

Food for Thought for Food Animal Veterinarians

Suggested outline of potential critical control points for biosecurity and biocontainment on large dairy farms

Aurora Villarroel, DVM, MPVM, DACVPM; David A. Dargatz, DVM, PhD, DACT;
V. Michael Lane, DVM, MPVM, DACT, DABVP; Brian J. McCluskey, DVM, PhD, DACVPM;
Mo D. Salman, BVMS, MPVM, PhD, DACVPM

The US dairy industry is moving toward fewer dairy farms with more cattle per farm. Between 1995 and 2005, the number of dairy farms decreased by 43.9% (from 139,670 to 78,295), but the total number of milk cows decreased by only 4.5% (from 9.47 to 9.04 million).¹ Consequently, the average herd size for dairies in the United States has almost doubled during the past 10 years.

It has become difficult for dairy farms to be completely self-sufficient, self-contained production units. Large dairy farms are at risk of exposure to disease agents from external sources of labor, feedstuffs, replacement cattle, supplies, and vehicles. In a USDA study,² it was estimated that 75.3% of large US dairy farms brought new cattle into the herd in 2001. Large dairy farms typically focus on milk-producing cows and may contract with outside services to manage their calves, heifers, or nonlactating cows. Numerous vehicles travel among several dairy farms on a daily basis; some of these collect milk, calves, or carcasses, whereas others deliver feedstuffs, pharmaceuticals, or genetic materials. Wildlife, rodents, and birds have access to dairy farms and pose a risk for transmission of disease.^{3,4} It is estimated that wild ruminants have physical contact with dairy cows or feedstuffs on 53% of US dairy operations.²

Interaction with all the aforementioned outside resources can increase the likelihood of introducing disease agents to a farm. This risk can be minimized by establishing and adhering to a structured biosecurity plan. Biosecurity is the result of management practices designed to avoid introduction of disease agents to a farm.⁵ Disease agents may include toxins or infectious pathogens, such as bac-

ABBREVIATIONS

HACCP	Hazard analysis and critical control point
NAHMS	National Animal Health Monitoring System
BVDV	Bovine viral diarrhea virus
NPV	Negative predictive value
MAP	<i>Mycobacterium avium</i> subsp <i>paratuberculosis</i>

teria and viruses. In contrast, biocontainment is the result of actions to prevent the spread of disease agents among groups of animals on a farm.⁵ Biocontainment measures will be most important to prevent the spread of endemic disease agents. Biocontainment also serves as an important backup system for biosecurity plans. When biosecurity is breached, biocontainment measures can prevent the spread of disease agents on a farm.

It is recommended that dairy producers, working closely with their veterinarian, develop an economically viable written biosecurity and biocontainment plan that reflects the health history and future health goals of each farm. A written plan is easier to execute, objectively evaluate, and revise than are unwritten policies.

Dairy cattle can be exposed to disease agents through several routes, such as oral exposure to contaminated feed or water, inhalation of dust and manure particles, exposure through other natural orifices (eg, teat ends) and wounds, indirect contact via fomites, and exposure through vectors. Calves, heifers, and adult cows differ in their resistance and their exposure to pathogens throughout the various production phases (shortly after parturition, during lactation, and during the nonlactating period). Therefore, some diseases that easily affect calves are less important in adult cattle, and other diseases, such as mastitis, are restricted to lactating cows. Despite these differences, methods to control the spread of disease agents are based on the same principles: avoid exposure to the agent by ensuring appropriate hygiene and disinfection of the environment and ensure better resistance (specific and nonspecific) against disease.

A visual representation of a farm and its dynamics can help identify potential routes for the introduction and spread of disease agents that need to be considered when developing biosecurity and biocontainment strategies. The approach uses the same principles as those of the HACCP

From the Animal Population Health Institute, Department of Clinical Sciences, College of Veterinary Medicine and Biological Sciences, Colorado State University, Fort Collins, CO 80523 (Villarroel, Salman); the USDA, Animal and Plant Health Inspection Service, Veterinary Services, Centers for Epidemiology and Animal Health, 2150 Centre Ave, Building B, Fort Collins, CO 80526-8117 (Dargatz, McCluskey); and the Department of Population Health and Reproduction, School of Veterinary Medicine, University of California, Davis, CA 95616 (Lane). Dr. Villarroel's present address is the Department of Clinical Sciences, College of Veterinary Medicine, Oregon State University, Corvallis, OR 97331.

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Address correspondence to Dr. Dargatz.

system.⁶ The HACCP system is primarily a risk-assessment approach that focuses on manageable risk factors identified as critical control points. The HACCP system is based on 3 principles: identifying hazards, defining critical control points and potential mitigation procedures, and designing a monitoring system to evaluate the effectiveness of any control method. A critical control point is a step within the production process at which specific actions may decrease the risk of a negative outcome. Control methods deemed to be of limited effectiveness should be changed.

The strength of the HACCP system is its flexibility of implementation through improvement of suboptimal control methods. Important critical control points to be included in a biosecurity and biocontainment plan for dairy farms should be identified (Figure 1). Visual identification of critical control points within each area of the farm can be a valuable aid in preventing intentional or unintentional introduction of diseases and avoiding the spread of disease agents among areas of a dairy farm. Flowcharts can be used to describe the biosecurity protocol to personnel that work on the dairy farm.

Biosecurity

Potential routes for introduction of disease agents onto a dairy farm should be identified. Potential haz-

ards of introduction of disease agents onto a dairy farm should be ordered from highest to lowest in accordance with perceived risk. Control methods and monitoring options should be determined for each hazard.

Cattle from other premises—Exposure to cattle from other herds is a risk factor for introduction of disease agents from other farms.⁷ Purchased cattle and cattle returning from off-premises locations could harbor pathogens that are endemic to the source farm but differ from those on the destination dairy farm. Incoming cattle may not appear ill but could be incubating a disease or be infected with an organism that can recrudescence when the cattle are exposed to the stress of transport or acclimation to a new environment. Control measures to avoid introduction of new disease agents onto a dairy farm may require testing new cattle before introduction, isolating purchased or returning cattle at arrival to a farm, or a combination of both.

Ideally, every new animal brought onto a dairy farm should originate from farms that have complete and accurate health and vaccination records. Before an animal arrives on a farm, its vaccination status and the lack of specific pathogens of interest to the farm should be assessed. However, this may not always be practical or

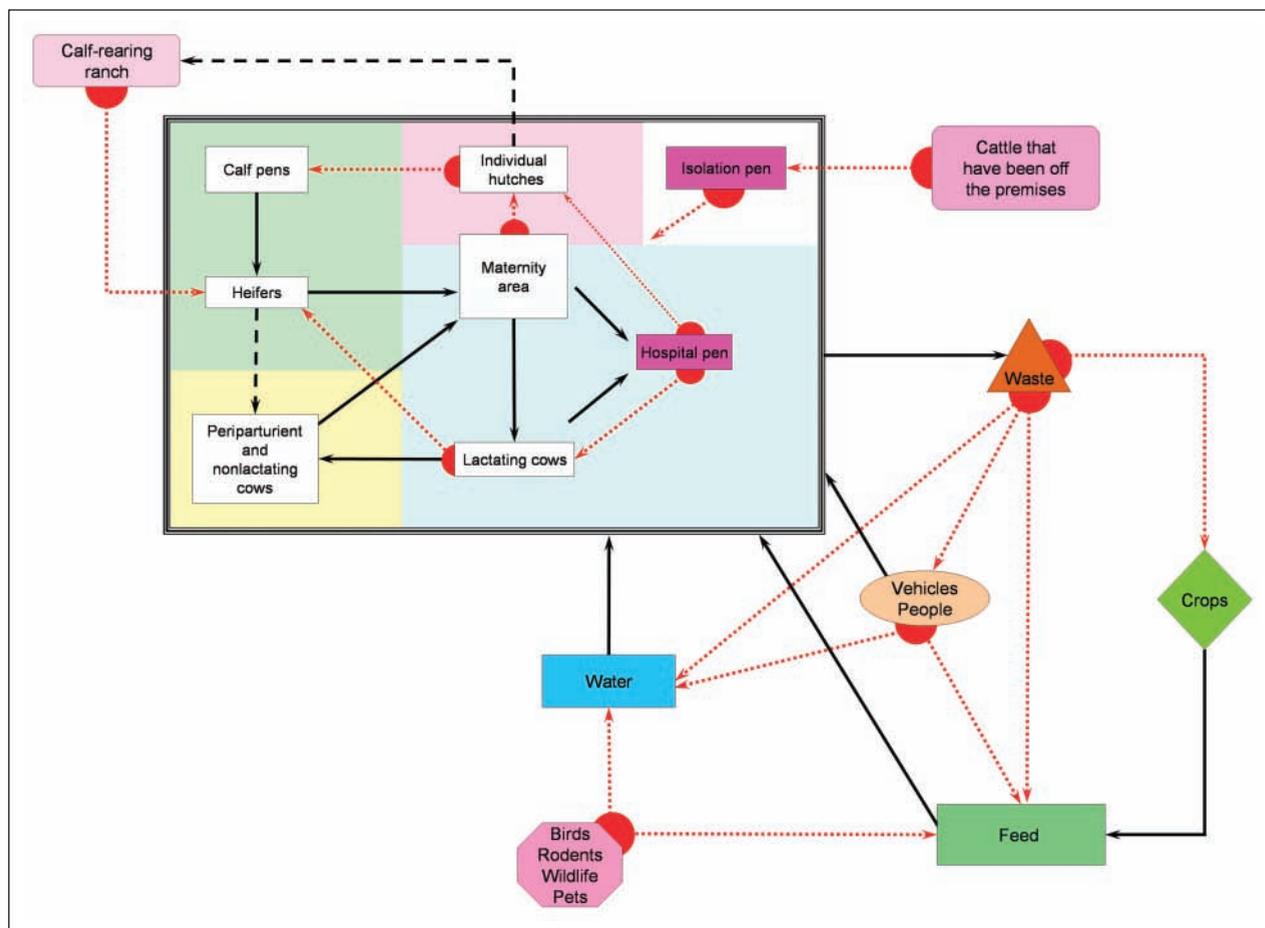


Figure 1—Comprehensive flowchart for biosecurity and biocontainment on large dairy farms. The dairy farm is represented by the black box, and each arrow pointing toward the farm represents a biosecurity risk. Arrows inside the black box represent biocontainment risks. Black solid arrows represent the typical flow of cattle or products on most dairies, whereas black dashed arrows represent events that may apply only to some dairy farms. Semicircles with red dashed arrows represent hazard and control points for transmission of disease agents.

economically feasible. This may explain the reason why in the USDA NAHMS 2002 dairy survey,⁸ an estimated 48.4% of all dairy farms did not require any vaccination for incoming cattle and 75.5% did not require any testing of new cattle.

The most commonly encountered infectious diseases and pathogens on dairy farms and how they can be prevented from causing clinical disease (ie, testing or vaccination) should be determined (Appendix). Each producer may choose to focus on a specific subset of these pathogens, depending on prevalence of disease in their area and their perceptions of risk and economic impact of the diseases. Appropriate testing procedures to be used for any pathogens will depend on the specific situation. For example, a single pooled blood sample can be used for testing to detect cattle persistently infected with BVDV when purchasing 50 heifers from a dairy farm that regularly vaccinates against BVDV, which assumes a low risk of purchasing a persistently infected heifer. In contrast, when purchasing 50 heifers at the livestock market that originate from 10 farms, it may be advisable to test each heifer separately or to use pooled blood obtained from heifers that originated from the same farm.

It is important to consider the NPV of a diagnostic test.⁹ The NPV is the confidence that a negative test result actually reflects a negative infection status. The NPV depends on the prevalence of the disease in the population as well as the sensitivity and specificity of the test. A particular test will have a higher NPV when used on cattle from source herds with a low prevalence of the disease than for cattle from source herds with a higher prevalence. Furthermore, when herds import cattle from various sources, the NPV will not be uniform for all tested animals. Tests with low NPV provide a false sense of security when cattle have negative test results. This is an important issue in testing for pathogens such as MAP for which detection of infection in a living animal is difficult (the criterion-referenced standard is microbial culture of tissue samples obtained by biopsy or during necropsy).¹⁰ It has been recommended that all cattle > 2 years old should be tested for MAP,¹⁰ and new cattle should originate only from dairies with a lower risk for MAP infection than the risk for the destination herd.

When lactating cows are introduced to a dairy farm, it is advisable to test them by microbial culture of milk samples for contagious intramammary infections caused by *Mycoplasma* spp, *Streptococcus agalactiae*, or *Staphylococcus aureus*.¹¹ Cattle of reproductive age may be tested for antibodies against *Neospora* spp and *Leptospira* spp, taking into account that detection of antibodies only indicates exposure to the organism, which could be a result of natural exposure or previous vaccination.

Historically, US dairy farms have not routinely isolated newly arrived cattle.^{2,8} Overall, only 20.6% of dairy operations quarantine any cattle at the time of arrival on the operation. Nonlactating and lactating dairy cows are least likely to be quarantined (7.1% and 9.5% of operations, respectively), whereas 37.0% of operations quarantine unweaned calves.

Therefore, it is highly recommended that all purchased cattle and all cattle that have been off premises

(eg, show cattle, unsold market cattle, cattle hospitalized at a veterinary clinic, cattle temporarily housed at other farms or cattle facilities, and leased cattle) be isolated for at least 10 days (but preferably 3 weeks) after returning to the operation. This period would allow for incubation and manifestation of clinical signs of highly infectious diseases such as salmonellosis, vesicular stomatitis, and foot-and-mouth disease; clinical infection with BVDV; and infection attributable to infectious bovine rhinotracheitis virus. Therefore, when any of these agents have been imported to a farm, infected cattle would have clinical signs while in quarantine and would be prevented from spreading disease agents to the remainder of the herd, assuming biocontainment practices are maintained at the quarantine facility. However, these short isolation periods will not allow detection of diseases with long incubation periods, such as paratuberculosis (ie, Johne's disease) and neosporosis. Infections imported via gestating fetuses are best detected by testing the calf after it is born. An example of this is testing to detect cattle persistently infected with BVDV.¹² The use of an isolation area can help detect diseases with short incubation periods, whereas those with longer incubation periods may be best detected through testing. The best biosecurity practices would not allow any animal to be released into the general population until all submitted biological samples are found to have negative results. Additionally, when cattle imported to a dairy farm are not current with regard to vaccinations, the isolation period should allow time for vaccination and development of active immunity.

On some dairy farms or in circumstances when numerous cattle are added to a farm, these recommendations may be difficult to implement because the logistics of the farm or substantial investment in facilities or personnel that are needed may not be economically viable. A cost-benefit analysis that accounts for potential losses incurred when disease agents are introduced will help determine the appropriateness of control methods.

Ideally, the isolation area should be a separate facility as far as possible from the remainder of the herd. It should be attended by specifically designated personnel who use clearly visible identified equipment and clothing (such as coveralls and boots). When it is impractical to hire specific personnel for the isolation facility, an alternative would be to assign trained personnel from the farm to complete their regular tasks and then attend to the isolation facility. Strict hygiene and disinfection protocols should be observed by these personnel. Under no circumstances should these personnel have immediate access to neonatal calves or maternity areas after working in the isolation facility because immature and stressed cattle are most susceptible to infections.^{13,14} When maintaining a separate isolation facility is not an option, an alternative would be to house new or returning cattle in a separate group in the most remote location on the farm.

Replacement heifer calves sent to a calf ranch are a special case of off-premises cattle. At calf-rearing facilities, calves are typically raised separately in individual hutches until weaning; calves are then subsequently

commingled in small groups. Calves in these small groups may have originated from multiple dairy farms. This situation creates a high risk of transmission of pathogens to the calf ranch when calves from several farms, with potential differences in pathogen prevalence, are commingled.

A larger concern for dairy producers is the return of these calves (typically as pregnant heifers) to the farm of origin because these heifers have been commingled with cattle from other farms and may have acquired pathogens that differ from those found on their home farm. Heifers returning from a calf ranch or calf-rearing facility constitute a relatively steady flow of animals that need to be isolated when they arrive on a dairy farm. It may be more efficient and economical to modify an existing pen for receiving returning heifers, rather than to use an isolation area. Modifications to such a pen should include use of double or solid fencing to prevent fence-line contact with other cattle and provision of unshared drinking water.

Advantages of the use of a modified receiving pen for heifers over an isolation area include prevention of possible contact with older cattle and immediate adoption of on-farm management systems, such as lock-ups or feeding of a total-mixed ration. A disadvantage is that it is potentially easier to have indirect contact with the resident population. Personnel attending this receiving pen for heifers should observe the same biosecurity protocols as designed for an isolation area.

Some calf-rearing facilities are requesting certain biosecurity standards of the source herds. These facilities will only accept calves that originate from dairy farms with a certain health status or from farms that adhere to standard biosecurity procedures. These requirements will allow calf-rearing facilities to minimize health problems in the calves and deliver a better product back to their clients. Biosecurity standards for the calf-rearing facility and source herds should be discussed and agreed to by the dairy operator and manager of the calf-rearing facility. It is suggested that these biosecurity standards be included in contract negotiations. Flowcharts can be adapted for calf-rearing facilities.

To allow monitoring of compliance with isolation practices, records should be maintained for all cattle that enter a farm. The foundation of any record system is that there be a unique and permanent identification for each animal. Records should contain the identification for each animal, place of origin, vaccination history, tests performed, date of entry to the isolation area, and date released to the general population.

Feedstuffs—Feed can be contaminated by spreading manure on fields where crops are grown or irrigating fields with contaminated water. The potential risk for disease introduction could happen when purchasing crops that have been fertilized with manure from other dairies. When feedstuffs are cultivated and harvested by a dairy producer, it will be necessary to maintain complete records of manure application to allow monitoring. All batches of feedstuffs should be visually inspected for mold. Because regular monitoring of feedstuffs by laboratory methods can be prohibitively expensive, samples should be stored for future testing for mycotoxins (aflatoxins, ergot alkaloids, fumonisins,

vomitoxin, and zearalenone^{15,16}) should there be an indication to do so. Samples from each batch or lot of every feedstuff should be stored at least until the entire batch or lot of feed has been consumed without incident. In the event of health or production problems, samples can be analyzed for detrimental bacteria, natural and chemical toxins, molds and mycotoxins, and fermentation products.

Another possible source of contamination of feedstuffs is through fecal material and urine from rodents, wildlife, and birds.^{3,4} Dairy farms typically do not have facilities that prevent access of these animals; however, many methods are available to help control access of these animals to a dairy farm and feedstuffs. The best method for each dairy farm can be determined by considering the design of the facilities and the cost of various methods of control.

Vehicles and people—Dairy farms are open facilities in that they have major traffic on and among farms. Many dairy farms are visited by the same milk transport truck as well as vehicles that pick up calves, culled cattle, or carcasses.¹⁷ Some farms share equipment and service providers (eg, hoof trimmer, veterinarian, and artificial insemination technician). According to a 2002 USDA report,¹⁸ 38% of US dairy farms shared heavy equipment with other livestock operations.

Methods of control to avoid introduction of pathogens on vehicles or people include restricting access to areas of the farm where animals are housed. These areas can be identified with signs (eg, Authorized Vehicles Only). Additional measures to prevent access by unauthorized vehicles could include an appropriately identified receiving area at the farm entrance that is located as far away from animals as possible; this receiving area is where all delivery trucks would unload their goods. Similarly, there could be a designated loading area where culled cattle or carcasses are loaded so that on- and off-farm vehicles do not cross paths. This may involve extra handling of goods or cattle within a farm and may not be economically or logistically feasible on some farms.

Visitors should not have access to any area beyond the business office without invitation. Farm biosecurity rules can be clearly indicated with traffic signs forbidding access, similar to biosecurity policies implemented on swine operations.¹⁹ Monitoring practices for the movement of people and vehicles onto a dairy farm may range from paper records to electronic surveillance systems.

Farm workers who have contact with other animals on other farms can also introduce diseases by acting as fomites. Control methods to avoid introduction of disease agents in this manner may include the use of dedicated clothes and footwear that cannot be taken from the farm, supplying locker rooms with different entrances for street access and farm access, and parking areas located away from animal areas and equipment.

Farm workers can also be the source for transmission of diseases or infectious agents such as tuberculosis, salmonellosis, *Taenia saginata* (ie, beef measles), and *S aureus* to animals.²⁰ Ideally, the best prevention practice would be to hire only workers who have negative results when tested for these agents and who do not

work with cattle on other farms or at other locations. For most dairy farmers, this may not be an option. Educating workers on basic hygiene procedures and in the areas of disease awareness, prevention, and control will provide an additional layer of biosecurity that cannot be duplicated by any single critical control point. Workers need to have easy access to equipment and facilities necessary for maintaining proper hygiene.

Drinking water—Many pathogens can be spread through contaminated drinking water. It was reported in the NAHMS 2002 dairy survey¹⁸ that 35.1% of all dairy farms used surface water (such as lakes, ponds, or rivers) as a water source. Surface water may carry disease agents from other animal facilities as well as bird droppings, urine and feces of wildlife, and human waste. Biosecurity control methods for drinking water include restricting access of birds and wildlife and minimizing risk of amplification of pathogens through filtration and chemical sterilization of water. Water obtained from wells for livestock should be tested regularly to ensure it is potable. Monitoring of water quality can be accomplished by regularly scheduled (eg, quarterly or biannually) analysis for chemicals, minerals, and bacteria. It is important to ensure that the monitoring process can detect when contamination happens and whether the contamination is from the water source or water delivery system.

Biocontainment

Biocontainment is the result of processes to prevent transmission of pathogenic agents within and among areas of a dairy farm.⁵ Various operational sections of a dairy farm and critical control points for biocontainment should be identified (Figure 1). Biocontainment integrity is best maintained by avoiding direct and indirect contact among groups of cattle, especially high-risk groups.

Vaccination—When working with populations (ie, dairy herds), vaccination is an important method for developing herd immunity²¹ and lowering the risk of spreading a disease after exposure to a pathogen. For example, BVDV spreads rapidly among cattle when biosecurity is breached, and vaccination is important to prevent catastrophes at the herd level.¹² Although vaccination may be an appropriate method to control some diseases in a herd, it does not confer absolute (100%) protection for each animal or the herd. Vaccinated cattle should be allowed sufficient time to develop an immune response before being exposed to potentially infectious animals. In general, a period of 4 weeks should be allowed for development of adequate protection after appropriate vaccination (1 inoculation for live vaccines and 2 inoculations for inactivated vaccines).²²

Facilities design and movement of animals and farm personnel—The facilities design of a dairy farm can help prevent spread of pathogens to more susceptible cattle (sick cows, periparturient cows, and newborns). On most dairy farms, there are 4 distinct groups of cattle (newborns, young stock, lactating cows, and nonlactating cows). Dairy farms can be organized such that each group occupies a different area, which will

help prevent direct contact with other groups. Flowcharts can be used to assist with management and movement of groups.

Most movement of cattle within a dairy farm is unidirectional. For example, cows move from the maternity area to a calving pen, continue on to high-production pens, and then move to low-production pens until they are culled or cease lactation. The maternity area houses cows in the periparturient period and newborns, which are 2 groups of cattle most susceptible to disease.^{13,14} Therefore, the maternity area should be located as far away from any hospital pens as possible to prevent transmission of disease agents. The maternity area should never be used to house sick cattle.

Lactating cows usually do not move back and forth among milking groups. Although they will be moved from higher to lower production pens as lactation progresses, all-in, all-out movement (moving all cows in the pen at once) is not typical. Therefore, movement of cows to lower production pens is a biocontainment risk that, unfortunately, may be unavoidable. The only bidirectional movement for adult cows should be between the general population of lactating cows and a hospital pen where sick cows are housed during treatment and elimination of drug residues. Identifying in a flowchart the location where a possible bidirectional flow of cattle may exist will help determine potential control methods.

Unidirectional movement is as important for young stock as it is for adult cows. General adherence to this policy usually is not a problem because calves and heifers are grouped and moved on the basis of age, which correlates with size. Some dairy farmers may decide to separate a heifer that has not maintained its growth rate commensurate with that of her cohorts (typically a heifer that has been sick) and house that heifer with younger calves. Older heifers have had the chance to be exposed to disease agents for a longer period than younger calves, which can result in increased immunity or chronic infections. Therefore, for this management practice, slow-growing or unthrifty heifers may pose a risk for transmission of disease agents to younger calves. A better option to prevent potential spread of disease agents to younger calves is to create a recovery pen where unthrifty heifers can catch up with the remainder of their cohort and then be returned to it. This would be equivalent to a hospital pen for young stock.

Indirect contacts can arise through movement of personnel, shared transit areas, shared equipment, movement of vehicles, shared feed (such as feeding left-over feed from cows to young stock), shared water, or movement of waste among groups. On large dairy farms with personnel designated to work in specific areas, it may be possible to provide color-coded clothing (eg, coveralls) and equipment (such as use of colored tape) for each area to identify potential sources of indirect contact. For example, a person with blue coveralls who used a shovel with green tape in a red area would be highly visible as a breach of biocontainment. Specific risk points for transmission of pathogens within various production areas of a dairy farm can be represented on a flowchart.

Isolation area—Healthy cattle coming onto a dairy farm could harbor pathogens that can be detrimental to

the resident population. Pathogens from the isolation area can be transmitted to all other areas of a farm when biocontainment is breached. Recommendations stated previously for biosecurity also apply to the biocontainment protocol for the isolation area. When lactating cows housed in the isolation area develop mastitis, strict milking hygiene protocols must be followed to prevent transmission of contagious mastitis pathogens among cattle housed in the isolation area while results of microbial culture of milk samples are pending.

Equipment must be routinely cleaned and disinfected to prevent disease transmission within groups of cattle housed in an isolation facility. The design of the isolation area ideally should allow for thorough cleaning and disinfection between subsequent uses. Therefore, a design that provides ample capacity should be considered. Records that reflect date of entry into the isolation facility, date of exit, biological samples submitted, and results of the tests can be monitored to assess compliance with biocontainment protocols.

Newborn calves—On large dairies, calves typically are born in a maternity area and then moved to individual hutches. This practice minimizes contact with cows and other calves and is consistent with the goal of preventing transmission of gastrointestinal tract and respiratory tract pathogens. Calves are particularly vulnerable to infection while in the maternity area because of the lack of humoral protection at birth.^{13,14}

Biocontainment principles include general cleanliness and hygiene of the maternity area to decrease pathogen load. Ideally, the maternity area should be designed to allow separation of a cow in labor from the remainder of the cows in the maternity area. This can help provide a less stressful environment for the cow in which to give birth and a cleaner environment for the newborn. Shared maternity areas for multiple cows can result in higher amounts of contamination and risk exposure for newborns. Regardless of the design of the maternity area, it is recommended that all calves be removed from their dams immediately after birth to minimize exposure to fecal pathogens from adult cattle.¹⁰ Thorough cleaning and disinfection of maternity areas between subsequent cows would be the best approach, although in many cases this is impractical. The more frequently the maternity area can be cleaned and disinfected between resident cows, the more effective biocontainment will be.

Another important control measure to limit susceptibility of newborns to pathogens from cows and their environment is proper colostrum management. Colostrum is the basis of neonatal health and immunity,²³ and it is the only exogenous source of energy and nutrients for newborns. Therefore, dairy producers should ensure that all calves consume adequate amounts (approx 4 L [4 quarts]) of high-quality colostrum within 24 hours after birth.^{23,24} Optimum immunoglobulin concentrations in calves can be achieved by proper vaccination of late-gestation cows to ensure transmission of immunoglobulins through colostrum. Controlled feeding of colostrum to newborn calves can be used to confirm the amount of colostrum ingested.²⁵ Special attention should be paid to cleanliness and hygiene of all equipment used to feed newborn calves because contamination of

colostrum diminishes its benefits.²⁴ Proper hygiene and disinfection of the environment for newborn calves will help decrease pathogen exposure of the calves.

It was reported in the NAHMS 2002 dairy survey² that 27% of all US dairy farms and 70% of large dairy farms (ie, farms with > 500 cows) fed pooled colostrum. Feeding of pooled colostrum should be discouraged because of the potential to disseminate pathogens, such as MAP¹⁰ and bovine leukemia virus,²⁶ that can be transmitted through colostrum. Selective feeding of colostrum from a cow to her offspring allows future vertical testing and culling for diseases such as neosporosis and MAP infection. When it is necessary to pool colostrum because of economic or logistical considerations, it is recommended that colostrum be used only from cows that have negative test results for MAP, bovine leukemia virus, and *Neospora* spp. When this is not possible, pasteurization of colostrum can be used to destroy pathogens, with the caveat that pasteurization may also destroy > 25% of the immunoglobulins in the colostrum.²⁷ There are commercial immunoglobulin products that can be used as colostrum supplements for calves when adequate amounts of safe colostrum are not available.²⁸

To monitor management of newborn calves, random or systematic testing of serum total protein concentrations in 2- to 10-day-old calves can be performed.²⁴ Other possible monitoring practices may include regular bacteriologic counts of bacteria in colostrum; testing the specific gravity of colostrum; and recording the time of birth, time of colostrum feeding, and source of colostrum for each calf. Monitoring the incidence of disease in calves during the first 1 to 2 weeks after birth may also be a valuable indicator of colostrum management.

Feeding waste milk to calves—On many dairy farms, waste milk is fed to calves. Waste milk is any abnormal milk (such as colostrum, milk from cows with mastitis, or milk containing drug residues) that cannot be sold for human consumption. In the NAHMS 2002 dairy survey,⁸ it was reported that 87.2% of all US dairy farms fed waste milk to calves. Bacteria can be transmitted to calves in milk from antimicrobial-treated cows.²⁹ The potential risk of transmission of these bacteria could be prevented by feeding calves normal milk or milk replacer. When dairy farmers do not want to discard waste milk, effective pasteurization offers an option to minimize transmission of highly contagious bacteria (such as *Mycoplasma* spp) from cows to calves through milk.¹¹ In the NAHMS 2002 dairy study,⁸ it was estimated that only 1% of dairy farms fed pasteurized waste milk. Another option would be to feed pasteurized waste milk to older calves to spare younger calves with less immunity from the potential exposure to pathogens.

Grouping of calves—Appropriate management for moving calves from individual hutches to group pens may be a major determinant of the incidence of respiratory tract disease in the calves after grouping. Coordinated vaccinations must precede the movement of calves from hutches to group pens. Calves should be vaccinated

against respiratory tract pathogens at least 3 weeks (and preferably 4 weeks) before movement to group pens to allow for development of active immunity.²² When killed vaccines are used, the first dose should be administered at a time point that will allow the booster dose to be administered 3 to 4 weeks before movement to group pens.

It is recommended that calves be weaned while they are still in the individual hutches to prevent adding the stress of weaning to the stress of movement to a group pen.³⁰ Other stressful events, such as dehorning and removal of supernumerary teats (and castration when male calves are raised), can be performed 2 to 3 weeks before or after calves are moved to group pens. Allowing a few days between subsequent procedures may also prevent added stress. One logical sequence would be to vaccinate, dehorn or castrate, booster vaccinate, wean, and move to group pens. Vaccination of calves before weaning when they still have maternal immunity from colostrum can improve resistance to respiratory tract pathogens.³¹ Sick calves housed in individual hutches should not be moved to group pens until they are healthy, weaned, and vaccinated. Compliance can be monitored through maintenance of accurate records.

Feeding leftover feed to young stock—One critical control point for transmission of pathogens from lactating cows to heifers is leftover feed, which is also known as feed refusal (Figure 1). Current nutritional guidelines for lactating dairy cows indicate that cows are not able to produce to their potential unless feed is available at all times.³² Therefore, lactating cows are commonly overfed to ensure that they constantly have feed available for consumption and are not hungry between subsequent feedings. A common target for nutritionists is to have 5% to 10% leftover feed.³² This leftover feed is from the most expensive ration on a dairy farm. In addition, nutrient requirements for growing heifers are similar to those for lactating cows. Therefore, economic considerations encourage providing leftover feed from lactating cows to growing heifers. However, these leftover feeds have been in contact with oronasal fluids from lactating cows and may have been exposed to pathogens that inhabit the digestive and respiratory systems of adult cows. When economics dictate that leftover feeds be fed to growing heifers, the heifers ideally should have active immunity against respiratory tract and enteric diseases as a result of rigorous vaccination. It should be mentioned that feeding leftover feeds to heifers entails a higher risk of transmission of diseases (such as MAP infection, tuberculosis, or salmonellosis) that are not controlled by vaccination alone.

Hospital pens—Hospital pens are used to house cattle that become sick. The main difference between a hospital pen and isolation area is that hospital pens house cattle currently on the farm, whereas the isolation area is for new arrivals. Once a sick cow has recovered and eliminated drug residues, it is returned to its appropriate production group. There is a risk for transmission of pathogens when cows are returned from a hospital pen to the general population. Movement of cows from the general population of lactating cows to a hospital pen and back to the general population can be represented on a flowchart (Figure 1).

Many dairy farms have a single milking parlor that is used to milk all cows in the herd, including cows that have recently calved and cows in hospital pens. On those farms, the risk for transmission of intramammary infections is higher than for farms with separate milking parlors for sick cows and healthy cows. Good milking procedures and a logical milking order³³ for the production groups are necessary to minimize the risk of transmission of contagious intramammary pathogens from infected to healthy cows. The logical milking order for milking groups should be based on the increasing prevalence of subclinical infection, as determined by use of somatic cell counts.³³ Cows that have recently calved and first-lactation cows generally have the lowest prevalence of mastitis; however, they are the most susceptible to infections because of immunosuppression. These groups should be milked first when the rubber liners are the least contaminated. They should then be followed by high-producing cows, lower-producing cows, and finally by cows that are at the end of lactation and ready to enter the nonlactating group.

Cows with contagious, untreatable intramammary infections (such as those attributable to *S aureus* and *Mycoplasma* spp)¹¹ should be grouped in a separate pen. When there is a pen of chronically infected cows, it is recommended that cows in this pen be milked last after all other healthy cows have been milked. It may be prudent to even use a different milking unit. When only 1 milking parlor exists to milk all cows on a dairy, cows in the hospital pen should be the last group milked, but only after the equipment that was just used to milk the chronic infection group has been thoroughly cleaned and disinfected. Bulk-tank milk can be monitored through cultures³³ to signal new infections with contagious pathogens, which indicates a breach of biocontainment protocols.

Cows that have an apparent clinical recovery may be returned to the general population while they still have the potential of being in a prolonged carrier state and shedding pathogens, such as *Salmonella* spp, *Mycoplasma bovis*, or *S aureus*.^{11,33} This poses a risk for transmission to other cattle. Control of this hazard and monitoring practices should be customized for the specific disease that caused the animal to be in the hospital pen. Consultation with the herd veterinarian should result in decisions regarding prolonged periods of isolation or even culling of cows with diseases that have a prolonged carrier or shedding state.

Feed and water—Animals from the various production areas (calves, heifers, and adult cows) have differences in the disease agents that are of primary concern and differences in susceptibilities to infection. Therefore, caution should be exercised to avoid direct contact as well as shared water, feed, and equipment. It was reported in the NAHMS 2002 survey² that 58.8% of US dairy farms had at some point used the same equipment to handle manure and animal feed, and of these, 15.2% did not use any cleaning or disinfecting procedures for the equipment after manure was handled. Vehicles and equipment used for waste management have been identified as a risk factor for contamination of feed when they are also used for feed-handling procedures.

Shared equipment for carcass disposal and handling of feed may also be a risk factor. Care should be taken to ensure that vehicles with manure-covered wheels do not contaminate feed bunks or silos during packing, loading, and delivery of feed. Monitoring for cross-contamination can be performed by visual inspection of equipment to ensure it is clean of manure before being used to handle feed. Cleaning of vehicles should be performed in areas where water or disinfectants would not splash onto feed or into drinking water.

Contamination of water delivery systems can arise from feces as well as feed and saliva that drop from the mouths of cattle. Water troughs can be designed to be easily cleaned, which includes regularly scheduled and impromptu cleaning. Stainless-steel water troughs that can be tilted to allow them to be rapidly emptied and that are located in easily accessible areas will be easier to clean. Organisms such as MAP³⁴ and *Salmonella* spp³⁵ can survive in drinking water for months when the water is not properly decontaminated. Visual inspection of water troughs for cleanliness would appear to be a simple, yet effective method to monitor possible water contamination.

Recycled water—Many large dairy farms separate solid material from flush water and use the recycled flush water to remove fecal material from alleyways and holding areas. This water runs along all the areas where cows walk; therefore, cows can have direct access to this water (drinking or licking), and feed and udders can become contaminated by splashing.³ Reducing pathogen transmission at this critical control point can be achieved by flushing areas when there are no cattle in that area (eg, during milking), delivering feed after an area has been flushed (rather than before), and designing the facilities to prevent cattle from being able to drink or lick runoff water after flushing. On farms where flush water is not used, care should be taken to ensure feedbunks do not get splashed when pressurized water is used to clean areas contaminated with feces. Visual observation can be used to monitor these processes.

Manure—Ideally, manure should be treated as biological risk material and be composted or removed, but this can be prohibitively expensive when considering disposal costs of manure, opportunity cost of lost nutrients, and increased costs for commercial fertilizers. Manure has an enormous bacterial load (10^3 to 10^8 bacteria/g of recycled manure³⁶) and is the most problematic waste produced on dairy farms. All nutrients contained in manure could be recycled as fertilizer for crops,³⁶ although excessive application of manure as plant fertilizer may result in potential contamination of groundwater sources. *Salmonella* spp, *Escherichia coli*, and MAP have all been isolated from microbial cultures of soil and crop samples obtained > 3 months after application of manure.³⁷

For large dairy farms, it is increasingly difficult to find adequate crop acreage where manure can be used, and many farms are turning to other manure management methods, such as composting. Although bacteria such as *Salmonella* spp, *E coli*, *Listeria* spp, and MAP can be killed in composted manure,^{38,39} incomplete composting could pose a risk for exposure to fecal pathogens

transmitted among areas of a dairy farm. Alternative uses of manure include recycling for bedding, anaerobic digestion as an alternative energy source (methane), or composting for use as commercial plant fertilizer.

Control measures include ensuring proper composting procedures and avoiding the use of manure from areas with a high pathogen concentration (eg, hospital pen). Monitoring practices include recording the origin of manure used for each composting batch and quality-control procedures for the composting process, such as temperature and microbial activity.⁴⁰

Biosecurity and Biocontainment During Expansion of a Dairy Herd

Dairy farms in an expansion phase may import and commingle cattle from various sources that have differing histories with regard to pathogen exposure. Expanding dairy farms also tend to keep cows that have lower milk production for longer periods to avoid a decrease in herd size that would result from culling. Cattle with low milk production could be harboring production-limiting disease agents, such as *Salmonella* spp, MAP, or any of several contagious mastitis agents.

Requirements for managing a rapidly growing herd can result in insufficient time for regular tasks on the farm because human resources usually are overtaxed.⁴¹ It is the belief of many dairy producers that short-term economic survival may take priority over long-term herd health; thus, dairy producers may decide to relax biosecurity and biocontainment safeguards in favor of a short-term economic advantage. By having in place a defined biosecurity and biocontainment plan that prioritizes diseases of interest, managers can focus on those with the highest perceived risk for each dairy. Some biosecurity measures can still be implemented during conditions of expansion. For example, rather than separately testing every animal in a group, pooled samples of all cattle or a representative subset of cattle can be tested. Pooled samples would be appropriate for detection of cattle persistently infected with BVDV or contagious mastitis, whereas a representative subset of cattle could be tested for MAP or *Neospora* spp.

All incoming cattle (even when originating from different sources) can be grouped together in 1 or more receiving pens (similar to the situation described for replacement heifers) and still be separated from the general population. These pens can be located at the periphery of a dairy farm. This procedure spares resident cattle from potential direct transmission of pathogens. In addition, because the incoming cattle are already segregated, they can be milked after the resident cows, which prevents potential transmission of contagious mastitis pathogens. When the expanding dairy farm intends to provide left-over feed from cows to the heifers, they should preferentially feed the leftovers from the resident cows of the herd, rather than the leftovers from the incoming cows.

An Example of Biosecurity and Biocontainment for a Large Dairy Herd

Consider a dairy farm that has 1,300 lactating cows in which the producer's primary concern is salmonellosis in calves and cows. The herd veterinarian

should visit the farm and indicate on a flowchart those hazards that are currently evident and in need of correction (Figure 2). Several control points can then be identified.

Critical control point 1—Approximately 200 purchased replacement heifers between 22 and 30 months of age (before calving or that were already lactating) and a few breeding-age bulls entered the herd at various time points during the past year. All these off-premises cattle were commingled with the resident population of cows and heifers without a period of isolation because there was not a specified isolation facility. An important critical control point needed on this dairy is an isolation area. The main reason the producer did not have an isolation area was the cost of building a new facility. A temporary pen at the periphery of the dairy could be used as an isolation area. This minor change should prevent contact between incoming and resident cattle.

Critical control point 2—Vehicles that sweep the feed alleys had to drive over areas heavily contaminated

with feces (mainly transit alleys leading to and from the milking parlor) to access the feedbunk. A recommendation would be to wash the transit alleys before the vehicles sweep the feed alleys, which would diminish the potential for contamination without requiring major construction or changes to the facilities.

Critical control point 3—Birds and rodents had access to all water and feed sources. Birds and rodents are difficult to control because of the ubiquitous nature of these pests. Possible control methods for this dairy farm would include traps, bait, and plastic predator decoys.

Critical control point 4—The producer sent female calves to a calf-rearing ranch when they were 10 months old. When they were pregnant (approx 7 months of gestation), they would return to the dairy to a separate pen located on a corner of the farm. Heifers were moved into or out of the dairy once each month. The separate pen functioned as an isolation area for heifers returning from the ranch, which allowed the detection of clinical signs of disease in the pregnant

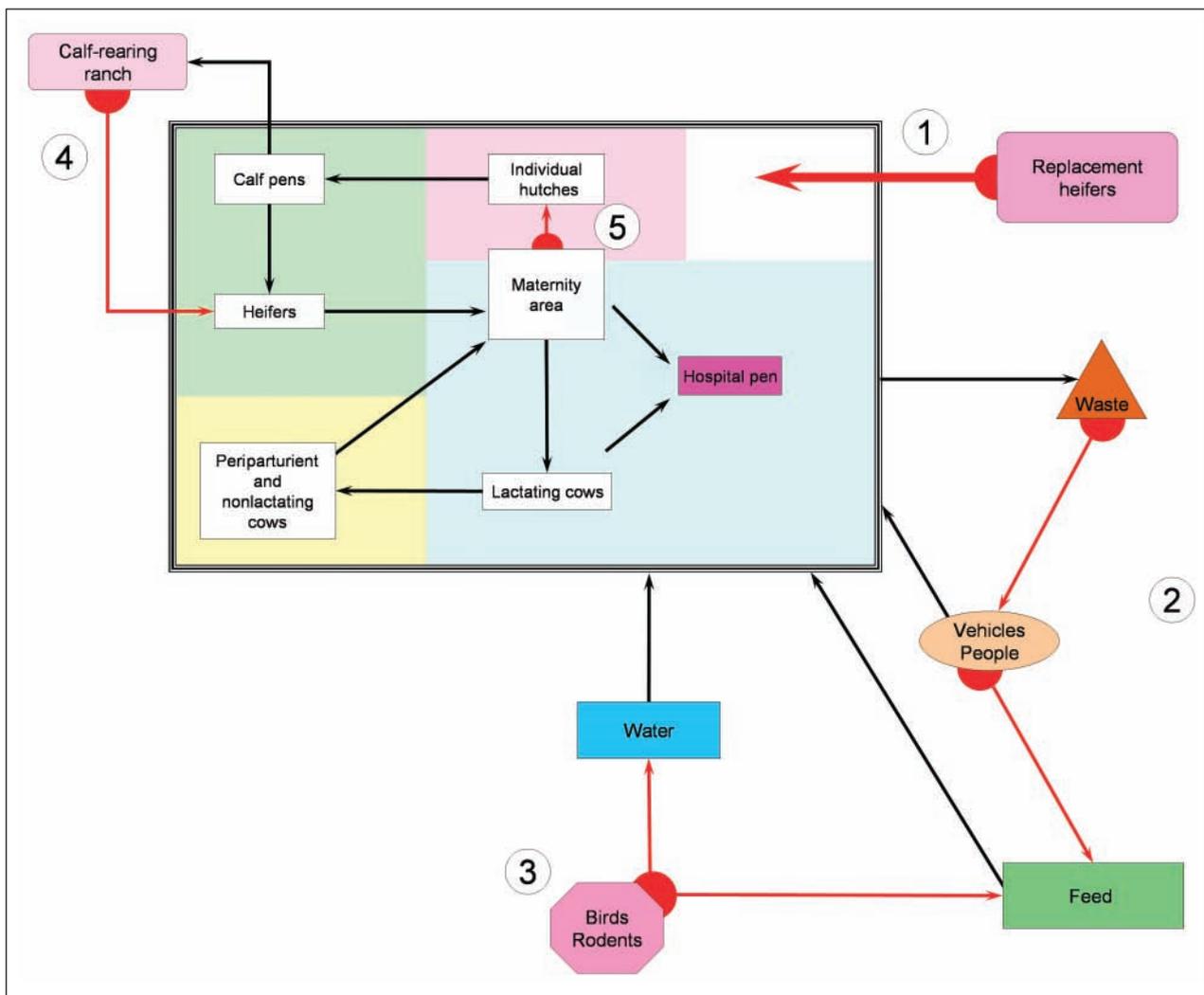


Figure 2—Flowchart depicting an example of biosecurity and biocontainment at a specific dairy farm for which the producer is concerned about salmonellosis in calves and cows. Black arrows represent actual practices on this farm, whereas semicircles with red arrows represent critical control points for salmonellosis. Each number in a circle represents a specific critical control point for this dairy.

heifers before they were commingled with the remainder of the herd. One potential problem was the size of the receiving pen because it was too large for all-in, all-out movement. When new heifers were returned from the calf-rearing ranch, they were mixed with heifers that were part of the group that had returned the previous month. New incoming cattle posed a risk for cattle already residing in the receiving pen. The producer considered these returning heifers to be part of the herd, even when they were residing at the calf-rearing ranch. Thus, the producer did not enforce any isolation among groups that returned to the dairy farm at different times.

In this situation, it was recommended that the pen be divided into 2 halves so that returning cattle would not have direct contact and to ensure that all cattle in 1 half were removed before subsequently adding other returning cattle. This strategy also allowed for cleaning and disinfection of the pen between subsequent groups. An additional option may have been to move fewer returning cattle every 2 or 3 weeks, instead of the large group that was moved once each month. It would be advisable to investigate whether there were any infectious disease episodes at the calf-rearing ranch and to examine health records of each of the returning pregnant heifers to assess the risk of introducing pathogens onto the dairy farm.

Critical control point 5—Calves were born in a common maternity area that housed 20 to 30 cows. A problem with this design was that it allowed clustering of cattle that are the most susceptible to disease (ie, periparturient cows and newborn calves). The advantage of the design was that it allowed for specially designated personnel to attend those cattle. The design allowed contact of newborn calves with multiple cows. It was suggested that the producer build several calving pens that would house only 1 cow (and her calf) to prevent contact of the newborn with other cows and to diminish the stress of cows in labor. The producer evaluated a design that would allow rapid cleaning of these individual calving pens between subsequent uses, thus preventing indirect contact of newborns with other cows.

Comparison of the flowchart for this specific dairy farm with the standard flowchart for dairy farms revealed that some potential hazards were not evident on this dairy because of control measures that were already in place. This dairy did not grow crops; therefore, there was no application of manure to croplands, although purchased feedstuffs may have been fertilized with manure from 1 or more animal species. Samples were not obtained from incoming feedstuffs. This practice will not allow identification of the source of exposure in the case of a feedborne outbreak of salmonellosis.

This dairy farm had a protocol to ensure that no cow with diarrhea housed in the hospital pen returned to the general population until there were 2 negative culture results for *Salmonella* spp on fecal samples obtained 2 or 3 days apart. Short of culling every cow with diarrhea, this may have been the best method to ensure that no latent shedders returned to the general popula-

tion. Therefore, additional control measures at the hospital pen were not considered necessary.

On the example farm, leftover feed was discarded, and waste milk was pasteurized and regularly cultured to monitor the process of pasteurization, which is the reason that those potential control points were not identified. Specifically designated personnel were assigned to the calves and never came into contact with the cows. Blood samples were collected at weekly intervals from randomly selected calves born during that week for measurement of total plasma protein concentrations, which was considered a proxy for colostrum management. Only calves that had no signs of disease during the preceding 2 weeks were moved from individual hutches to group pens. The design of waterers and feedbunks minimized direct contamination from manure. Finally, providing numerous access points for personnel allowed them to enter and exit pens without stepping on the feed with manure-contaminated boots.

Conclusions

Conceptually, biosecurity and biocontainment are easy to embrace. The goal is to avoid the introduction and spread of disease agents on a dairy farm. Difficulties arise in practical implementation, such as how to determine which specific control methods should be adopted and how to implement them within the economic constraints of food animal production. Solutions lie in accurately identifying critical control points and prioritizing control methods in accordance with economic considerations (cost-benefit analysis).

Flowcharts are a useful tool to depict the dynamics within a dairy farm and, therefore, identify specific practices that represent a risk for the introduction and spread of disease agents. Clear identification of risk-management practices within a dairy farm, including potential costs and benefits, will facilitate the transition from conception to implementation. Maintenance of complete and accurate records is important for monitoring compliance and effectiveness.

Specifying the disease concerns of the herd veterinarian and dairy producer will ensure that a robust biosecurity and biocontainment program is implemented. Involvement of key personnel will provide an additional component to ensure compliance with the program. Control methods should be prioritized to focus on the most important diseases for each dairy. Corrective actions designed to control the primary disease concerns will automatically resolve some of the lower-ranked concerns.

Biosecurity and biocontainment programs should be monitored and regularly reevaluated and updated. Regularly scheduled reviews of such programs will help identify opportunities for the development of new control methods or further refine existing control methods. The use of flowcharts will facilitate evaluation of the integrity of an existing program and aid in identifying critical control points that should be updated or addressed through the creation of new protocols.

Appendix

Infectious diseases or disease agents most commonly encountered on dairies and possible control methods to avoid introduction of disease onto a dairy farm.

Classification*	Control method	Disease or disease agent
Primary	Testing	BVDV†, brucellosis, tuberculosis, MAP, <i>Mycoplasma</i> spp, <i>Staphylococcus aureus</i> , <i>Streptococcus agalactiae</i> , <i>Neospora</i> spp, and <i>Salmonella</i> spp
	Vaccination	BVDV, brucellosis, infectious bovine rhinotracheitis virus, parainfluenza-3 virus, and bovine respiratory syncytial virus
Optional‡	Testing	<i>Leptospira</i> spp, bovine leukemia virus, and <i>Tritrichomonas foetus</i>
	Vaccination	<i>Leptospira</i> spp and <i>Salmonella</i> spp

*Diseases are classified on the basis of perceived effectiveness of available control methods and perceived risk. †Represents testing to detect cattle persistently infected with BVDV. ‡Optional diseases may be endemic on some dairy farms; those farms may opt to refrain from testing or vaccinating new additions to the herd.

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