11(2):165. https://doi.org/10.3390/antibiotics11020165

66. Ekakoro JE, Caldwell M, Strand EB, Okafor CC. Drivers of antimicrobial use practices among Tennessee dairy cattle producers. Vet Med Int. 2018;2018:1836836. https://doi.org/10.1155/2018/1836836

67. Ruegg PL. Realities, challenges and benefits of antimicrobial stewardship in dairy practice in the United States. Microorganisms. 2022;10(8):1626. https://doi.org/10.3390/microorganisms10081626
68. Llanos‐Soto S, Vezeau N, Wemette M, et al. Survey of perceptions and attitudes of an international group of veterinarians regarding antibiotic use and resistance on dairy cattle farms. Prev Vet Med. 2021;188:105253. https://doi.org/10.1016/j.prevetmed.2020.105253
69. Kates AE, Knobloch MJ, Konkel A, et al. Use of a systems engineering framework to assess perceptions and practices about antimicrobial resistance of workers on large dairy farms in Wisconsin. medRxiv. 2020. https://doi.org/10.1101/2020.10.28.20221747
70. USDA. Dairy 2014: Milk Quality, Milking Procedures, and Mastitis on U.S. Dairies. USDA–APHIS–VS–CEAH; 2016.
71. Ekakoro JE, Caldwell M, Strand EB, Okafor CC. Drivers of antimicrobial use practices among Tennessee dairy cattle producers. Vet Med Int. 2018;2018:1836836. https://doi.org/10.1155/2018/1836836
72. .Ruegg PL. Realities, challenges and benefits of antimicrobial stewardship in dairy practice in the United States. Microorganisms. 2022;10(8):1626. https://doi.org/10.3390/microorganisms10081626
73. Anderson D. Survey of biosecurity practices utilized by veterinarians working with farm animal species. Online J Rural Res Policy. 2010;5(7). https://doi.org/10.4148/ojrrp.v5i7.263
74. Zanon T, Alrhmoun M, Gauly M. Assessing the impact of biosecurity practices and animal welfare in small-scale mountain dairy farming. Sci Rep. 2024;14(1). https://doi.org/10.1038/s41598-024-63841-y
75. Pruvot M, Kutz S, Meer F, Musiani M, Barkema H, Orsel K. Pathogens at the livestock-wildlife interface in western Alberta: does transmission route matter? Vet Res. 2014;45(1):18. https://doi.org/10.1186/1297-9716-45-18

76. Jones B, Grace D, Kock R, et al. Zoonosis emergence linked to agricultural intensification and environmental change. Proc Natl Acad Sci U S A. 2013;110(21):8399–8404. https://doi.org/10.1073/pnas.1208059110

77. Anderson D. Survey of biosecurity practices utilized by veterinarians working with farm animal species. Online Journal of Rural Research & Policy. 2010;5(7). https://doi.org/10.4148/ojrrp.v5i7.263

78. Jones BA, Grace D, Kock R, Alonso S, Rushton J, Said MY, et al. Zoonosis emergence linked to agricultural intensification and environmental change. Proc Natl Acad Sci U S A. 2013;110(21):8399–8404. https://doi.org/10.1073/pnas.1208059110

79. Pruvot M, Kutz S, Meer F, Musiani M, Barkema HW, Orsel K. Pathogens at the livestock–wildlife interface in western Alberta: does transmission route matter? Vet Res. 2014;45(1):18. https://doi.org/10.1186/1297-9716-45-18

80. Zanon T, Alrhmoun M, Gauly M. Assessing the impact of biosecurity practices and animal welfare in small-scale mountain dairy farming. Sci Rep. 2024;14(1). https://doi.org/10.1038/s41598-024-63841-y

81. Casseri E, Bulut E, Llanos‑Soto S, Wemette M, Stout A, Safi A, et al. Understanding antibiotic resistance as a perceived threat towards dairy cattle through beliefs and practices: a survey-based study of dairy farmers. Antibiotics. 2022;11(8):997. https://doi.org/10.3390/antibiotics11080997

82. Down P, Bradley A, Breen J, Green M. Factors affecting the cost-effectiveness of on-farm culture prior to the treatment of clinical mastitis in dairy cows. *Prev Vet Med*. 2017;145:91–99.https://doi.org/10.1016/j.prevetmed.2017.07.006

83. Aksomaitienė J, Ramonaitė S, Tamulevičienė E, Novoslavskij A, Alter T, Malakauskas M. Overlap of antibiotic resistant *Campylobacter jejuni* MLST genotypes isolated from humans, broiler products, dairy cattle and wild birds in Lithuania. *Front Microbiol*. 2019;10:1377.https://doi.org/10.3389/fmicb.2019.01377

84. Zhang T, Mu Y, Gao Y, Tang Y, Mao S, Liu J. Fecal microbial gene transfer contributes to the high-grain diet-induced augmentation of aminoglycoside resistance in dairy cattle. *mSystems*. 2024;9(1):e00810-23. https://doi.org/10.1128/msystems.00810-23
85. Ježek J, Grabnar P, Beci B, et al. Management practices affecting calves welfare on farms in Slovenia. Acta Univ Agric Silvic Mendel Brun. 2019;67(5):1147–1152. https://doi.org/10.11118/actaun201967051147
86. Vasseur E, Borderas F, Cue R, et al. A survey of dairy calf management practices in Canada that affect animal welfare. J Dairy Sci. 2010;93(3):1307–1316. https://doi.org/10.3168/jds.2009-2429
87. Shivley C, Lombard J, Urie N, Weary D, von Keyserlingk MAG. Management of preweaned bull calves on dairy operations in the United States. J Dairy Sci. 2019;102(5):4489–4497. https://doi.org/10.3168/jds.2018-15100
88. Casseri E, Bulut E, Llanos-Soto S, Wemette M, Stout A, Safi A, et al. Understanding antibiotic resistance as a perceived threat towards dairy cattle through beliefs and practices: a survey-based study of dairy farmers. Antibiotics. 2022;11(8):997. https://doi.org/10.3390/antibiotics11080997
89. Chauhan A, George M, Chatterjee P, Lindahl J, Grace D, Kakkar M. The social biography of antibiotic use in smallholder dairy farms in India. Antimicrob Resist Infect Control. 2018;7(1):40. https://doi.org/10.1186/s13756-018-0354-9
90. Azevedo M, Pinheiro C, Yaphe J, Baltazar F. Portuguese students' knowledge of antibiotics: a cross-sectional study of secondary school and university students in Braga. BMC Public Health. 2009;9:359. https://doi.org/10.1186/1471-2458-9-359
91. Jones BA, Grace D, Kock R, Alonso S, Rushton J, Said M, et al. Zoonosis emergence linked to agricultural intensification and environmental change. Proc Natl Acad Sci U S A. 2013;110(21):8399–8404. https://doi.org/10.1073/pnas.1208059110
92. Miller RS, Sweeney SJ, Slootmaker C, Grear DA, Salvo P, Kiser D, et al. Cross-species transmission potential between wild pigs, livestock, poultry, wildlife, and humans: implications

for disease risk management in North America. Sci Rep. 2017;7:7821. https://doi.org/10.1038/s41598-017-07336-z

93. Down P, Bradley A, Breen J, Green M. Factors affecting the cost-effectiveness of on-farm culture prior to the treatment of clinical mastitis in dairy cows. Prev Vet Med. 2017;145:91–99. https://doi.org/10.1016/j.prevetmed.2017.07.006

94. Singh N, Sunitha N, Tripathi G, Saikanth D, Sharma A, Jose A, et al. Impact of digital technologies in agricultural extension. Asian J Agric Ext Econ Sociol. 2023;41(9):963–70. https://doi.org/10.9734/ajaees/2023/v41i92127

95. Chambers D, Glasgow R, Stange K. The dynamic sustainability framework: addressing the paradox of sustainment amid ongoing change. Implement Sci. 2013;8(1):117. https://doi.org/10.1186/1748-5908-8-117

96. Schattman R, Hurley S, Greenleaf H, Niles M, Caswell M. Visualizing climate change adaptation: an effective tool for agricultural outreach? Weather Clim Soc. 2020;12(1):47–61. https://doi.org/10.1175/wcas-d-19-0049.1

97. Rajkhowa P, Qaim M. Personalized digital extension services and agricultural performance: evidence from smallholder farmers in India. PLoS One. 2021;16(10):e0259319. https://doi.org/10.1371/journal.pone.0259319

98. Fabregas R, Harigaya T, Kremer M, Ramrattan R. Digital agricultural extension for development. In: Digital Revolution in Agriculture. Cham: Springer; 2022. p. 187–219. https://doi.org/10.1007/978-3-030-86065-3_8

99. Boone C. Leveraging TikTok and other new media for optics educational outreach. Proc SPIE. 2022. https://doi.org/10.1117/12.2646001

100. Longhurst M, Judd-Murray R, Coster D, Spielmaker D. Measuring agricultural literacy: grade 3–5 instrument development and validation. J Agric Educ. 2020;61(2):173–92. https://doi.org/10.5032/jae.2020.02173

101. Ahmed N, Boxley C, Dixit R, Krevat S, Fong A, Ratwani R, et al. Evaluation of a text message–based COVID-19 vaccine outreach program among older patients: cross-sectional study. JMIR Form Res. 2022;6(7):e33260. https://doi.org/10.2196/33260

102. Cassel S, Fenelon HT, Rott E, Blazes L, Willess LM, Baines AE, Ramirez V, Kauber K, Rabinowitz P, Burbick CR, Fuhrmeister ER. Antimicrobial prescription practices and stewardship in washington state small and mixed animal veterinary medicine. Zoonoses and Public Health. 2025 Mar;72(2):117-26.

103. Farrell S, McKernan C, Benson T, Elliott C, Dean M. Understanding farmers' and veterinarians' behavior in relation to antimicrobial use and resistance in dairy cattle: a systematic review. J Dairy Sci. 2021 Apr;104(4):4584-4603.

Basic Information

Please complete the survey below.

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Thank you!

Basic Information

Your name ______________________

Your email address ______________________

Farm name ______________________

Farm Address and Location ______________________

Your role
- ☐ Owner
- ☐ Manager
- ☐ Employee
- ☐ Other

If the answer to the above question is "other", please specify ______________________

Farm address (main address, could be physical or mailing) ______________________

Which of the following products does your farm provide? (Check all that apply)
- ☐ Retail raw milk
- ☐ Milk for pasteurization
- ☐ Cheese
- ☐ Yogurt
- ☐ Other

If the answer to the above question is "other", please specify ______________________

Herd Characteristics & Management

Please complete the survey below.

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Thank you!

Which one category best describes your dairy herd size? Please include both milkers and dry animals. (Select one)	◯ Less than 25 dairy animals ◯ 25-99 dairy animals ◯ 100-199 dairy animals ◯ 200-499 dairy animals ◯ 500-999 dairy animals ◯ 1000+ dairy animals
Please estimate the herd size of your farm animal including both milkers and dry animals.	______________________________
Which one category best describes the maximum number of female animals who have not yet given birth (4 to 24 months of age) on your operation in the last 12 months? (Select one)	◯ 1-24 female animals ◯ 25-49 female animals ◯ 50-99 female animals ◯ 100-399 female animals ◯ 400+ female animals ◯ None
Which one category best describes the maximum number of preweaned (less than 4 months of age) replacement young animals on your operation in the last 12 months? (Select one)	◯ 1-19 female animals ◯ 20-39 female animals ◯ 65-199 female animals ◯ 200+ female animals ◯ None
Which one breed of dairy animals best describes the majority of your herd? (Select one)	◯ Holstein ◯ Jersey ◯ Guernsey ◯ Mixed ◯ Other
If the answer to the question above is "Mixed", please list the mixed breeds	______________________________
If the answer to the question above is "other", please specify	______________________________
Which best describes your herd's average somatic cell count? (Select one)	◯ Less than 200,000 ◯ 200,00-299,000 ◯ 300,000 -399,000 ◯ 400,000+ ◯ I don't Know
When facing animal health management problems, whom do you rely on most other than yourself? (Select one)	◯ County Extension Agent ◯ Veterinarian ◯ Other Dairy Farmers ◯ Nutritionist ◯ Other
If the answer to the question above is "other", please specify	______________________________

Which of the following continuing education resources do you use? (Check all that apply)	☐ Dairy Herd Management Journal ☐ Dairy Quality Assurance newsletter ☐ Other dairy publications ☐ Dairy Line online ☐ Other internet resources ☐ Extension, Industry conferences or meetings ☐ Other
If the answer to the question above is "other", please specify	__________________________________

Colostrum Management & Sanitation

Please complete the survey below.

Note: Once you proceed to the next page, you will not be able to return to this page.

You can save and return later by clicking on the "Save & Return Later" button. Simply send the survey link to your email and revisit it when you're ready to continue.

Thank you!

How often do male animals born on your operation receive colostrum? (Select one)

- ◯ Never
- ◯ Sometimes
- ◯ Always
- ◯ Don't know

What do your newborn female animals normally receive in the first 24 hours? (Check all that apply)

- ☐ Nursing
- ☐ Colostrum by hand
- ☐ Waste milk
- ☐ Milk replacer
- ☐ Bulk tank milk
- ☐ Colostrum replacer

If your answer to the question above is colostrum replacer, please specify

____

If it is bulk tank milk, do you pasteurize it before feeding?

- ◯ Yes
- ◯ No

What is your best estimate of how much colostrum female animals receive during the first 24 hours? (Select one)

- ◯ less than 2 quarts
- ◯ 2-4 quarts
- ◯ More than 4 quarts
- ◯ Do not receive colostrum
- ◯ Don't know

Do you test colostrum for immunoglobulin levels? (Select one)

- ◯ Yes
- ◯ No

What method do you use for testing immunoglobulin levels?

____

If you do not test colostrum for immunoglobulin levels, which of the following are reasons? (Select all that apply)

- ☐ Cost of testing equipment
- ☐ Time it takes to test
- ☐ I am not familiar with how to test
- ☐ It is not necessary to test colostrum
- ☐ Other

If your answer to the question above is "Other", please specify

____

How often do you test female animals for effective immune protection (passive transfer of antibodies)? (Select one)

- ◯ Never
- ◯ Sometimes
- ◯ Always

How often do you clean and sanitize animal housing (pen)?

- ◯ Daily
- ◯ Weekly
- ◯ Monthly
- ◯ Other

If your answer to the question above is "Other", please specify	__________________
What personal hygiene practices do you enforce for farm workers? (Select all that apply)	☐ Handwashing ☐ Wearing gloves ☐ Wearing masks ☐ Other
If your answer to the question above is "Other", please specify	__________________
What animal hygiene practices do you implement? (Select all that apply)	☐ Regular grooming ☐ Footbath treatments ☐ Routine health checks ☐ Other
If your answer to the question above is "Other", please specify	__________________
How do you perform the milking process?	◯ Manual milking ◯ Machine milking ◯ Combination of both ◯ Other
If your answer to the question above is "Other", please specify	__________________
How often do you clean and sanitize milking equipment?	◯ After each use ◯ Daily ◯ Weekly ◯ Other
If your answer to the question above is "Other", please specify	__________________

Animal Health

Please complete the survey below.

Note: Once you proceed to the next page, you will not be able to return to this page.

You can save and return later by clicking on the "Save & Return Later" button. Simply send the survey link to your email and revisit it when you're ready to continue.

Thank you!

Have you purchased replacement animals in the past 2 years?	◯ Yes ◯ No
If yes, how long do you keep your newly purchased animals separated before joining the herds? (Select all that apply)	☐ Not separated ☐ Separated for 24 hours or less ☐ Separated for 1 to 13 days ☐ Separated for 14 to 27 days ☐ Separated for 4 weeks or longer
Do you test purchased animals for infectious disease prior to joining the herds?	◯ Yes ◯ No
If yes, please indicate which diseases you test for	______________________
If you do not test newly purchased animals for infectious diseases, which of the following are the reasons? (Select all that apply)	☐ Cost of testing ☐ Time it takes to collect specimens ☐ Time it takes to receive results ☐ I am not familiar with how to test ☐ I am not familiar with what diseases to test for ☐ I do not have a regular veterinarian ☐ It is not necessary to test ☐ Other
If the reason why newly purchased animals are not tested for infectious disease is ''it is not necessary to test", please explain	______________________
If the reason why newly purchased animals are not tested for infectious disease is "Other", please specify	______________________
Do you think the following statement is true or false? "A healthy animal I purchase at auction is not at the auction barn long enough to pick up a disease that could spread on my farm."	◯ True ◯ False ◯ Other
If your answer to the question above is "Other", please explain	___________________________
Is your pen used for purposes other than calving/lambing/kidding?	◯ Yes ◯ No
If yes, which one reason best describes why you use the pen for multiple purposes? (Select all that apply)	☐ Don't see the need to restrict use to calving/lambing/kidding only ☐ Don't have the physical facilities or space ☐ Other

If the answer to the question above is "Other', please explain	__________________________________
Is the pen you use for sick animals used for other purposes?	◯ Yes ◯ No
If yes, which one reason best describes why you use the sick pen for multiple purposes? (Select all that apply)	☐ Don't see the need to restrict use for sick animals only ☐ Don't have the physical facilities or space ☐ Other
If the answer to the question above is "Other", please explain	__________________________________
Do you use the same equipment (tractors, etc.) for handling feed and for handling waste?	◯ Yes ◯ No
If yes, how often do you clean this equipment after handling waste	◯ Never ◯ Sometimes ◯ Always

Visitor Management

Please complete the survey below.

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Thank you!

Do you usually get visitors coming to your farm?

- ◯ Yes
- ◯ No

How often do you have visitors do the following at your farm?

	Never	Sometimes	Always
a. Have visitors to the farm sign a logbook	◯	◯	◯
b. Provide protective clothing to visitors	◯	◯	◯
c. Have an employee accompany visitors during the entire visit	◯	◯	◯
d. Provide protective footwear	◯	◯	◯

If you never provide protective footwear to visitors, what are the reasons?

- ☐ No need to do it
- ☐ Costs too much
- ☐ Too difficult to provide to everyone who comes
- ☐ Other

If the answer to the question above is "Other', please explain?

____

Does the rendering truck ever pass through areas where live animals are fed or housed?

- ◯ Yes
- ◯ No

Do you have footbaths for human use on your operation?

- ◯ Yes
- ◯ No

Vaccination and Written Protocol

Please complete the survey below.

Note: Once you proceed to the next page, you will not be able to return to this page.

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Thank you!

For each of the following diseases, please indicate whether or not you vaccinate against it.

a. Bovine viral diarrhea (BVD)

○ Do not vaccinate
○ Vaccinate

If you answered Do not vaccinate the above, please indicate the reason(s). (Please check all that apply.)

☐ Don't need to vaccinate because there is no threat from the disease
☐ Don't believe in vaccinating
☐ Cost is not worth it
☐ Not familiar with the vaccine
☐ Other

If the answer to the question above is "Other", please specify?

____

---

b. Infectious bovine rhinotracheitis (IBR)

○ Do not vaccinate
○ Vaccinate

If you answered Do not vaccinate the above, please indicate the reason(s). (Please check all that apply.)

☐ Don't need to vaccinate because there is no threat from the disease
☐ Don't believe in vaccinating
☐ Cost is not worth it
☐ Not familiar with the vaccine
☐ Other

If the answer to the question above is "Other", please specify?

____

---

c. Parainfluenza Type 3 (PI3)

○ Do not vaccinate
○ Vaccinate

If you answered Do not vaccinate the above, please indicate the reason(s). (Please check all that apply.)

☐ Don't need to vaccinate because there is no threat from the disease
☐ Don't believe in vaccinating
☐ Cost is not worth it
☐ Not familiar with the vaccine
☐ Other

If the answer to the question above is "Other", please explain?

____

---

d. Bovine respiratory syncytial virus (BRSV)

○ Do not vaccinate
○ Vaccinate

If you answered Do not vaccinate the above, please indicate the reason(s). (Please check all that apply.)	☐ Don't need to vaccinate because there is no threat from the disease ☐ Don't believe in vaccinating ☐ Cost is not worth it ☐ Not familiar with the vaccine ☐ Other
If the answer to the question above is "Other", please explain?	__________________________________
e. Salmonella	◯ Do not vaccinate ◯ Vaccinate
If you answered Do not vaccinate the above, please indicate the reason(s). (Please check all that apply.)	☐ Don't need to vaccinate because there is no threat from the disease ☐ Don't believe in vaccinating ☐ Cost is not worth it ☐ Not familiar with the vaccine ☐ Other
If the answer to the question above is "Other", please explain?	__________________________________
f. E. coli mastitis	◯ Do not vaccinate ◯ Vaccinate
If you answered Do not vaccinate the above, please indicate the reason(s). (Please check all that apply.)	☐ Don't need to vaccinate because there is no threat from the disease ☐ Don't believe in vaccinating ☐ Cost is not worth it ☐ Not familiar with the vaccine ☐ Other
If the answer to the question above is "Other", please explain?	__________________________________
Do you have written protocols for diagnosing common medical conditions?	◯ Yes ◯ No
Do you have written protocols for treating common medical conditions?	◯ Yes ◯ No
How strongly do you agree or disagree with the following statements? a. Having written protocols for diagnosing and treating common infectious diseases can help reduce errors	◯ Disagree strongly ◯ Disagree somewhat ◯ Agree somewhat ◯ Agree strongly ◯ Don't know
b. Having written protocols for diagnosing and treating common infectious diseases can reduce loss of production	◯ Disagree strongly ◯ Disagree somewhat ◯ Agree somewhat ◯ Agree strongly ◯ Don't know
When an animal is diagnosed with mastitis, how often do you do the following? a. Culture milk from the affected quarter(s)	◯ Never ◯ Sometimes ◯ Always

b. Test with an on-farm mastitis test kit

◯ Never
◯ Sometimes
◯ Always

Animal Health Problems

Please complete the survey below.

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Thank you!

Has clinical mastitis (inflamed udder or abnormal milk) occurred in your herd in the last 3 months?	◯ Yes ◯ No
If yes, indicate the percentage of animals that have been infected with clinical mastitis in the last 3 months	__________________
Were most animals infected with clinical mastitis in the last 3 months treated with antibiotic?	◯ Yes ◯ No
Name(s) the antibiotic usually used in treating clinical mastitis	__________________
Has respiratory infection in animals occurred in your herd in the last 3 months?	◯ Yes ◯ No
If yes, indicate the percentage of animals that have been infected with respiratory infection in the last 3 months	__________________
Were most animals infected with respiratory infection in the last 3 months treated with antibiotic?	◯ Yes ◯ No
Name(s) the antibiotic usually used in treating respiratory infections in animals	__________________
Has diarrhea in animals occurred in your herd in the last 3 months?	◯ Yes ◯ No
If yes, indicate the percentage of animals that have been infected with diarrhea in animals in the last 3 months	__________________
Were most animals infected with diarrhea in animals in the last 3 months treated with antibiotic?	◯ Yes ◯ No
Name(s) the antibiotic usually used in treating respiratory infections in animals	__________________
Has lameness in animals occurred in your herd in the last 3 months?	◯ Yes ◯ No
If yes, indicate the percentage of animals that have been infected with lameness in the last 3 months	__________________

Were most animals infected with lameness in the last 3 months treated with antibiotic?	◯ Yes ◯ No
Name(s) the antibiotic usually used in treating lameness in animals	__________________________

Antibiotic Use

Please complete the survey below.

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Thank you!

What criteria are used in your operation to determine the need for antibiotic treatment for mastitis? (Select all that apply)	☐ Symptoms ☐ Positive on-farm mastitis test ☐ Positive culture results ☐ Other
If the answer to the question above is "Other", please specify	__________________________________
For what reasons do you use antibiotics on your farm? (Select all that apply)	☐ Treatment of illness ☐ Prevention of illness ☐ Growth promotion ☐ Other
If the answer to the question above is "Other", please specify	__________________________________
Please list the name(s) of the antibiotics used on your farm	__________________________________
What percentage of animals do you use antibiotics on an annual basis?	__________________________________
What kind of animals are antibiotics used on?	__________________________________
Do you use milk replacer to feed young animals?	◯ Yes ◯ No
Is the milk replacer you use medicated with an antibiotic? (Select one)	◯ Yes ◯ No
What is the name of the antibiotic in the milk replacer you use most often?	__________________________________
Have you found that antibiotics that worked well in the past are no longer as effective for treating the same condition now?	◯ Yes ◯ No
What percent of your animals are treated with intramammary infusion at dry-off?	◯ None ◯ 1 to 49% ◯ 50 to 99% ◯ 100% (NB: Intramammary infusion at dry-off refers to the practice of administering a treatment directly into the udder (mammary gland) of a dairy cow at the time when milking is stopped.)

What is the name of the product you use most often for this treatment?	__________________________
What is the average quantity of this product used in your herds per month?	__________________________
Under what conditions do you top-dress feeds with antibiotics?	◯ Never ◯ Seasonally ◯ During outbreaks of disease ◯ Other (NB: Top-dress feeds with antibiotics refers to the practice of adding antibiotics to animal"s feed, typically by sprinkling or mixing it on top of the feed.)
If the answer to the question above is "Other", please specify	__________________________
Do animals of age group "less than 4 months old" get their feed top-dressed with antibiotics?	◯ Yes ◯ No
If yes, please list the name(s) of antibiotic(s)	__________________________
Does weaned animals less than 12 months old get their feed top-dressed with antibiotics?	◯ Yes ◯ No
If yes, please list the name(s) of antibiotic(s)	__________________________
Do animals of age group "12 to 24 months old" get their feed top-dressed with antibiotics?	◯ Yes ◯ No
If yes, please list the name(s) of antibiotic(s)	__________________________
Do lactating animals get their feed top-dressed with antibiotics?	◯ Yes ◯ No
If yes, please list the name(s) of antibiotic(s)	__________________________
Do dry animals get their feed top-dressed with antibiotics?	◯ Yes ◯ No
If yes, please list the name(s) of antibiotic(s)	__________________________
How familiar are you with the subject of antibiotic resistance?	◯ Never heard of it ◯ Heard of it but know nothing about it ◯ Know a little about it ◯ Know a lot about it

Which of the following best defines antibiotic resistance?

- ◯ After taking an antibiotic, an animal or human can become resistant to the antibiotic
- ◯ Antibiotic residues are excreted in the body fluids (such as milk or urine) of animals or humans who have taken antibiotics
- ◯ The germs present in an animal or human who have taken an antibiotic may become resistant to the antibiotic
- ◯ Do not know.

How strongly do you agree or disagree with the following statements?

	Disagree strongly	Disagree somewhat	Neutral	Agree somewhat	Agree strongly	Don't know
a. If an animal has an infection that is resistant to antibiotics, this could be a threat to the rest of my herd.	◯	◯	◯	◯	◯	◯
b. If an animal has an infection that is resistant to antibiotics, this could be a threat to my farm workers.	◯	◯	◯	◯	◯	◯
c. If I cannot use antibiotics to prevent disease, more animals would die.	◯	◯	◯	◯	◯	◯
d. If I did not use antibiotics for dry animal treatment, overall milk production would ultimately decrease.	◯	◯	◯	◯	◯	◯
e. Antibiotics become less effective the more they are used.	◯	◯	◯	◯	◯	◯
f. The use of antibiotics in food-producing animals can impact human health.	◯	◯	◯	◯	◯	◯