Student Sessions

Bovine nutrition and ration formulation basics in veterinary medicine

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Abstract

One of the most needed services by clients in food animal production is nutritional consulting. While many of the management tools needed by successful food animal producers can be acquired by experience, hard work, and good instincts, the understanding and application of sound nutritional principles is not easily obtained. Because food animal veterinarians are well educated, trusted, and in close proximity to their clients and their animals, they are in a unique position to bridge this nutritional knowledge gap. The important relationship of nutrition to disease, healing, and productivity make sub-optimal nutrition a significant deterrent to the goals of both veteriniarian and producer. While most veterinary students receive a relatively brief course on food animal nutrition, many opportunities exist to supplement that education with post-doctoral courses, both formal and informal, that can elevate their nutritional expertise to a level that can have a significant impact on the health of animals, the productivity of producers, and the growth of a veterinary practice. This presentation highlights a few of the ways that an innovative bovine practitioner can acquire and provide these needed services to the beef and dairy communities.

Key words: nutrition, consulting, veterinary practice

Résumé

La consultation en nutrition est l'un des services les plus demandés par les clients impliqués dans l'élevage d'animaux destinés à l'alimentation. Bien que plusieurs des outils de gestion requis par les producteurs performants d'animaux de production peuvent s'acquérir avec l'expérience, le travail acharné et le gros bon sens, une bonne compréhension et l'application de solides principes de nutrition ne s'obtiennent pas aussi facilement. Parce que les médecins vétérinaires pour les animaux de production sont bien éduqués, fiables et proches de leurs clients et de leurs animaux, ils sont dans une position unique pour combler cet écart en matière des connaissances nutritionnelles. En raison du lien étroit entre la nutrition et la maladie, la guérison et la productivité, l'alimentation sous-optimale n'est pas compatible avec les buts du médecin vétérinaire et du producteur. Bien que la plupart des étudiants en médecine vétérinaire suivent une brève formation en nutrition des animaux de production, il existe d'autres chances d'enrichir ses connaissances avec des cours formels ou informels suivant l'obtention du diplôme. Cette nouvelle formation peut élever l'expertise en nutrition à un niveau tel qu'elle permet d'avoir un impact significatif sur la santé des animaux, la productivité de l'élevage et l'expansion de la pratique vétérinaire. Cette présentation illustre comment un praticien innovateur dans les bovins peut acquérir et fournir les services requis par les éleveurs de bovins laitiers et de boucherie.

Introduction

If there is any single area of veterinary education that is both sorely needed and sadly neglected it may well be the understanding and application of the principles of animal nutrition. In bovine medicine specifically and in food animal production generally, good nutrition, or the lack of it, affects virtually every aspect of animal health and well-being. Undernourished animals get sick more often, heal more slowly, and produce less efficiently than those properly fed. It is not difficult to identify a nutritional component to nearly every case of sickness, injury, or poor performance. Even if adequate nutrition is not an element in the etiology of a disease or injury, it almost certainly will impact the duration and severity of pathology and the length and degree of recovery. Because feed costs are the largest single expense in most animal production systems, the veterinarians' understanding of feeds and feeding is essential to deliver effective whole-herd health programs. It is therefore hard to over estimate the value of a sound understanding of nutrition and the ability to deliver nutritional services to the bovine industry.

The Basics of Nutrition

What most veterinary students do learn are the basic elements of nutrition. Water, energy, protein, minerals, and vitamins are the groupings under which we organize the essential elements of nutrition for optimal health and performance. It is easy to get sidetracked by the details of balancing for energy and protein, as these change by age, stage of production, and even by environmental conditions. Minerals and vitamins can often be neglected because of their complexity, and water because of its simplicity. "Energy" is perhaps mistakenly labeled as a nutrient, when in reality it is a heading under which we list molecules that supply efficient sources of energy such as glucose and carbohydrates. One could argue that "fiber" is missing from the list of essential nutrients. In diets where fiber is abundant little attention to that detail is necessary, but in "hotter" rations where concentrates are high and fiber may be low, maintaining adequate levels of fiber are critical. In the end, the art of nutritional consulting is the ability to keep sight of all the critical elements of good nutrition while focusing on the category of immediate concern.

Relationship to Health and Healing

Nutrition plays a pivotal role in the immune response and nutrients can influence several, if not all, aspects of the immune response. In a detailed literature review of periparturient immune suppression in dairy cattle the major energetic fuels used by immune cells (i.e. glucose, NEFA, BHBA, and glutamine) were examined in detail.[1] It is clear that deficiencies in basic nutrients can have direct impacts on immune effector cells, thereby defining the direct links between altered states of nutrition and resultant disease. For example, increased levels of ketones and fatty acids resulting from negative energy balance can inhibit phagocytosis and secretion of IgM antibodies. Conversely, upregulation of immune responses such as increased cytokine production and antigen presentation can also be observed in low energy states.

Every practitioner should be trained to consider the nutritional components of each case they are called to manage. Whether the apparent complaint is infectious, environmental, injury caused, or a production decline, the complete art of healing requires that one answer correctly the questions 1) "What nutritional problem may be contributing to this case?" and 2) "What nutritional adjustments are necessary to effect rapid and complete recovery?"

Economic Impact

Beyond the financial losses associated with morbidity and mortality, the economics of poor performance related to nutritional imbalance are also significant. For example, dairymen often test the delicate balance between reducing feed costs and maintaining a profitable level of milk flow. If a dairy of 1,000 cows reduced feed costs by $0.05/cow/day, an apparent annual savings of over $18,000 would result. However, if that cost reduction resulted in an improperly balanced ration, then milk production might decrease. If the same herd of 1,000 cows reduced milk production by just 2 lb (0.91 kg)/cow/day, the annual loss of revenue (@$15.00/cwt) would exceed $109,000. Thus, an ill-advised change of ration resulted in a significant loss rather than the anticipated savings.

Beef producers often face a similar decision. Mineral supplements are a constant source of frustration for economic evaluation. If a 1,000 cow beef operation spends $.05 per/cow/day for mineral, the annual bill is over $18,000. That can be justified if the mineral increases weaning weights of calves and/or increases conception rates of the dams, but those effects are sometimes difficult to measure over time. If the value of gain in this example was $2.00/lb (0.45 kg) then an increase in weaning weight of 9 lb (4.1 kg)/calf would cover the entire cost of the mineral program.

Services to Provide

A veterinarian with the desire to provide nutritional guidance can focus on a handful of services ranging from very basic to very complex. A good beginning point for any practitioner is to facilitate feed testing. This is a relatively simple process, but commonly regarded by producers as an optional exercise. The default use of "average" values for energy, protein, fiber, and dry matter can be a costly mistake in diet evaluation as the variation can be large between fields, seasons, and years. A regular herd health service of collecting and testing feed samples can be simple and rewarding.

Another basic service to provide is an analysis of the relative economy of available feedstuffs. It is easy for a producer to rank feeds in the order of cost/ton, (and then select what appears to be the cheapest), but they often lack the information necessary to rank them in order of cost/unit of nutritive value. For example, which is a better source of supplemental protein to a cow herd, 22% alfalfa hay priced at $200/ton or a 14% "hay replacer" block that is $175/ton? Simple math concludes that a unit of protein from alfalfa in this scenario costs $9.09 compared to $12.50 for the block. By providing ranked lists of protein and energy sources available to the producer, informed and effective decisions become more likely.

Mineral evaluations can be more complex, but the correct answer is still primarily a matter of good math. Every producer is looking for the mineral mix that costs $500/ton that will be just as effective as the $1,100/ton mineral suggested by a local salesman. A good spreadsheet can do the work of matching the mineral requirements for the animals in question and compare them to the labeled ingredients. The opportunity for an unbiased third opinion in these cases is invaluable and very difficult to find for most livestock owners. This is a skill that can rapidly build a nutritional reputation in the cattle community.

Acquiring Nutritional Skills

Veterinary practitioners do not need to be PhD nutritionists in order to offer valuable and correct nutritional advice. However, "above all else, do no harm" is a phrase worth remembering in regards to nutrition consulting as well as other areas of veterinary medicine. One must be careful not to masquerade as an experienced nutritionist while in the developmental phase of acquiring nutritional skills. Honesty is the best policy, and clients appreciate the practitioner who readily admits "I don't know" followed by "but I do know where to find your answer". Often a working relationship with a PhD nutritionist is highly desirable.

Fortunately, there are a variety of good resources that can lay the foundation for a successful career in nutritional counseling. AABP seminars are a great place to start, as well as continuing education offered from other professional associations. The NRC publications for beef and dairy cattle are the basic text books for nutritional training. Excellent software programs are available to facilitate diet evaluations and ration formulation once the underlying processes are well understood. Each of these come with a community of experienced mentors that will prove invaluable to your professional progress.

Conclusions

The level of nutrition education commonly offered in veterinary schools appears to be inversely related to the importance of nutritional expertise in bovine medicine and production. The health and economic goals of veterinarians and producers are intricately intertwined with the principles of optimal nutrition. Those veterinarians who have an interest in providing these services can set themselves apart from their competition and grow their practice by accessing the resources available to obtain advanced education in this arena.

Reference

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Professionalism, networking and negotiating associate's value proposition to prospective employers

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Abstract

As a part of a veterinary practice team, you may need to negotiate with vendors, and with challenging clients – and almost certainly there will be times that you need to negotiate with your employer about a raise, a revised benefits package, and evolving workplace perks and policies. When you negotiate fair compensation for yourself, you will become more committed to the practice, which translates into better care for the practice's clients and their pets. As an employer, when you negotiate fairly with employees, you will help to build loyalty that will stabilize and strengthen your practice. Gaining the ability to negotiate well help you to be more successful at work long after you've begun a particular job.

Résumé

En faisant partie de l'équipe d'une pratique vétérinaire, il est possible qu'on vous demande de négocier avec des vendeurs et aussi des clients très exigeants. De plus, il vous faudra presque assurément négocier avec votre employeur pour une augmentation de salaire, un ajustement des bénéfices sociaux ou de conditions eu égard aux règles et avantages du milieu de travail en constante évolution. Si vous vous négociez une juste rémunération, vous serez plus engagé dans la pratique vétérinaire ce qui se traduira par un meilleur soin des clients de la pratique et de leurs animaux. En tant qu'employeur, lorsque vous négociez de bonne foi avec les employés, vous allez renforcer la loyauté ce qui stabilisera et renforcera votre pratique. Être apte à bien négocier va vous aider à avoir plus de succès au travail bien après avoir commencé un emploi particulier.

Introduction

When you're offered a job at a veterinary practice, it's important to get as much information as possible about the specifics. You'll typically be offered a certain wage, often along with benefits such as health insurance, retirement benefits, vacation time, and the like. But, the offer may not mention workplace flexibility and other perks that can have a significant impact on your job – and so it's crucial to negotiate all of the key elements of the offer.

Many people feel uncomfortable when negotiating a work package, but gaining the ability to negotiate well help you to be more successful at work long after you've begun a particular job. As a part of a veterinary practice team, you may need to negotiate with vendors, and with challenging clients–and almost certainly there will be times that you need to negotiate with your employer about a raise, a revised benefits package, and evolving workplace perks and policies.

When you negotiate fair compensation for yourself, you will become more committed to the practice, which translates into better care for the practice's clients and their pets. As an employer, when you negotiate fairly with employees, you will help to build loyalty that will stabilize and strengthen your practice.

What Negotiations Are and Why They're Needed

A negotiation is a process in which 2 or more parties attempt to resolve differing needs and interests through a series of communications. An employer, for example, may want to offer someone higher wages, but needs to consider the overall profitability of a practice. Meanwhile, an employee may understand and support the need for a thriving practice, but also needs to earn a certain wage to support his or her family.

Employers and employees negotiate because they each have what the other one needs, and they believe they can obtain a better outcome through the process than if they simply accept what the other party is offering. Sometimes, negotiations occur because the status quo is no longer acceptable for 1 or both parties. Negotiations take finesse because, besides dealing with specific tangible points (wages, insurance benefits and workplace perks, as just 3 examples), emotions play a part and ongoing relationships are involved. The parties are choosing to try to resolve their different positions through discussions, rather than arguing, ending the relationship, having 1 person dominate the relationship or taking the dispute to another party with more authority.

Negotiation Terminology

Using the example of wages, employers and employee alike have a *target point*, which are the wages they would like the other party to agree to. The difference between what an employee wants to be paid and the employer wants to pay is the *bargaining range*. Meanwhile, the *resistance point* is where a party would walk away from negotiations; if too low of a wage or raise is proposed, an employee may begin job searching or a job candidate may decline an offer; the employer also has a point at which he or she will reject a wage request and end negotiations.

When the buyer (employer) has a resistance point that's above the seller's (employee), this situation has a *positive bargaining range*. The employer, in this case, is willing to pay more than the employee's minimum requirements, so this situation has a good chance of being satisfactorily resolved. With a *negative bargaining range*, though, 1 or both of the parties must change their resistance point(s) for there to be a possibility of resolution.

In a wage negotiation scenario, either the employer will offer a starting wage or raise, or an employee or job candidate will request a certain dollar amount; the first person to name a dollar amount is making the *opening offer*. If at least 1 of the parties has a *BATNA – best alternative to negotiation agreements*–then he or she will probably approach the discussions with more confidence, having another alternative. So, if an employer offers someone a job, but has another excellent candidate waiting in the wings, the employer has another alternative and can set a higher and/or firmer resistance point. Conversely, if an employee or job candidate has a unique set of skills that are needed in today's practices, that person probably has more options in the job market–perhaps even other pending offers. The quality of a negotiator's alternatives drive his or her value by providing the power to walk away and/or set a higher and/or firmer resistance point.

Bargaining Styles

There is more than 1 type of bargaining style. One way to differentiate them is to divide them into distributive bargaining and integrative bargaining.

In distributive bargaining, parties' needs and desires are in direct conflict with one another's, with each party wanting a bigger piece of a fixed tangible such as money or time, so these negotiations are typically competitive. Parties are not concerned with a future relationship with the other person. A slang term for this type of negotiation is "playing hardball" or "one upping" someone. Strategies often include making extreme offers, such as an employer offering a very low wage or a job candidate asking for an exceptionally high one. Tactics include trying to persuade the other party to reconsider his or her resistance point because of the value being offered–in this example, the job candidate might say that a high salary was required because of his or her abilities or an employer could say that lower wages would be compensated by a great work environment.

With integrative bargaining, though, the goal is win-win collaborations that will provide a good opportunity for both parties. The employer would acknowledge the employee's value and need for a decent wage, and negotiate accordingly, while the employee or job candidate would recognize the value of working at a particular practice as well as the fact that the employer has numerous other financial commitments to fulfill. They recognize that they need one another to maximize their respective opportunities and negotiate from a place of trust and integrity, with a positive outlook that recognizes and validates the other party's interest in the transaction.

Here's an interesting psychological truth. Negotiators are more satisfied with final outcomes if there is a series of concessions rather than if their first offer is accepted, because they feel they could have done better.

Negotiation Styles

To successfully negotiate, it's crucial to clearly define the issues involved, and to prepare for the negotiations. Each party should be clear about his or her target point, opening offer, resistance point and BATNAs.

Multiple negotiation styles exist, each on the spectrum of assertiveness and cooperativeness. Here are summaries of common styles:

- Competing (high in assertiveness, low in cooperativeness): these negotiators are self-confident and assertive, focusing on results and the bottom line; they tend to impose their views on others
- Avoiding (low in assertiveness and cooperativeness): these negotiators are passive and avoid conflict whenever possible; they try to remove themselves from negotiations or pass the responsibility to someone else without an honest attempt to resolve the situation
- Collaborating (high in assertiveness and cooperativeness): these negotiators use open and honest communication, searching for creative solutions that work well for both parties, even if the solution is new; this negotiator often offers multiple recommendations for the other party to consider
- Accommodating (low in assertiveness, high in cooperativeness): these negotiators focus on downplaying conflicts and smoothing over differences to maintain relationships; they are most concerned with satisfying the other party
- Compromising (moderate in assertiveness and cooperativeness): these negotiators search for common ground and are willing to meet the other party in the middle; they are usually willing to give and take and find moderate satisfaction acceptable

As long as both parties are committed to the business relationship and believe there is value in coming to an agreement, negotiations can typically proceed. If one or both parties, though, are unreasonable, uninformed or stubborn – or listening to advisors with those characteristics – negotiations can fall through. Other challenges exist when 1 party doesn't necessarily need the deal, isn't in a hurry or knows that the other party is without other options and/or in a time crunch.

Negotiation Fears

You may dread negotiation. If so, you're not alone. Common reasons for this include:

You have not yet solidified your position: in this case, more preparation is clearly needed

Fear of looking stupid: nobody likes looking foolish, so some people will avoid negotiations altogether rather than taking the risk of not negotiating well

Liking people and wanting to make them happy (but perhaps not being able to give them what they want!)/ not wanting to affect someone else in a negative way: if you are interviewing for a promotion at a practice, say, and you really like the practice manager, you may worry that negotiations will upset the manager or put him/her in a difficult position

Fear of failure: some people would prefer to not negotiate at all, rather than making an unsuccessful attempt

Feeling uncomfortable with money: some people were taught that it wasn't polite to talk about money!

Still other people have an aversion to conflict, overall, and so they avoid the potential of it by not negotiating. Yet others feel vulnerable when negotiating.

Women in particular are reluctant to negotiate, with only 7% doing so. They suffer the costs associated with not negotiating because they tend to have lower expectations, fear being considered a "bitch" and can be penalized for negotiating. As a solution, women can consider framing their wants into the value that they will bring to the other party, and share how they can solve the underlying problem of the other party.

Areas where negotiating may not feel as intimidating include:

- Negotiations for resources, whether it's asking for more equipment or for a practice to hire more people
- Negotiations about how to use resources; with a common purpose, solutions can be reverse engineered fairly easily
- Negotiations where you have expertise
- Negotiations with big companies where nothing is personal
- Negotiations where you have evidence to support your position, including facts, data and logical reasoning

Salary and Benefits Negotiation Tips

Even though the examples given so far have focused on monetary compensation, when negotiating, don't focus solely on wage or salary. Also discuss benefits offered and workplace perks – meaning the entire package. This can include, but is not limited to, health care coverage, life insurance, retirement programs, vacation time, and flextime. If you're job hunting, investigate what companies are offering. Where do you think the place you're interviewing falls on that spectrum? What is the minimum pay level that you're willing to accept? What is your preferred wage? What benefits are important to you?

If you want to work at a particular practice, but the pay rate isn't quite what you want, ask if you can have a salary review in, say, 6 months. This doesn't mean accepting a salary that is clearly sub-par, nor does it mean that you should try to put more pressure on a potential employer who is already offering you a good deal. It is simply something to consider in relevant circumstances.

What workplace perks might be desired? Would a company cell phone help you? Better equipment or software? If so, you could consider accepting somewhat lower pay if you get more tools to do your job.

Although telecommuting is seldom an option for veterinary staff, outside of perhaps financial or other purely admin functions, you could negotiate coming in half an hour later so that you can take your children to school or schedule a lunch break that coincides with when you need to pick them up. If you bring crucial skills to the negotiating table, you're more likely to get these concessions than if you are entry-level.

If relevant, ask about practice policy if you become pregnant. How acceptable is the policy to you? How important of a negotiating point is this for you? What about if you are injured in the workplace? Educate yourself on your workplace rights before negotiations occur, as well as company policy. If you are valuable to the practice, perhaps you can negotiate some additional flexibility.

Who should be the first to make an offer? Some experts believe that, if you allow the other party to provide a starting dollar figure, he or she has shown his or her hand. But, research indicates that final figures tend to be closer to the original number stated than what the other party had originally hoped.

What NOT to Do

Beware of "between"! It probably feels reasonable to ask for a certain salary range – or range for a raise. But if you do that with a current or prospective employer, you have basically tipped your hand as far as how low you would go. Using the word "between" is actually a concession!

Another risky term: "I think we're close." A savvy negotiator will recognize "deal fatigue" on your end and perhaps stall in the hopes that you'll concede, just to complete the deal.

For Best Results

People tend to feel more confident during negotiations when it focuses on an area of their expertise and/or where solid evidence exists to back up the negotiations. Overall, success is achieved when you first:

- Determine the interests of the other party

- Embrace compromise
- Observe the Golden Rule, treating others as you would like to be treated: fairly and reasonably, without defensiveness
- Be prepared, both in factual information and in strategy

Good luck!

Veterinary Employment Contract Legal Issues©

High turnover among veterinary associates is caused principally by the failure of practice owners and employees to properly articulate their respective expectations and negotiate and document the employment relationship. Time and effort invested up front will help avoid mismatched expectations, misunderstandings and separation down the road.

Can the practice even afford another full-time veterinarian?

Management consultants estimate that a small animal practice vet needs to produce 3,000 to 4,000 transactions annually and collect a minimum of $225,000 to $300,000 gross income (excluding OTC product sales) to be worth his or her salary.

I. What is an Employment Contract? A contract is a set of bargained for promises between 2 or more people, where 1 party promises to do X in exchange for another party's promise to do Y. Courts require that an enforceable promise meet certain conditions. For example, the parties must be of age (no minors), of sound mind, and not under duress; there must be no fraud or mutual mistake over an important aspect of the transaction, and the deal must not be so one-sided as to be "unconscionable."

Consideration. To distinguish binding promises from charity or gifts (you can't sue Santa Claus because he didn't give you enough presents last year), the law requires that the party to whom the promise is made give "consideration" for the promise in the form of a benefit to the promissor and/or detriment to the promisee. Thus, Dr. Newgrad promises to work 50 hours per week in consideration for an annual salary of $58,000 (i.e., a benefit to Newgrad and detriment to Oldguy). Oldguy promises to pay such salary to Newgrad in consideration for Newgrad's labor (benefit to Oldguy and detriment to Newgrad). Consideration exists for each promise which is therefore enforceable.

Avoid Oral Contracts. Oral contracts generally are binding only if their performance lasts less than a year, because the law assumes that the parties' recollections of what was agreed to become unreliable over time, increasing the tendency to remember events in a self-serving way. Few disagreements are less productive than the "you promised X," "I don't remember X but you promised Y" litany. Prevent such wasteful bickering by always insisting on a written contract, regardless of its term.

II. Contract Formation. Legal theory provides that a contract is formed once an offer is accepted. Real life usually is a lot messier.

Offer. An offer can be oral or written (e.g., employer advertisement in a professional journal, on a bulletin board or mailed to the applicant). Typically, the prospective employee will ask for clarification and wish to change the terms of the original offer by making a counter-offer. The employer counters such counter-offer with his own counter-counter-offer. This confusing and frustrating process continues until either the parties reach an agreement or, realizing they can't make a deal, go their separate ways.

Acceptance. Legally, the contract is formed as soon as the offer is accepted. This can be a trap for an impulsive party who accepts an offer, but who later (like Columbo) asks for "just 1 more thing." After acceptance, it's too late and the other party can sue for damages if the impulsive party doesn't perform his or her obligations under the originally accepted offer.

Ideally, an accepting party will clearly indicate his acceptance to the offering party, at best by signing an employment agreement or acknowledging acceptance in writing on the offer. More difficult to prove, but still unambiguous is an oral "I accept" or words to that effect.

Avoid unclear contract formation situations. Courts have created the so-called "action in reliance" (promissory estoppel) doctrine to find enforceable contracts even when 1 of the parties thought no contract existed. Courts have found valid contracts in cases where an:

- employer knew or should have known that the employee had acted " in reliance upon the offer" such as incurring expenses to move to the job location, searching for lodging thereat, and informing other employers they no longer are job applicants; and
- employee made the last offer or counter-offer, and such employee knew or should have known that in reliance thereon, the employer ceased advertising for the position, informed candidates that the job was filled, or bought new equipment or hired additional support staff in anticipation of the employees arrival.

Accordingly, a party considering an offer should not talk or act in a way it knows or should know will lead the other party to believe that such offer was accepted and should make sure that the other party is not taking action "in reliance" on anything it did or said.

III. Contract Terms. Assuming that the offer, counter-offer, counter-counter offer, etc. ballet results in the bliss of acceptance, the employment contract terms contain the nuts and bolts of the "meeting of the minds" of the parties. Following is a list of the main questions addressed in a proper employment agreement:

1. How Long? Is there a fixed term (period) of employment (6 months, 1 year, 2 years, or is it "at-will" (i.e., the contract continues until a party decides to terminate it)? Is the term automatically renewed on the expiration date?

2. Work Schedule. How many scheduled hours per week must the employee work, and beyond the schedule, how many additional hours will employees actually spend phoning clients, performing diagnostics, interpreting laboratory work, overseeing patient care, etc. What is the schedule for any required emergency work? Is it equitable?

3. Duties. What are the associate's responsibilities? May employees decline (without penalty) to perform procedures they deem ethically wrong? How much emergency duty is required?

4. Compensation. Is compensation a fixed salary or commissions based on the revenue generated by the employee and collected by the practice, or is it a hybrid system under which the employee earns the higher of a base salary or a percentage of generated (and collected) revenue (a.k.a. percentage based compensation)? How are production bonuses calculated? Is there a performance bonus and if so what are the evaluation criteria? What is it based on? Is emergency work paid extra? How much?

- National starting salary information is published at least annually in the *Journal of the AVMA*. See also the latest biennial edition of the American Animal Hospital Association's *Compensation and Benefits-An In-Depth Look* and the AVMA's *Economic Report on Veterinarians and Veterinary Practice*. Two periodicals, Veterinary Economics and Veterinary Hospital Management Association Newsletter, also regularly publish helpful articles.
- **Pay attention to deductions**. What will be deducted from employee compensation? Some employers deduct not only the employee's portion of payroll taxes, but also the employer's share.

5. Employee Benefits. Practices usually offer at least some of the employee benefits described below to their employees. The cost of many benefits (such as health, professional, and disability insurance, qualified retirement plans) are tax deductible business expenses to the employer and are not included in the employee's income, resulting in a savings to the employee of 25 to 40%. Not taking advantage of this juicy gift from Uncle Sam is wasteful. On the other hand, employees must realize that the practice probably can't afford all the benefits they desire. One leading veterinary management consultant has calculated that small animal veterinary employers cannot afford to allocate more than 23 to 27% of the collected income generated by an associate veterinarian to pay his or her salary and benefits (due to lower overhead, the range is 28 to 32% for large animal practices).

- **Health Insurance.** Does the employer offer health insurance? If not, what does the employer do when *he* or *she* gets sick? If so, what kind of medical plan is it (e.g., fee for service, HMO, PPO)? What about pre-existing conditions, vesting, eligibility, deductibles and co-payments?
- **Disability Insurance**. Employees at age 25 have a 58% chance of becoming disabled for more than 3 months (with an average disability duration of 3 years), so employees need disability insurance to protect their greatest asset: the ability to work. If the employer does not offer disability insurance, employees are well advised to get it on their own (after asking, of course how the employer, protects himself or herself against disability).
- **Professional Liability Insurance PLUS License Defense**. Do employers pay the premiums on the employees' professional liability insurance?
- **Retirement Plans**. Has the employer established a retirement plan for the employees? (Profit sharing plans are the most common type of retirement plan offered by veterinary practices.) When do employees become "vested" or "eligible?" If the employer does not offer a retirement plan, employees will need to save on their own, and that means more than just the annual IRA contribution.
- **Vacation**. One week? Two weeks? More? How many consecutive days may be taken? How much advance notice must be given? May unused vacation days be carried forward to next year? How are vacation days paid for percentage-compensated employees?
- **Sick Leave and Disability**. Does the employer offer paid sick leave? Disability leave? After how long can disabled employees be terminated? May unused sick days be carried forward?
- **Continuing Education**. How many CE leave days are granted and are they paid? To what extent do employers reimburse CE expenses?
- **Association Dues**. Are national, state and/or local veterinary association dues reimbursed?
- **Veterinary License Fees and DEA Registration**. Are these fees paid by the employer? Should the employee register with the DEA so she is permitted to prescribe and order controlled substances rather than just administer them under the supervision of a DEA licensed veterinarian?
- **Relocation (moving) Expenses**. Most corporate and government employers provide some form of moving expense. Sometimes a "signing bonus" or short-term loan can cover all or part of these costs.
- **Vehicle allowance or mileage payments.** Employees using their personal vehicles for practice business should be reimbursed for a pro-rata portion of their insurance, general maintenance, registration and inspection fees, fuel, repairs, depreciation, and lost opportunity costs.

6. Performance Evaluation. Will the employer provide written and/or oral performance evaluations? How often? Will these be used to modify compensation?

7. Non-Competition. Many employers require their employees to sign non-competition clauses (also called restrictive covenants) forbidding terminated employees from competing with the employer. Such clauses must be limited in time (e.g., 3 years after termination) and geographic area (e.g., 15 air-miles from the practice) to be enforceable. The precise limits on the scope of such clauses vary from state to state. From the employer's perspective, this is the most important reason to have a contract. Without a non-compete, employers cannot protect the goodwill they have worked so hard to build.

8. Termination. Does the contract have a specific term, e.g., "this agreement will expire after one year" or is it employment "at-will", in which case, either party can terminate the relationship at any time, for any reason? Contracts with no term are deemed to be "at-will" in most states. If there is a term, then an employee leaving or an employer firing before the term would constitute a breach unless the contract provides otherwise. Most contracts which provide for termination before the expiration of the term require that the terminating party give advance notice, e.g., 30 days to the other party. Such contracts usually also contain a list of situations (e.g., suspension of the associate veterinarian's license) permitting the employer to fire the employee at any time without notice (a.k.a. termination "for cause").

Employees should make every effort to leave their employer on good terms even if they are not requesting a reference. The veterinary industry is quite small, and an employee's reputation can easily suffer through casual conversation among colleagues.

9. Option to Buy-In. Experienced associates that have their own clientele may not wish to enter into an employment agreement with a non-compete without also being provided with an opportunity to buy an interest in the practice after a 1 to 3 year "try-out" period. These often are complex provisions to negotiate depending on the amount of security the associate wants up-front, and should not be undertaken without consultation with an attorney that has experience with medical practice transactions. Too often associates lock themselves into a non-compete, and agree to an "option" provision that turns out to be a smoke screen.

IV. Lawyer Review. Negotiating and drafting an employment contract can be long, painful and complicated. It therefore makes as much sense to seek professional help in this endeavor as it does to take a pet to a qualified veterinarian when it is sick. Lawyers are expensive, of course, just as much as veterinarians...

Pearls of Wisdom, Red Flags, and Other Things to Know

Recommendations from a New Grad

Pearls of Wisdom

- **Have your Contract Reviewed**
- **Walking Money** – Always make sure you have some extra money just in case you need to leave a job before you have found another. Many money market companies will allow you to set up an account with $0 if you let them automatically debit $25/month from a checking or savings account. Start now!
- **Meet Everybody** – The 1 doctor in the practice who you haven't met could very well be a thorn in your side. Hospitals are very good at conveniently having you around when this person is out. Ask lots of questions. If you want colleagues who will mentor you ask them; don't assume that everybody who hires a new graduate will be willing to teach.
- **Never Agree To Give More Than 1 Month Notice** – 1 month is tough, 2 months is unbearable, 3 months is impossible. Rejection is a difficult emotion for some people to deal with; even the nicest employer may have difficulties with professionalism after you have given your notice. The support staff may also have difficulties and have feelings of abandonment.
- **Make Sure You Have a Lunch and Dinner Break** – This time will not be spent eating. There are always cases to finish, blood work to read, and phone calls to make. If the break is less than 1 hour you may very well not have time to finish the above tasks, let alone eat.
- **Avoid Exclusivity Clauses** – You never know when you might want or need to work at another hospital to make some extra money. Relief work is very lucrative.
- **Don't Agree to an Excessive Restrictive Covenant** – You may be making an investment in where you live, especially if you are buying a house. You don't want to make an agreement where you can't work anywhere within a reasonable distance from your home. Also try to have your restrictive covenant go into effect AFTER your 90 day review. The good folks at Priority Veterinary Consultants will help you define a reasonable distance. ***Please*** have youR contract reviewed, especially if your covenant is > 5 miles.
- **Have a Relief Work Clause Written into Your Contract** – You don't want a restrictive covenant prohibiting you from serving as a relief veterinarian several days a month or preventing you from helping with a low cost spay and neuter program. Also, you shouldn't be restricted at all from working in an emergency facility whose hours do not coincide with you previous employer's hours of operation.
- **Have Your Contract Reviewed!!**

Red Flags

- **Revolving Doors** – If the turn around time for a hospital needing a new vet is a year or even worse less than a year RUN THE OTHER WAY. This information can be difficult to find. Join a mentorship program or ask subtle questions to tease out this valuable information. Don't forget you can ask a prospective employer for references from previous employees.
- **Family Members In Important Positions** – A deadly combination exists when the boss's spouse is the office manager–trust me you will NEVER win.
- **Newly Created Positions** – Filling a vacancy is always a safer bet than becoming the new addition. Many times a hospital overestimates how busy they really are. Also, it takes time for staff to make the adjustments needed when a practice is growing. You'll have enough to deal with in your first year out; therefore, this may be a situation to avoid at first.

Other Things to Know

- **Respect Yourself** – Remember that in order to take good care of patients you must take care of yourself first. Take time to eat, sleep, and enjoy life outside of the hospital. You deserve it!!!
- **Don't be Afraid to Ask for Help** – The veterinary profession can be very stressful. There may be times when it's helpful to talk to a mental health professional, religious professional, legal professional.
- **Keep in Touch** – Your friends from school will all be going through the same things that you are. They will be a wealth of knowledge.
- **Treat Support Staff With Respect**. Receptionists, technicians, and doctors may have different job descriptions, but we're all earning our livings through bettering the lives of animals.

AABP & AASRP Joint Session

Moderator: *Dale Duerr*

What bovine practitioners need to know about caseous lymphadenitis

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Abstract

Caseous lymphadenitis (CL) is one of the costliest, but most under-appreciated infectious diseases of sheep and goats, often leading to premature culling or death. *Corynebacterium pseudotuberculosis* in sheep and goats results in lifelong infection, with reoccurring abscesses of the peripheral and/or internal lymph nodes and the associated clinical signs. Transmission is by direct contact and indirectly by contamination of feeders, equipment, and the environment. Diagnosis is by abscess culture or necropsy. The serologic test has limitations but can be used to detect exposure to the organism; it may be used to facilitate segregation or culling in herds with low incidence of CL or to exclude introduction of infected animals. Premises hygiene, vaccination, segregation of herd by disease status, and isolation of clinical animals during treatment are the main strategies used to control CL in heavily infected herds. Intensive management of clinical abscesses with early detection of ripening abscesses, animal isolation until the abscess is healed, lancing abscesses in an isolation environment, and preventing cross-contamination of premises and potential fomites are keys to successful management. Vaccination can be used to reduce the number of animals with abscesses and the number of abscesses per animal, thereby reducing the overall herd exposure in endemic herds. Control and eradication of CL requires long-term commitment to an integrated management approach to reduce environmental contamination and prevent direct transmission in the herd or flock.

Key words: sheep, goats, caseous lymphadenitis, CLA

Résumé

La lymphadénite caséeuse (LC) est l'une des infections les plus coûteuses bien que très peu reconnue chez les moutons et les chèvres. Elle mène souvent à la réforme prématurée ou à la mort. La bactérie *Corynebacterium pseudotuberculosis* cause une infection à vie chez les moutons et les chèvres avec récurrence d'abcès des nœuds lymphatiques périphériques et/ou internes et des signes cliniques associés. La transmission se fait par contact direct et indirectement par la contamination des mangeoires, de l'équipement et de l'environnement. Le diagnostic se fait avec la culture des abcès ou par la nécropsie. Le test sérologique comporte des limites mais peut être utilisé pour détecter l'exposition de l'organisme. On peut aussi l'utiliser pour faciliter la ségrégation des animaux et la réforme dans les troupeaux avec une faible prévalence de LC ou pour prévenir l'introduction d'animaux malades. L'hygiène des installations, la vaccination, la ségrégation du troupeau selon le statut de maladie et l'isolement des animaux présentant des signes cliniques durant le traitement sont les principales stratégies utilisées pour contrôler la LC dans les troupeaux fortement infectés. La gestion efficace de la situation implique plusieurs éléments essentiels tels que la régie intensive des abcès cliniques avec détection précoce des abcès en développement, l'isolement de l'animal jusqu'à ce que l'abcès soit guéri, le crevage des abcès dans un environnement isolé et la prévention de la contamination croisée des installations et des vecteurs passifs potentiels. La vaccination peut être utilisée pour réduire le nombre d'animaux avec des abcès et le nombre d'abcès par animal ce qui permet de réduire l'exposition de tout le troupeau dans les troupeaux endémiques. Le contrôle et l'éradication de la LC exigent un engagement à long terme à une approche de gestion intégrée pour réduire la contamination environnementale et prévenir la transmission directe dans le troupeau.

Introduction

Caseous lymphadenitis (CL, CLA, contagious boils) can be one of the most costly lifelong infections in a goat herd or sheep flock. Abscesses caused by *Corynebacterium pseudotuberculosis* result from lifelong infection with reoccurring abscesses of the regional lymph nodes. Draining of external abscesses results in transmission to other sheep and goats by direct contact, as well as spread by indirect contact with contaminated feeders, equipment, and the environment. The organism remains viable for months in the environment and remains a source of long-term transmission by ingestion or inoculation to susceptible sheep and goats. Abscessation of internal lymph nodes may result in chronic weight loss and premature culling. Definitive diagnosis is by culture of pus from an abscess or by necropsy. Serologic testing with the synergistic hemolysin inhibition (SHI) test will detect exposure to the organism and can be used to exclude imposed and potentially infected animals from herd introduction and as an aid to segregate or remove sheep or goats as part of a herd cleanup program. Serologic testing and segregation or culling may be used in herds with low incidence of CL, while premises hygiene, vaccination, and isolation of affected animals will be main strategies used to control CL in heavily infected herds.

Intensive management of clinical abscesses with early detection of ripening abscesses, isolation of the sheep or goat until the abscess is healed, lancing abscesses in an isolation environment, and preventing cross-contamination of premises and potential fomites are keys to successful management. Fly control will aid in dissemination of the bacterium among goats. Premises disinfection and herd segregation on the basis of infection status will reduce the incidence of new infections in the herd. Vaccination with commercially available sheep CLA vaccine or with autogenous bacterins can be used to reduce the number of sheep and goats with abscesses and the number of abscesses per animal, thereby reducing the overall herd exposure in endemic herds.

The sporadic *C. pseudotuberculosis* infections in that cause "pigeon fever" in horses and the hemorrhagic-appearing *C. pseudotuberculosis* abscesses found sporadically in cattle are caused by closely related bacteria, but are not transmitted from or among sheep and goats.

Prevention

For flocks and herds without known *C. pseudotuberculosis* infection, intense precautionary measures to prevent introduction of infected animals into the herd and flock, and preventive measures to prevent exposure of animals to infected animals and contaminated equipment and facilities are to be highly encouraged. Shared equipment for shearing/clipping should be avoided or disinfected carefully before use. Many sheep flocks are accidentally infected at shearing by the use of contaminated blades used on infected animals within or outside of the flock, as abscesses are easily ruptured during shearing; the minor skin abrasion created by shearing blades/combs creates an efficient means of bypassing the host defense created by intact healthy skin. Abscesses in the scrotal region of rams commonly result from inoculation of skin at time of shearing.

Exhibitors of show sheep and goats should take time to disinfect pens (and trailers, if indicated) prior to unloading show animals at fairs and shows. Exhibitors should encourage fair managers to employ veterinarians for health inspections at fairs and shows, and show rules should clearly state the expectation of health status. For example, some fairs may allow enlarged lymph nodes (if not unsightly) but do not allow any evidence that the skin is not intact or that an abscess is ripening, while other fairs/shows/sales may not allow any evidence of pre-existing infection, such as an abscess scar. Regarding sale animals, breeders of yearling rams may not be aware that the apparently healthy rams they are selling in premium sales may already be infected with CL.

Serologic Testing

Serologic testing is one means of screening new herd introductions for evidence of *C. pseudotuberculosis* exposure and thus excluding both exposed and infected animals for the "zero-tolerance" herd. However, in the endemic herd/flock and in herds/flocks employing vaccination as a control strategy, serologic testing would not be encouraged unless its use would be to segregate groups of potentially infected and presumed uninfected animals.

Using the synergistic hemolysin inhibition (SHI) test, titers of <1:8 for goats are considered negative. Titers between 1:8 and 1:256 are interpreted as evidence of infection or vaccine exposure. In goats (no data are available for sheep), titers >1:512 are highly associated with internal abscess formation.

Monitoring and Disease Surveillance

Successful control for chronic diseases relies on continued disease surveillance. Management decisions regarding disease control grouping, treatment, production, and culling should be based on accurate lifelong records on each animal. Unique individual animal identification (tattoos, ear tags, neck tags, etc.) is needed before permanent accurate records can be maintained to monitor CL and other infectious disease status. Dam disease status and cohort exposure are needed as part of the permanent animal record.

Necropsy surveillance will allow monitoring of the magnitude of clinical CL in the flock or herd and will allow appreciation for the role that abscesses due to CL contribute to the mortality caused by otherwise non-fatal cases of competing diseases in the flock or herd. Planned routine necropsy of selective herd culls as well as deaths will allow monitoring for all major contributors of disease in the herd, not just primary cause of death. Additional testing for tissue copper and selenium, parasites, and other items of interest can help identify concurrent disease problems which may confound the efforts of specific disease control programs such as CL control. Johne's, scrapie, CL, CAEV/OPPV, and mycoplasma can all be monitored by necropsy even though the cause of death may be unrelated to these diseases. Serologic testing for CL may be part of an ongoing control program for the herd or used to screen new herd introductions.

Recommendations for Control of Caseous Lymphadenitis

The best strategy for controlling *C. pseudotuberculosis* infection in infected flocks and herds will depend on the initial prevalence, resources available to employ management strategies and diagnostic testing, and the owner's philosophy toward herd health management in the herd or flock. A combination of segregation and hygienic treatment (lancing) of abscesses, vaccination, premises clean-up, and prevention of fomite transmission strategies can achieve success in control of the disease. Complete eradication could at some point also involve serologic testing and segregation or removal in the final stages of eradication.

Vaccination

Vaccination with either the commercially available sheep bacterin, goat bacterin where available or with an autogenous bacterin can be a useful part of a control strategy to control CL. Vaccinated animals still may become infected with the organism, but would be expected to have few abscesses during their life, and fewer infected animals would be expected to become clinically affected during their life. The resulting increased herd immunity and decreased environmental contamination help to decrease overall herd/flock exposure. Herd replacement animals should be vaccinated prior to introduction into the adult herd/flock, according to manufacturer's recommendations. Known-infected animals should not be vaccinated; adverse vaccine reactions have been reported in infected goats with some vaccines.

Segregation of Infected Sheep and Goats

Detection of animals with clinical disease is very difficult, as enlarging lymph nodes may be masked by thick hair coat (especially in winter) or heavy fleece. Routine palpation of superficial lymph nodes during animal handling and identifying animals with suspicious enlargement will facilitate isolation of clinically affected animals in the endemic herd or flock. While the risk of contamination (and transmission risk) from an external abscess may be able to be visually assessed, abscesses shedding bacteria from the pharynx and respiratory tract cannot be detected. In flocks with intense segregation programs, serologic testing can be used to segregate presumed infected or exposed animals from seronegative animals.

Segregation of Animals after Lancing Abscesses

Animals with open or draining abscesses are at highest risk of 1) directly infecting other sheep and goats, and 2) heavily contaminating the environment, thus contributing to long-term environmental challenge or magnitude of risk. Common concentration areas like working corrals and chutes and milking parlors are common points of maximum exposure. Animals with open abscesses should be milked by hand and kept out of the milking parlor until the abscess is healed. Alternate handling facilities and isolation areas should be used until the skin surface is completely healed. Every deviation from that standard (e.g. dry but scabbed abscess site) results in increased risk of effective exposure to another animal and increased risk contamination of the environment.

Best Practices for Lancing Abscesses

Abscesses are ready to lance when they are bald over the surface and the skin is immovable over the hairless surface. This surface should be soft and thin-walled. Lancing abscesses before they are sufficiently localized superficially can result in cellulitis of surrounding tissues. Always wear gloves to lance or flush abscesses; producers sometimes do not recognize the importance of this practice! Abscesses should be lanced away from usual goat housing and handling areas. Collect all pus and contaminated materials into a plastic trash bag for incineration or disposal. Avoid contamination of clothing with discharge from abscess, and change clothes or coveralls before handling other animals if abscess pus contaminates them. Shoes, jackets, and other outer clothing are commonly overlooked as potential fomites.

To lance an abscess, restrain sheep or goat securely, and incise over softest part of abscess with scalpel blade. Use of a #12 blade allows an outwardly directed incision and reduces risk of unintentional wound extension. Express pus into plastic bag to minimize environmental contamination. The incision should be large enough (in "+" or "0" shape) to allow abscess to drain and be flushed until drainage stops, in order to prevent closure of the capsule before the abscess cavity has granulated in, otherwise it will refill with pus. Once pus has been expressed, insert a gloved finger (with gauze over fingertip) and explore abscess to remove pus adhering to the capsule (wall) of the abscess. When all the pus has been removed from abscess, flush with either hydrogen peroxide or tincture of iodine in a catheter tip syringe (but note that abscesses must be superficially localized for these to be used, as they damage healthy tissue). When the abscess has been flushed thoroughly (no pus comes out with fluid), applying an astringent wound powder in the abscess cavity of superficial abscesses can hasten their resolution. On successive days, flush abscess again if any drainage is present. Keep the wound open to allow the abscess to heal from inside to outside; apply fly/insect repellent daily. Keep the sheep or goat in "abscess pen" isolation until the wound is completely healed if possible, as scabs may contain infective material. Disinfect the surrounding hair coat or skin area with povidone iodine solution or dilute bleach before returning the animal to the herd or flock once the abscess is healed. Be sure to note the abscess on herd/flock records.

This protocol applies to superficial abscesses only. Deep abscesses that have not localized to be adherent to the skin must be handled more gently to avoid infection and inflammation of surrounding tissue. If a deep abscess occurs, flush with diluted povidone iodine solution instead of tincture of iodine or hydrogen peroxide; other techniques such as marsupialization or surgical excision of intact abscess may be needed to safely treat abscesses near vital structures.

Carefully discard all contaminated material from treating contagious abscesses. Maintain dedicated supplies and equipment to be used for treating contagious abscesses, and store all abscess-treatment supplies and equipment separately from "clean" medications and equipment to avoid cross-contamination between clean and abscess-associated supplies. In dairy animals, do not lance or medicate abscesses in the milking parlor to avoid risk of contaminating milking equipment or milkers' hands or clothing.

Eradication

Once the herd or flock prevalence is at a low enough level that the owner could consider removing infected animals to eradicate disease, serologic testing could be used to segregate potentially exposed animals from presumably naïve animals. Animals testing positive in the "naïve" group can then be removed through regular testing, and either sold or moved to the "exposed" herd at another location. Before any decision to entirely eradicate disease is made, the herd owner should consider 1) what action will be taken for test-positive animals in the future, 2) will all animals be screened before introduction into the herd, 3) what measures will be taken to prevent exposure of the herd/flock to contaminated facilities and animals, and 4) whether the owner is willing to make a multi-year commitment to assure completion of the program.

Once eradication is achieved, owners should develop a group of trusted trading partners with similar health management philosophy to continue successful animal breeding without jeopardizing the health status of the herd or flock.

Conclusion

Caseous lymphadenitis can be one of the most costly lifelong infections in a goat herd or sheep flock. Intensive management strategies are needed to prevent introduction of this disease into susceptible flocks and herds, and to control and eradicate the disease in flocks with pre-existing infection. Efforts to control and eliminate *C. pseudotuberculosis* from sheep and goat flocks and herds lead to lower mortality from other diseases in the population and to enhanced overall herd health.

Management strategies for infectious disease control in a variety of production systems

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Abstract

Strategies for disease control in goat herds should be individualized to account for the diversity in management type, risk levels, and owner factors. Goat herd type, for example dairy, meat, fiber, companion or other; intensive or extensive management; confinement, grazing or browse; as well as owner's experience level, beliefs and budget all must be considered in planning prevention and control programs for contagious disease in goat herds. Caseous lymphadenitis, caprine arthritis-encephalitis virus, Johne's disease, *Mycoplasma* spp infections, contagious abortion agents, and scrapie all should be considered in planning an integrated pathogen control program to address as many diseases as possible using the same critical control steps in disease management. Pasteurized kid-rearing programs, disease-specific testing and segregation, testing and removal or culling are strategies commonly employed for important infectious diseases. Optimizing and economizing herd diagnostic surveillance through routine necropsies and selective herd testing provide the basis on which sound, informed decisions can be made. Conscious decisions should be made whether to tolerate, control or eradicate each important infectious disease in the herd or, if not in herd, what resources should be committed to preventing the introduction of agents causing lifelong infection in the adult herd.

Key words: goats, herd health, diagnostics

Résumé

Les stratégies de lutte contre la maladie dans les troupeaux de chèvres doit être adaptée pour tenir compte de la diversité de type de gestion, les niveaux de risque et les facteurs de propriétaire. Troupeau de chèvres type, par exemple les produits laitiers, la viande, les fibres, compagnon ou autres ; intensif ou extensif ; gestion de l'accouchement, le pâturage ou parcourir ; ainsi que le niveau d'expérience du propriétaire, de croyances et de budget doivent tous être pris en compte dans la planification de programmes de prévention et de contrôle des maladies contagieuses dans les troupeaux de chèvres. Lymphadénite caséeuse, l'arthrite-encéphalite caprine virus, la maladie de Johne, Mycoplasma spp infections, avortement épizootique, et tous les agents de la tremblante devraient être considérés dans la planification d'un programme intégré de contrôle des agents pathogènes d'adresse que de nombreuses maladies que possible en utilisant les mêmes mesures de contrôle critique dans la gestion des maladies. Kid-pasteurisé, programmes d'essais spécifiques à la maladie et la ségrégation, les essais et l'élimination ou l'abattage sont des stratégies couramment pour maladies infectieuses importantes. Optimiser et économiser de diagnostic de routine grâce à la surveillance du troupeau et les autopsies troupeau sélective offrent la base sur laquelle des décisions peuvent être prises. Conscients que les décisions devraient être prises à tolérer, contrôler ou éradiquer les maladies infectieuses importantes dans le troupeau ou, si ce n'est pas en troupeau, de quelles ressources devraient être déterminés à empêcher l'introduction d'agents causant l'infection dans le troupeau adultes.

Introduction

Many of the chronic infectious disease problems in the goat herd are lifelong infections from exposure of kids near the time of birth. Infectious disease control programs start with planning kid-rearing strategies to minimize infection of the neonate. Pasteurized rearing strategies are commonly used to prevent mycoplasmosis and caprine arthritis-encephalitis virus (CAEV); however, pasteurized rearing (with age segregation) also reduces the risk of Johne's disease (*Mycobacterium paratuberculosis*) and caseous lymphadenitis (CL, *Corynebacterium pseudotuberculosis*). Removing kids from the kidding/maternity pen environment would reduce potential exposure to the scrapie agent in infective placental tissues. Pasteurized rearing alone will reduce the overall prevalence of these diseases, but serologic testing and segregation or culling is needed to fully control CAEV. Similarly, pasteurized rearing must be combined with milking hygiene measures, routine milk cultures and segregation for mycoplasma control. Serologic testing and segregation or culling may be used in herds with low incidence of CL, while premises hygiene, vaccination, and isolation of affected animals will be main strategies used to control CL in heavily infected herds. Integrated approaches to control the chronic infectious diseases acquired early in life can greatly enhance longevity of goats in the herd.

Strategies for Approaching Infectious Disease Control

What is the current herd status with respect to each disease of interest? A herd with 70% mycoplasma prevalence will likely adopt a control strategy first, followed by an eradication strategy after prevalence is reduced to a level that would economically allow complete removal of infected goats.

What is the current herd status with respect to other infectious and metabolic diseases? Concurrent infections and nutritional deficiencies may result in more severe clinical expression of a disease of interest. Co-infection with agents with common tissue trophism (e.g. CAEV and mycoplasma) may modify resistance to and clinical outcome of disease.

Does a records infrastructure exist to allow prevention and management of infectious disease? Most chronic infections are lifelong, and ability to categorize goats by disease status and trace risk to the postnatal environment are key to success in infectious disease control.

Are the goats commingled or share risk of exposure with other species? Scrapie and CL are shared between sheep and goats. Johne's risk assessment should include all animals on the farm as well as off-farm sources of milk and colostrums. Caprine and ovine lentivirus control programs should be considered together as part of a herd approach to CAEV control.

Is the herd closed (raises all their own replacements) or open (and to what degree), and what are the owner's long-term goals with respect to herd replacements? In some cases, raising replacements may be the only way to maintain high standards of herd health. In other cases, susceptible replacements coming into a herd may be at high risk of massive exposure and high likelihood of clinical expression of disease.

What are the owner's goals for the herd, and what will the budget allow? Costs of pasteurized rearing programs and serologic/necropsy surveillance for disease will need to be assessed in prioritizing disease control strategies. The veterinarian and the producer may have different views of a tolerable level of endemic disease.

Caprine Arthritis-Encephalitis Virus (CAEV) Infection

Caprine arthritis-encephalitis virus infection is a lifelong lentivirus infection affecting monocytes and macrophages. The major route of transmission is via colostrum and milk. Postweaning transmission of CAEV occurs following prolonged contact between susceptible and infected goats. Long-term, high-density commingling of infected and susceptible goats would favor the likelihood of effective contact. Clinical signs associated with CAEV infection include adult-onset polyarthrtitis and polysynovitis, leukoencephalomalacia of kids 2 to 6 months of age (rare), and histologic mononuclear infiltrative changes in lung, CNS, and mammary gland. Approximately 35% of infected goats will develop the most frequent clinical sign, polyarthritis, during their productive lifetime. Diagnosis is based on clinical signs, serologic testing, testing for virus-infected cells by PCR or by necropsy. This lifelong infection has no effective treatment; infected goats shed the virus in their milk.

Pasteurized kid-rearing methods are the cornerstone of prevention of milk and colostrum as a route of CAEV infection. Additionally, the long-range success of a CAEV prevention program lies in identification and segregation or removal of infected goats. Serologic testing is the most practical means of herd surveillance for CAEV infection. Since CAEV infection is lifelong, the presence of antibody is presumptive evidence of CAEV infection.

Heat-treatment of Colostrum and Pasteurization of Milk

Heat-treating colostrum for 60 minutes at 134 °F (56 °C) has been shown to prevent transmission of CAEV or *Mycoplasma* spp to kids. Colostrum can be heated in a double boiler, pasteurizer or water bath to 135 °F (57 °C) and held in a preheated thermos bottle or stable water bath for 60 minutes, with exit temperatures carefully monitored. Care must also be taken to assure even heating of colostrum to prevent failure of the method. Heat-treated colostrum can then be frozen for later use. Colostrum that exceeds 138 °F (59 °C) tends to denature immunoglobulins and develop clumps. Overheated colostrum should be discarded, as feeding it usually results in osmotic diarrhea.

Standard pasteurization has been recommended for milk to be fed to kids. Minimum pasteurization temperature of 165 °F (74 °C) for 15 seconds is recommended for control of other pathogens such as *Coxiella burnetti*. Pasteurization can be done on a stove or in small commercial pasteurizers, but routine monitoring of exit temperatures and times are necessary to prevent failures in pasteurization due to inadequate temperature or duration of treatment.

Raw cow colostrum and milk have been used for CAEV and caprine *Mycoplasma* spp prevention. Although successful in preventing transmission of these caprine pathogens, herd biosecurity may be compromised by the potential for introduction of *Mycobacterium paratuberculosis*, *Salmonella* spp, or other pathogens with less species specificity. Quality of cow colostrum and milk are still essential in assuring successful passive transfer and preventing colibacillosis and other opportunistic infections. Artificial colostrum replacers have been used successfully in some herds.

Control of CAEV in Goat Herds

Recommendations to prevent CAEV transmission should be considered a permanent part of herd health management programs. Many producers have been disappointed at the reemergence of CAEV infection or the appearance of *Mycoplasma* spp infection after discontinuing pasteurization and segregation procedures. A negative herd serologic status is not a guarantee of a negative herd infection status.

Many factors including delayed seroconversion, viral latency, restricted viral replication, herd management, and limitations of available tests for detecting infected animals make the goal of eradication of CAEV difficult to achieve. Although eradication may be difficult to achieve, the economic impact of CAEV infection is markedly decreased when herd prevalence is low. Even on premises where testing and segregation cannot be implemented, pasteurized rearing alone (removal at birth and feeding of heat-treated colostrum/pasteurized milk) significantly reduces the economic impact of disease by delaying the time of infection.

In meat goat herds or other herds where kids are raised on their dam, prevention of infection of herd replacements is accomplished by testing and segregating doe/kid pairs based on CAEV status. Prevention of introduction of CAEV into an uninfected group or herd would require repeated testing strategies.

Recommendations to control CAEV infection are:

1. Prevent perinatal transmission by removing kids at birth without allowing contact (sniffing, licking) with the doe. Kids may be rinsed in warm water to remove cellular debris of maternal origin, as long as kids are thoroughly dried. Cardboard boxes can be used to house separate litters of kids for the first few weeks of life; disposable boxes aid in preventing transmission of neonatal pathogens.
2. Prevent milk-borne transmission. Although heat-treated colostrum and pasteurized goat milk are recommended, there may be some risk associated with feeding heat-treated colostrum from infected does to kids. Diligent monitoring of treatment times and exit temperatures is critical to the success of pasteurization programs. Additionally, pasteurized milk should be marked with food coloring to minimize the risk of accidentally feeding unpasteurized milk to kids, particularly if several people are involved in the care of kids. Heat-treatment of cow colostrum and pasteurization of cow milk, if possible, is desirable to assure its microbial quality and prevent colibacillosis and other neonatal infections in kids. Cow colostrum, cow milk, and high-quality milk replacer are alternatives to feeding goat colostrum and milk. Processed commercial colostrum products and hyperimmune serum give variable results. Feeding cow colostrum or heat-treated colostrum from seronegative does allows the opportunity to confirm suspected accidental nursing of seropositive does via detection of colostral titer in kids.
3. Maintain a serologic surveillance program at intervals determined by existing herd prevalence and herd goals. PCR testing may be used to clarify an animal's serologic status or as an additional means of screening herd introductions for potential infection.
4. Segregate or cull seropositive animals. Segregation must be complete with either solid barriers or a 2 to 3 m alley between seropositive and seronegative goats. If possible, pen grouping of goats by age and restricting group size will limit exposures to smaller groups of goats. Ideally kids born to seropositive does should be housed separately until serologic status can be determined and monitored. Feeders and waterers should not be shared, and commingling of seropositive and seronegative goats should not be allowed (for example, during transportation or housing at shows).
5. Milk seronegative does before milking seropositive does, and milk younger does before older does.
6. Potential for venereal transmission of CAEV exists. When possible, breed seronegative does with seronegative bucks. If seronegative and seropositive animals are mated, single hand-mating allowing minimal oral or oral-genital contact is advised.
7. Avoid potential risk of iatrogenic transmission. Do not share needles, tattooing equipment, or dehorning instruments without taking measures to eliminate virus and virus-infected cellular debris.

In herds which commingle with sheep, control programs should also include control of ovine progressive pneumonia virus (OPPV). The major route of OPPV infection in sheep is by close contact and transmission of virus by respiratory secretions over long periods of commingling of infected and susceptible sheep. As suggested by the name, chronic respiratory signs, dyspnea, exercise intolerance, and weight loss are common signs. Hard udder/agalactia may result in hungry, low-growing lambs from affected ewes. Principles of testing are the same as for CAEV, and these antigens cross-react. Testing and segregation or testing and removal are the cornerstones of OPPV control.

Mycoplasma Infections in Goats

Mycoplasma mycoides spp *capri* (formerly *M. m.* spp *mycoides* (large colony type) is a highly pathogenic mycoplasma that may cause mastitis, polyarthritis, pneumonia, meningitis, abortion, and occasionally sudden death. Most commonly, outbreaks present as polyarthritis in goat kids being fed raw goat's milk occurring concurrently with mastitis in adult milking does. Joint fluid from affected kids and/or milk from affected does can be cultured to confirm the diagnosis. Mortality in kids and does, as well as abortions, may also be reported by the owner. In herds with endemic infection, kid morbidity (polyarthritis/pneumonia) may be the predominant complaint while milking herd exposure through the purchase of an infected doe(s) will present most commonly as mastitis and abortions, followed by polyarthritis in kids. Asymptomatic clinically infected does will often shed the organism after a stress such as movement to a new herd, or even to a new pen on the dairy. Herd outbreaks may have a prolonged history with infection of the milking does occurring in one lactation and infection of kids occurring during the subsequent lactation. Antibiotic treatment of goats infected with mycoplasmosis is unrewarding, as recovered animals are usually intermittent shedders throughout their life.

Mycoplasma putrefaciens - This mycoplasma is generally implicated in outbreaks of a highly contagious mastitis characterized by a fibrino-purulent odorous exudate and sudden agalactia. Does may shed the organism for 3 to 10 days prior to the onset of clinical signs. Increased California Mastitis Test (CMT) scores or somatic cell counts (SCC) without clinical mastitis may be the first sign of infection. Clinical illness (fever and anorexia) associated with *M. putrefaciens* is highly variable. In a few outbreaks does with polyarthritis and kids with polyarthritis and pneumonia have been reported. In these instances the goats had concurrent nutritional deficiencies, disease or other management problems. Control of *M. putrefaciens* is based on identification of the organism and instituting strict milking sanitation procedures as described below for *M. mycoides* spp *capri*. Isolation of infected does is ideal, but practically speaking the outbreak is often well advanced and exposure rate high by the time the diagnosis is confirmed. At the least, young fresh does should be milked first and not mixed with older milkers. Kids on the dairy should not be fed raw goat colostrum or milk. Complete cleaning and sanitation of the milking system is essential or there will be viable organisms present at the next milking. Routine culturing of bulk-tank milk will help to prevent explosive uncontrollable outbreaks of mastitis.

Recommendations for Mycoplasma Control in Goat Herds

Pasteurized kid-rearing programs used as the basis for CAEV control programs are the cornerstone of Mycoplasma prevention programs. Several management practices should be considered for preventing mycoplasma transmission. In dairy herds, control of *Mycoplasma* spp in the adult goat requires repeated culture of milking does to detect infected does, which are then culled to slaughter. Less desirable, but necessary in high-prevalence herds, is the formation of an infected milking string(s) which is (are) housed separately and milked last. Extreme attention to milking sanitation is required to prevent doe-to-doe transmission. Does should be spray pre-washed or pre-dipped and individual paper towels used to dry the udder. Post-milking teat dipping (and assuring thorough application of teat dip) is essential and milkers must wear gloves and disinfect them between does. Teat cups should be back flushed or dipped in disinfectant between does and proper clean-up of the pipeline and milking equipment must be done after every milking. Does with elevated CMT, elevated SCC or clinical mastitis should be removed at once from the milking string and a milk sample frozen for culture. Initially for 2 to 6 weeks, bimonthly milk cultures are taken until new cases are not detected for 2 culture periods, then monthly samples for 2 to 3 months followed by string pooled samples for 6 months. Dairies should have weekly samples frozen from the tank for routine monitoring, and increases in SCC or CMT on the dairy should be aggressively pursued. Infected groups of kids should be culled to slaughter and only kids fed heat-treated colostrum, cow colostrum (note Johne's disease risk) and pasteurized goat, cow milk or milk replacer should be retained for replacement.

In meat goat herds, or other herds where kids are raised on their dams, the cornerstone of mycoplasma control is to 1) prevent the introduction of mycoplasma-infected animals into the herd by culture of milk and potentially ear swabs; 2) segregate breeding does by level of risk; and 3) adopt an artificial kid-rearing program to generate an uninfected pool of replacement females. These kids should be maintained segregated from "exposed" herd through a period of total herd replacement.

Control of mycoplasma in a herd requires a long-term commitment by the producer, as there may be undetected animals in the herd for months, if not years, after the adoption of a control program. Accidental nursing of kids may result in undetected milk-borne mycoplasma transmission. Milking practices may facilitate efficient intramammary transmission among lactating does. Biosecretions from aborted does and does with pneumonia should be considered potentially high risk. Because special media are required to culture mycoplasma organisms, infections may go undetected until a clinical crisis occurs. Practitioners should be sure to request mycoplasma cultures on all suspected necropsies and milk samples. Recovery from clinical disease is often followed by conversion to an asymptomatic carrier status with intermittent milk shedding of mycoplasma most often when animals are stressed. Long-term surveillance by milk culturing is necessary to detect infected does. The ear mites *Psoroptes cuniculi* and *Raillietia capri* may carry multiple species of mycoplasma and may represent a natural reservoir for pathogenic *Mycoplasma* spp. Ear cultures and control of ear mites may be warranted as an added control point in some eradication and prevention programs.

Caseous Lymphadenitis (Contagious Abscesses, CL)

Abscesses caused by *Corynebacterium pseudotuberculosis* result from lifelong infection with recurring abscesses of the regional lymph nodes. Draining of external abscesses results in transmission to other sheep and goats by direct contact, and indirectly by contamination of feeders, equipment and the environment. The organism remains viable for months in the environment and remains a source of long-term transmission by ingestion or inoculation to susceptible goats. Abscessation of internal lymph nodes may result in chronic weight loss and premature culling. Definitive diagnosis is by culture of pus from an abscess, necropsy. Serologic testing with the synergistic hemolysin inhibition (SHI) test will detect exposure to the organism and can be used to exclude exposed and potentially infected animals from herd introduction and as an aid to segregate or remove goats as part of a herd cleanup program. Serologic testing and segregation or culling may be used in herds with low incidence of CL, while premises hygiene, vaccination, and isolation of affected animals will be main strategies used to control CL in heavily infected herds.

Intensive management of clinical abscesses with early detection of ripening abscesses, isolation of the goat until the abscess is healed, lancing abscesses in an isolated environment, and preventing cross-contamination of premises and potential fomites are keys to successful management. Fly control will reduce dissemination of the bacterium among goats. Premises disinfection and herd segregation on the basis of infection status will reduce the incidence of new infections in the herd. Vaccination with commercially available sheep CL vaccine, conditional-license goat vaccines or with autogenous bacterins can be used to reduce the number of goats with abscesses and the number of abscesses per animal, thereby reducing the overall herd exposure in endemic herds.

Johne's Disease Management

Johne's disease risk management plans similar to those for cattle are appropriate for goat herds. Pasteurized kid-rearing programs designed for CAEV and mycoplasma control reduce exposure to *Mycobacterium avium* sub spp *paratuberculosis* (MAP) in the maternity-pen environment. Segregation of preweaning and juvenile goats in the commercial herd help to prevent exposure to MAP until kids enter the adult herd. In utero transmission and identification of "safe" colostrum sources should be considered, even where heat treatment of colostrum is used. If outside sources of milk and colostrum are used for kid rearing, including cow milk/colostrum, potential risk of infection should be considered. In dairy herds adopting pasteurized rearing programs alone, a reduction in clinical Johne's cases is often observed. Johne's risk assessment in the herd should include cattle, sheep, and other Johne's-susceptible species as part of an overall farm plan. Availability of affordable testing by serology and/or fecal culture for MAP infection varies from state-to-state. Specific testing strategies are less well defined for goats than for cattle. Similarly, vaccination strategies may be possible in infected herds under the cooperation of regulatory veterinarians.

Scrapie

Although scrapie is assumed to be less prevalent in goats than in sheep herds in the US, surveillance for and prevention of introduction of scrapie into goat herds is critical. Herd replacement sources should provide official identification and traceback information, and buyers should research for potential risk associated with commingling of does with lambing ewes. Veterinarians should consider scrapie as a differential diagnosis for any progressive weight loss or neurologic disease, and the herd health plan should include necropsy of all animals with chronic wasting and/or progressive neurologic signs. All sheep and goats, including companion or backyard animals, must comply with mandatory National Scrapie Eradication Program identification and records requirements.

Ongoing Disease Surveillance

Successful control for chronic diseases relies on continued disease surveillance. Management decisions regarding disease control grouping, treatment, production, and culling should be based on accurate lifelong records on each animal. Unique individual animal identification (tattoos, ear tags, neck tags, etc.) is needed to before permanent accurate records can be maintained to monitor infectious disease status. Dam disease status and colostrum source are needed as part of the permanent doe record.

Planned routine necropsy of selective herd culls as well as deaths will allow monitoring for all major contributors of disease in the herd, not just primary cause of death. Additional testing for tissue copper and selenium, parasites, and other items of interest can help identify concurrent disease problems which may confound the efforts of a specific disease control program. Johne's, scrapie, CL, CAEV, and mycoplasma can all be monitored by necropsy even though the cause of death may be unrelated to these diseases.

Serologic testing for CL or CAEV may be part of an ongoing control program for the herd or used to screen new herd introductions. Ongoing serologic surveillance for CAEV will allow effective segregation of infected animals to reduce adult transmission of disease. Milk cultures for mycoplasma and other contagious pathogens allow for ongoing reduction or elimination strategies.

Culling

Planning for removal of sheep or goats from herds of all sizes and uses is critical to monitoring for disease, reducing disease risk, and maintaining optimal use of resources. Small or "backyard" herds often develop issues with overcrowding or conversely lose the opportunity to make desired matings because of excessive animals (and overcrowding) in the herd that are unmarketable, of advancing age or otherwise beyond serving their initial purpose. In herds where normal culling channels are not appropriate, the veterinarian can assist owners by planning castration and adoption (healthy animals) or, if indicated, euthanasia of animals (diseased) to maintain a herd of sound, healthy animals that will allow the owner to meet the goals of their breeding program. Euthanized animals submitted for necropsy can play a vital role in mineral nutrition and infectious disease surveillance in the herd.

Conclusion

Goat herds are highly diverse, and individualized approaches are needed to design herd health programs that meet the needs of the herd owners–taking advantages of their strengths and interests while taking their constraints into consideration. Thoughtful consideration of which health issues are limiting herd productivity and helping the owner prioritize disease management strategies will help to build a sustainable approach to health management which will afford the producer continued long-term progress in disease control and production improvement.

A clinician's guide to what kills adult sheep and goats, as diagnosed by necropsy

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Abstract

Techniques for efficient field necropsy of adult sheep and goat are described. Common conditions that kill adults, as well as older lambs and kids, are then presented, with emphasis on diagnosis by gross examination of the body. Additional laboratory tests that may be warranted and management considerations for the remainder of the herd are included to guide the practitioner in addressing the problems that have been identified. Conditions leading to the death of adult sheep include the following: anemia from haemonchosis, copper toxicosis, malnutrition, heavy strongyle burden, dental disease, paratuberculosis, liver flukes, caseous lymphadenitis, bacterial pneumonia, retroviral pneumonia, endocarditis, grain overload, enterotoxemia, intestinal accidents, toxic mastitis, dystocia with uterine rupture or retained fetuses, pregnancy toxemia, hypocalcemia, urolithiasis, polioencephalomalcia, listeriosis, and other neurologic diseases.

Résumé

Les techniques de champ efficace de l'autopsie de moutons et de chèvres adultes sont décrites. Conditions communes qui tuent les adultes, ainsi que les agneaux plus âgés et les enfants, sont ensuite présentés, en mettant l'accent sur le diagnostic par l'examen de l'organisme. D'autres tests de laboratoire qui peuvent être justifiées et considérations de gestion pour le reste du troupeau sont inclus à guider le praticien dans le traitement des problèmes qui ont été identifiés. Conditions conduisant à la mort de la brebis adulte sont les suivantes : anémie de haemonchosis, le cuivre de la toxicose, malnutrition, lourd fardeau strongyle, les maladies dentaires, paratuberculose, des douves du foie, lymphadénite caséeuse, pneumonie bactérienne, la pneumonie, l'antirétroviral, endocardite, surcharge grain entérotoxémie, accidents intestinaux, la mammite toxique, une dystocie avec rupture utérine ou conservé des fœtus, la grossesse la toxémie, hypocalcémie, urolitiasis, polioencephalomalcia, la listériose, et d'autres maladies neurologiques.

Introduction

Much useful information about the individual dead animal and health issues in the herd can be gleaned by performing a necropsy. However, autolysis occurs rapidly and makes interpretation of lesions difficult. The herd veterinarian should ideally examine the body within two (for gastrointestinal diseases) to four hours after death if timely submission to a diagnostic laboratory is not possible. This paper describes a protocol for performing a necropsy and typical lesions produced by common fatal conditions of small ruminants. Documentation with digital pictures of the necropsy findings will assist the veterinarian if consultation with a pathologist is required to make or confirm a diagnosis.

Necropsy Techniques

An excellent necropsy manual by King et al. describes a systematic but efficient technique for field necropsies.[12] Additionally, several journal articles[6,7] and many textbooks of small ruminant diseases[1,8,9,13,14,16] include information on performing a necropsy or list and illustrate numerous causes of sudden death. Videos of various necropsy techniques are also available on the internet. These include a sheep necropsy video targeting the feedlot lamb[10] and a complete cattle necropsy, also applicable for sheep and goats.[3] A protocol for collecting digital images of small ruminant necropsies is also available on line.[15] Images of suspected lesions can be shared with a veterinary pathologist or compared with an online databank of veterinary pathology lesions.[11]

Necropsies are best performed in a warm, well-lit area, on a surface that can be easily sterilized or a plastic sheet that can be disposed of afterwards. Disposable gloves are imperative.

Supplies such as sample containers, formalin, culture swabs, markers, and paper or a recorder for taking notes should be organized before the first body is opened. A digital camera to record lesions is desirable, especially if an assistant with clean hands is available to take the pictures. A sharp necropsy knife is ideal but a box cutter or even several size 22 scalpel blades can substitute for the knife, while a hatchet or tree branch pruner is used to cut ribs and a saw or hatchet can be used to open the skull.

Start by weighing the animal if possible and recording all ear tags and tattoos, sex, age, estimated weight, body condition score, and any grossly visible abnormalities as well as the history and clinical signs reported. Examine the conjunctiva for pallor or icterus and the eye for evidence of keratitis from exposure or infectious pinkeye. Examine the feet, palpate all joints and external lymph nodes, and examine the perineum for evidence of diarrhea, discharges, or prolapses. Check the incisor teeth to verify reported age.

The sheep or goat should be placed on its left side and the two right limbs should be reflected out of the way after cutting the skin and muscles over the axilla and inguinal area and the ligament to the head of the femur. The two openings in the skin are then connected and the remaining skin is peeled back off the side of the animal. The skin incision is also extended up the neck to the intermandibular space. Slice into both sides of the udder or scrotum and examine the contents. Next the abdominal cavity is entered through an incision just caudal to the costal arch. The abdominal wall is reflected and the diaphragm is severed along its attachment to the ribs. A branch pruner or (if the animal is immature) a necropsy knife is then used to cut each rib at the costochondral junction. The ribs can then be reflected dorsally by breaking them near the backbone or cutting them with the branch pruner. The thoracic and abdominal cavities are now exposed and individual organs can be examined. Open the pericardial sac and examine its contents before removing the pluck (tongue, larynx, trachea, esophagus, lungs and heart) from the body. The lungs are examined visually and by palpation. Open the esophagus and trachea longitudinally and follow larger airways into the parenchyma of the lung. The four chambers of the heart and the valves are examined, following the flow of blood.(King necropsy) Return to the abdomen, noting presence of fluid and omental fat. Both kidneys should be located and incised and the bladder and its contents examined. Locate and examine the uterus in females. The liver should also be incised, looking for abscesses and flukes. The gastrointestinal tract is opened last, with special attention being paid to rumen contents (feed material present, consistency, pH, presence of poisonous plants) and abomasal contents (*Haemonchus* worms, foreign bodies). Consider retaining rumen contents, a fecal sample for parasitology, liver and potentially kidney for trace mineral analysis, and samples from all lesions identified, for laboratory testing.

Several joints should be examined routinely during the necropsy. These include the right hip and shoulder and both stifle joints. Finally, the head can be disarticulated from the spine using a ventral approach to examine the atlanto-occipital joint and the skin is removed from the top of the skull in preparation for brain removal. Using a saw or hatchet and starting at the dorsolateral aspects of the foramen magnum, the skull cap is reflected to permit inspection of the brain. If the animal has horns, remove them flush with the skull before attempting to access the brain. Wear a face shield and double gloves in regions where rabies is endemic.

After the necropsy has been completed, the carcass should be disposed of safely and properly, according to state laws. Composting, deep burial and landfill disposal are typical choices to prevent contact with people, pets, other livestock, or scavengers. Equipment and surfaces should be sanitized and contaminated gloves disposed of properly, with due consideration for the risks of zoonotic diseases.

Haemonchosis

Blood loss to abomasal parasites should always be suspected in the animal with pale mucosa and muscles. In some cases thousands of 'barberpole' worms can be visualized in the abomasum to confirm this diagnosis or a quantitative fecal reveals thousands of strongyle eggs per gram. In other animals the worms are no longer present because of recent anthelmintic administration or because the animal was so anemic that the *Haemonchus* deserted the abomasum. The practitioner should check the FAMACHA score[2] of other animals on the farm, take additional fecal samples for quantitative analysis, and review previous treatments, nutrition and pasture management. A comprehensive parasite control program can then be developed, following the guidelines of the American Consortium for Small Ruminant Parasite Control.[2]

Copper Toxicosis

The body fat of sheep and goats should be white, including in the axilla where staining from gastrointestinal organs is not a concern. If icterus is identified, the most likely cause is copper toxicosis, although other liver diseases or even leptospirosis occasionally cause icterus. The liver may be discolored, the kidney may be a dark gray color, and any urine retained in the bladder may be coffee or port wine colored. Confirmation will require copper analysis of the liver, and of the kidney as well if liver copper concentrations are not elevated. Before leaving the farm obtain a thorough feeding history including tags from salts and concentrates fed and any possible access to poultry, swine, cattle, or horse feeds. Also determine if copper oxide wire particles have been administered for parasite control. Although sheep are more susceptible to copper toxicosis, goats can also be poisoned. The occasional animal dies of copper-induce liver failure without displaying icterus. Routine histology of animals with undiagnosed death and trace mineral testing, including copper, for flock monitoring purposes will aid in reaching a diagnosis.

The Emaciated Animal

Malnutrition in small ruminants can be the result of many diseases and management problems. Common deficiencies leading to a low body condition score include protein, energy, cobalt or copper. Abundant omental fat may remain in an emaciated animal, so always palpate the loin area before commencing the necropsy to determine the body condition score. With severe cachexia the fat in the marrow of the long bones and in the coronary groove is replaced by gelatinous tissue referred to as serous atrophy of fat.

A simple agroceriosis may occur with the feeding of low quality, late cut hay or inadequate quantities of feedstuffs.

Crowding at the feed bunk or commingling of animals of different sizes or horn status may cause starvation of some while others are in adequate body condition. This is especially true with goats, where the social order is strong.

Parasitism, especially with gastrointestinal strongyles, is a common cause of emaciation and hypoproteinemia, visible antemortem as edema below the chin, termed 'bottle jaw'. When *Haemonchus* is not the primary parasite involved, egg counts in the fecal sample harvested from the rectum or cecum may be modest. Poor quality feed and anthelmintic resistance will contribute to parasitism as a cause of death. In particular, adequate dietary selenium, vitamin E, and copper are needed for a proper immune response to parasites.

Dental disease will lead to emaciation of individual older animals, such as pets, but even young adults can suffer from periodontal disease and be unable to properly chew roughage. A 'gummer' who has lost incisors will have reduced ability to graze but can function well on harvested feeds. Often a palpable thickening of a mandible heralds a tooth root abscess. The cheeks should be slit at necropsy of any thin animal to permit a thorough examination of the molar teeth. Sharp points are normal, but missing or abscessed teeth will hinder mastication. When older animals are retained in a herd, owners should be instructed to evaluate body condition score frequently and provide pelleted roughages as needed.

Enzootic nasal tumor is a retroviral disease that can lead to emaciation as breathing becomes progressively more difficult for the sheep (or less commonly goat) with tumor occluding its nasal passages. There may be a history of stertor, nasal discharge, or bulging of an eye. Use the saw to open the nasal passages transversely if this condition is suspected.

Paratuberculosis or Johne's disease is common in sheep and goats over one year of age but less commonly diagnosed, as diarrhea occurs in only a small proportion of animals that die of the condition. Animals that die of paratuberculosis lack body fat and are usually moderately anemic. They frequently have an increased parasite load. Intermandibular edema and tricavitary effusion secondary to hypoproteinemia may be evident at necropsy. Sometimes dilated lymphatics are visible on the serosa of the ileum, and mesenteric lymph nodes may be mineralized. Testing will be required to confirm the diagnosis, with histology of the ileum, ileocecal junction, and adjacent mesenteric node ideal. An acid fast stained smear of the intestinal mucosa in one of these locations and a fecal culture or PCR for antigen are other options.

Liver flukes, especially *Fasciola hepatica* and *Fascioloides magna*, will lead to emaciation, anemia, and hypoproteinemia. Presence of the flukes and their black migratory tracts makes the initial diagnosis simple, but flukes may need to be submitted to a parasitologist to confirm the species identity, which is needed to determine drug dosages to use. This is because *Fascioloides* does not reach the bile duct (or establish patency), so higher doses of flukicides are needed. Wet areas of the pasture should be fenced off and an eight way clostridial vaccine administered to protect against sudden death from black disease, caused by the toxins of *Clostridium novyi*.

Abscesses from **caseous lymphadenitis** (*Corynebacterium pseudotuberculosis*) may be found in the lungs, liver or kidney and adjacent lymph nodes and in these locations they commonly cause emaciation. Involvement of just peripheral lymph nodes, by contrast, has little effect on the overall health of the infected sheep or goat. The pus in the abscess may be creamy or layered, and culture will be required to confirm the diagnosis so that a herd control program of culling and/or vaccination can be instituted. Differentials include *Trueperella pyogenes*, tuberculosis, meliodosis in other parts of the world, and necrotic neoplastic lesions. Lymphosarcoma is not rare in goats and can infiltrate lymph nodes or internal organs;[4] an impression smear of a lesion will allow differentiation from caseous lymphadenitis. Older animals that have reached 'tumor age' can have any imaginable neoplasm as a cause of emaciation.

Pneumonia

Bacterial pneumonia is a frequent cause of acute death or chronic debilitation in sheep and goats. *Mannheimia haemolytica* is more commonly involved than *Pasteurella multocida*. In some herds *Mycoplasma* species are an important contributing cause, but special culture techniques will be required to confirm their presence. These pneumonias are located in the cranioventral portions of the lung, especially on the right side where a separate bronchus serves the right apical lobe. The affected lung is firm on palpation and commonly has fibrin on the surface. Culture will confirm the organisms involved but as there are no appropriate vaccines against the strains affecting small ruminants, management will need to focus on improving nutrition and ventilation and, possibly, drenching techniques if the pneumonia began as an inhalation.

Retroviral pneumonias (ovine progressive pneumonia in sheep, caprine arthritis-encephalitis in goats) sometimes cause locally extensive areas of palpably firm pneumonia in animals over one year of age. These animals are usually thin and have a history of dyspnea and exercise intolerance. A bacterial pneumonia may also be present, as such an infection will upregulate/activate the virus. Confirmation will require histology. Positive serology is proof of a herd problem but does not prove that the virus was involved in the death of the animal.

Endocarditis may lead to embolic pneumonia or to congestion of the liver and fluid accumulation in the abdomen due to heart failure. Lesions will be evident on the heart valves. White muscle disease of the heart can also present as acute heart failure, often with well delineated white streaks in the myocardium of the pulmonary outflow tract or other parts of the heart or skeletal muscles.[12] The diet should be evaluated for selenium and vitamin E adequacy.

Gastrointestinal causes of acute death

Enterotoxemia due to the toxins of *Clostridium perfringens* type D can cause rapid death in inadequately vaccinated small ruminants allowed access to rapidly digested carbohydrates in the form of concentrates or lush pasture. A gross diagnosis is difficult to make, and even a laboratory diagnosis is usually only tentative, as the organism is a normal inhabitant of the intestinal tract and proliferates rapidly after death, producing toxin. Presence of fluid and a fibrin clot in the pericardial sac is strongly suggestive of enterotoxemia, in the absence of evidence of a bacterial pneumonia. The classic 'pulpy kidney' lesion of enterotoxemia is very subjective and varies with the postmortem interval. The practitioner can confidently advise a vaccination program (two doses of commercial vaccine 3 or 4 weeks apart, boosters prelambing, boosters at 6 month intervals if heavy feeding) in unprotected animals, even if enterotoxemia is not proven to be the cause of death of the animal necropsied. Just be aware that there is a 21 day meat withdrawal for the vaccine.

Animals that are properly vaccinated against enterotoxemia can still die of grain overload, or **lactic acidosis**. Sudden access to excessive quantities of grain (especially if finely ground, as in chicken or hog feed) will lead to the production of increased quantities of propionic and butyric acid in the rumen. High concentrate diets require less cud chewing, and less saliva reaches the rumen to buffer it. As the pH of the rumen contents drops, normal flora that digest roughages die off and are replaced by acid loving streptococci and lactobacilli and lactic acid is produced. The pH then drops further until it goes below 5.5 and the normal buffering system is overwhelmed. At necropsy these animals will have sunken eyes and a splashy rumen. Rumen contents often contain a lot of visible grain and are milky. In addition to checking pH, a gram stain of the rumen fluid can be done to demonstrate a preponderance of Gram positive cocci and bacilli. Control measures for the rest of the herd may include better locks on the grain storage area, smaller concentrate meals, less finely ground grain products, and providing high quality grass hay before concentrates are fed. Some farms believe that offering sodium bicarbonate free choice also helps to prevent acidosis.

Sheep and goats are occasionally afflicted by **intestinal accidents** such as intussusception, mesenteric torsion, or obstruction of the rumen, abomasum, or spiral colon with an ingested foreign body. These problems can be identified by opening the ruminoreticulum and abomasum and by carefully following the full length of the intestinal tract.

Acute liver fluke disease occurs in regions where *Fasciola hepatic* infests small ruminants. The grazing animal that has consumed large numbers of metacercaria may develop a rapidly fatal fibrinous peritonitis accompanied by liver necrosis and hemorrhage. Migrating flukes can also cause sudden death by creating anaerobic conditions in the liver that allow *Clostridium novyi* spores to germinate, leading to production of a fatal toxin in unvaccinated animals.

Poisonous plants occasionally lead to sudden death, and a careful history may indicate that the animal had access to yew (*Taxus*), members of the rhododendron family, or cyanide containing plants, amongst others. The rumen contents should be searched for plant fragments and the environment for toxic plants.

Mastitis

Toxic mastitis in small ruminant is most commonly caused by infection with *Staphylococcus aureus*, but *Mannheimia* from the pharynx of nursing lambs or kids or other organisms spread by the milking machine are also possible. The affected udder half will be swollen and firm at necropsy, often with gangrene of the skin of the udder and ventral abdomen or the presence of abscesses or discolored fluid in the udder parenchyma. A postmortem culture will confirm the causative bacterium, but the teat ends should be examined for evidence of trauma or infection with the contagious ecthyma (sore mouth) virus that might have predisposed to the entry of pathogens into the udder. The milking system and procedures should also be evaluated in dairy herds.

Uterine Causes of Acute Death

Dystocia can occur if a fetus is malpresented - breech, head back, transverse - or if multiple fetuses enter the birth canal at the same time. The head back position is a frequent cause of death either because of unskilled manipulation by an owner or because the dam can strain hard enough against the fetus to rupture its own uterus. Fetuses with arthrogryposis also lead to dystocia, and Cache Valley virus is one potential cause of these malformations. Fetal fluids need to be tested for antibodies to confirm the diagnosis. A retained fetus, for whatever reason, decomposes rapidly, killing the dam via toxemia.

Other less frequent causes of death related to parturition include the metabolic disease discussed below, uterine torsion, and rupture of the middle uterine artery.

Metabolic Diseases

Pregnancy toxemia should be suspected if a late pregnant or periparturient female dies with an almost empty rumen and a fatty liver. Generally two or more fetuses will have been present. Any urine present in the bladder may be tested for ketones, but it is more reliable to obtain ocular fluid (aqueous humor) to test for betahydroxybutyrate. The results are still valid 24 hours after death, and values greater than 2.5 mmol/L support a diagnosis of pregnancy toxemia.[5] Unless the individual animal had a specific problem that resulted in decreased feed consumption in late pregnancy, such as lameness or poor teeth, the diet of the remainder of the herd needs to be evaluated and corrected.

Hypocalcemia can rapidly kill females that are late pregnant or lactating heavily. There will probably be few or no gross lesions, but a suspicion based on the history or a lack of other diagnosis can be confirmed by testing the aqueous humor for calcium, with a value less than 1.0 mmol/L being diagnostic.[5]

Tetany (**hypomagnesemia**) is another metabolic disease that does not result in postmortem lesions but can be diagnosed with aqueous humor. In this instance, a magnesium concentration less than 0.33 mmol/L is diagnostic.[5] The history may include recent transport or access to lush pastures high in potassium.

Urinary Tract Diseases

Urolithiasis is a very, very common cause of death of intact and castrated male sheep and goats of all ages. Necropsy may reveal evidence of obstruction, including a distended, hemorrhagic bladder, hydronephrosis, urine in the abdomen from rupture of leakage through the distended bladder wall, or subcutaneous urine where the urethra has ruptured. The urethral process and the sigmoid flexure should be examined closely, as these are common sites for obstruction. Stones or precipitate collected at necropsy can be sent for free analysis at the University of Minnesota Urolith Center.[18] Gold colored round BB shaped stones do not need to be sent for analysis as they are invariably calcium carbonate. Dietary management for the remainder of males in the herd will include interventions such as increasing the consumption of water by adding salt to the hay or grain, avoiding the feeding of excessive minerals, and very commonly by not feeding grain to pet wethers or allowing them access to chicken feed.

Pyelonephritis, often the result of an ascending infection from the urachus or bladder, results in swollen kidneys with pus accumulated at the hilus. Toxins such as oxalates (from various poisonous plants or ethylene glycol) and copper can cause nephrosis in small ruminants. A whitish line of precipitate near the corticomedullary junction may be visible in the case of oxalates, and the kidneys are often dark when affected with hemoglobinuric nephrosis from copper toxicosis. Additionally, lambs that die of hyperthermia have been reported to have swollen, pale, moist kidneys in which severe tubular necrosis is visible histologically.[17]

Neurologic Diseases

The two most common neurologic causes of acute death in small ruminants are polioencephalomalacia (cerebrocortical necrosis) and listeriosis. Scrapie can also cause either neurologic signs or emaciation in sheep or goats. These conditions will be difficult or impossible to diagnose without laboratory support, but gross examination of the brain (with due care to avoid potential exposure to rabies) may reveal trauma or presence of a brain abscess.

A history of blindness or convulsions or of an indigestion accompanied by diarrhea is compatible with **polioencephalomalacia**. There may be coning of the cerebellum because intracranial pressure has forced the caudal part of the cerebellum against the foramen magnum. The cerebral cortex may appear yellowish and these areas often fluoresce under an ultraviolet light. The diet should be investigated to identify deficiencies of fiber or excesses of sulfur, possible predisposing causes of polioencephalomalacia.

Listeriosis is best diagnosed by histology and immunohistochemistry of the brain stem, but historical clues of facial nerve paralysis or circling or gross evidence of exposure keratitis would be suggestive. Sometimes the rumen contents are rather watery because the animal was inappetent in the days preceding death, but some sheep and goats die within 12 hours of first being noted ill. Exposure keratitis may suggest a facial nerve paralysis, a common sign of listeriosis.

Conclusions

A gross field necropsy will often lead to the proper diagnosis of cause of death in small ruminants. The practitioner who performs the necropsy on the farm is ideally placed to observe the remainder of the herd for signs of illness and the environment and diet for possible deficiencies. Additional animals can be tested if indicated. Then, with the aid of confirmatory tests from a diagnostic laboratory and consultation with pathologists, diagnosticians and standard textbooks, a plan can be formulated to control the problem in the remainder of the herd.

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A clinician's guide to what kills lambs and kids, as diagnosed by necropsy

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Abstract

It is common for neonatal losses to exceed 10% of lambs and kids delivered. A simple on-farm necropsy technique for examining these animals and determining the probable cause of death is described. Important categories for mortality include abortion, stillbirth, dystocia, hypothermia and starvation, umbilical infections, diarrheal diseases, septicemia, pneumonia, and abomasal bloat. Once the relative importance of these conditions in the herd has been determined, appropriate samples can be sent to a diagnostic laboratory and suggestions for management changes can be tailored to address the problems of the greatest economic importance.

Key words: small ruminants, necropsy

Résumé

Il est courant pour les pertes à dépasser 10 % des agneaux et chevreaux livrés. Une simple technique d'autopsie à la ferme pour l'examen de ces animaux et de déterminer la cause probable du décès est décrit. Catégories importantes de mortalité : l'avortement, de mortinatalité, la dystocie, l'hypothermie et la famine, maladies diarrhéiques, infections ombilicales, septicémie, pneumonie, et ballonnement caillette. Une fois que l'importance relative de ces conditions dans le troupeau a été déterminé, des échantillons appropriés peuvent être envoyés à un laboratoire de diagnostic et des suggestions pour les changements de direction peuvent être adaptées pour répondre aux problèmes de la plus grande importance économique.

Introduction

It is common for 15 to 25% or more of the lambs or kids on larger farms to die within the first week after birth.[7,8] All too often, no use is made of the losses and corrective measures are not taken. The goal relative to perinatal mortality should be for less than 10% to be stillborn or die early; less then 5% is achievable in intensively managed herds.[2]

Necropsy Technique for Neonates

In preparation for investigation of a neonatal mortality problem, farm personnel should be instructed to label each untagged dead animal with dam identification, date, and circumstances of its death, using plastic tape on the leg or bag. The veterinarian should plan to examine many lambs or kids briefly, to get an overview of what is causing the majority of losses.

Necropsies are best performed in a warm, well lit area, on a surface that can be easily sterilized or a plastic sheet that can be disposed of afterwards. Disposable gloves are imperative; zoonotic diseases commonly cause abortion, stillbirth, and weak neonates. Pregnant women are advised to not necropsy lambs and kids because of the risk of zoonoses.

Supplies such as sample containers, formalin, culture swabs, markers, and paper or a recorder for taking notes should be organized before the first body is opened. A digital camera to record lesions is desirable, especially if an assistant with clean hands is available to take the pictures. A sharp necropsy knife is ideal but a 22 scalpel blade can substitute for the knife, while sheep foot trimmers are used to cut ribs and open the skull.

Start by weighing the lamb or kid if possible and recording ear tag or other identification. sex, estimated weight, and any grossly visible abnormalities, including yellow staining of the fiber. Palpate the limbs for fractures or swollen joints from septic arthritis. If there is evidence of predation, do not assume that the animal was healthy or even alive when an eye was pecked out or the body partially consumed. Complete a necropsy on the remainder of the body, searching for underlying problems that would have made the lamb or kid an easy target.

Although others may suggest a different orientation of the body,[4,6,7] the author prefers to place the neonate on its left side as this approach provides an excellent view of lung, liver, and abomasal lesions. The two right limbs should be reflected out of the way after cutting the skin over the axilla and inguinal area. The two openings in the skin are then connected and the skin flaps are peeled off the side of the carcass dorsally and ventrally. The skin is also incised up the neck to expose the thyroid gland and the mandibular symphysis is cut to allow easy access to the mouth and tongue.

Next the abdominal cavity is entered through an incision just caudal to the costal arch. The abdominal wall is reflected and the diaphragm is severed along its attachment to the ribs. Small ruminant foot trimmers, a necropsy knife, or a scalpel blade is then used to cut each rib at the costochondral junction. The rib cage of a neonate can then be reflected dorsally by breaking the ribs near the backbone or cutting them with the foot trimmers. The thoracic and abdominal cavities are now exposed and very little further manipulation is needed to diagnose most losses that are not induced by abortion diseases. The umbilical vein to the liver and the umbilical arteries on each side of the bladder should be identified. Hemorrhage in the arteries is an indication that the lamb was alive when it separated from its placenta. Both kidneys should be located, incised and inspected. A mild hydronephrosis may reflect failure of the dam to stimulate urination. The liver should also be sliced, looking for abscesses. The lungs are examined visually and by palpation. Removing the pluck from the tongue back or after transecting the esophagus and trachea at the thoracic inlet will expose the left side of the lungs and rib cage; note fractures. The pericardial sac should be opened, and the four chambers of the heart should be examined if there is any indication of heart failure. The nature and quantity of abomasal contents should be assessed, as well as intestinal contents, including retained meconium. The perineum should be inspected for evidence of diarrhea. Finally, the head can be disarticulated from the spine and the skin removed from the top of the skull. Using foot trimmers and starting at the dorsolateral aspects of the foramen magnum, the skull cap is reflected to permit inspection of the brain. Check for hydrocephalus or hydranencephaly, which can result from in utero bluetongue virus or Cache Valley virus infection.

After necropsies have been completed, the carcasses should be disposed of safely and properly, according to state laws. Composting, deep burial and landfill disposal are typical choices to prevent contact with people, pets, other livestock, or scavengers. Equipment and surfaces should be sanitized and contaminated gloves disposed of properly, with due consideration for the risks of zoonotic diseases.

Abortion Diseases

If more than 2% of ewes abort an infectious cause should be suspected.[3] Goats are prone to stress-induced as well as infectious abortions. Dead lambs delivered before lambing is due to start will likely be abortions, but once normal lambing is underway it may be difficult to determine if fetuses have been aborted or died of some other cause. If an abortion disease is suspected by the timing or magnitude of losses, laboratory support will be needed to make an etiologic diagnosis.[4] Refer to the sampling directions provided by the local diagnostic laboratory or send multiple fetuses with placenta and maternal blood directly to the lab. Typical requirements are lung, abomasal contents, and placenta fresh; placenta, lung, liver, brain, and heart in formalin, and serum from the dam. If abortion diseases are ruled out by laboratory testing, noninfectious causes of abortion (nutritional deficiencies, pregnancy toxemia, improper handling, other stress, liver flukes, etc.) should be investigated.[2]

In some instances, a gross examination will provide helpful clues to the cause of abortion. Chlamydiosis is usually accompanied by regional or generalized placentitis that involves both cotyledons and intercotyledonary areas. Smears can be made of placenta, umbilicus, or mouth and submitted for acid fast stains or fluorescent antibody tests. *Coxiella burnetii* (Q fever) also can cause a generalized placentitis with acid fast organisms, or may be shed in the placenta at normal lambing. Campylobacteriosis is associated with autolyzed fetuses but a normal placenta. Less than 15% of *Campylobacter* lambs show necrotic liver lesions. Cultures of abomasal contents are useful for diagnosis. Campylobacteriosis is much less common in goats than sheep. Toxoplasmosis may cause fetal mummification or an autolyzed fetus accompanied by an apparently healthy lamb or kid. A mummy will be a uniform brown color with sunken eyes and elongated nose. The intercotyledonary placenta is normal with toxoplasmosis but white, necrotic and mineralized foci may be demonstrated by pressing a cotyledon with a glass slide or holding it under running water. Remember the zoonotic potential for these diseases and keep pregnant women away from the fetuses and placentas. Pregnant ewes should be removed to a clean pen or pasture, leaving the aborted ewes isolated in the contaminated area.[4] Treatment with oxytetracycline might be started while waiting for laboratory results in the case of an abortion storm.

Autolytic Changes

If the lamb or kid dies in utero and is retained for several hours, it is common to find reddish, gelatinous fluid accumulated under the skin. This is an autolytic change and should not be interpreted as hemorrhage. Likewise, gas bubbles in the lung may result from postmortem growth of bacteria that ascended through the cervix and were swallowed or inhaled into the lungs of the fetus in utero.

Stillbirth

The stillborn lamb or kid will have lungs that are not inflated and do not float in water. Occasionally a small fraction of the lung is inflated, indicating that the lamb was not quite dead at delivery. Placenta may cover the nose because it was passed when the dead lamb was expelled or because failure of the amnion to break caused suffocation. Stillborn lambs will have a normal amount of brown fat around the kidney and heart. Sometimes autolysis or the weight of other bodies previously piled on top makes it hard to evaluate the lungs visually. If the navel has been dipped, or the lamb or kid has been ear tagged, or there is milk in the abomasum, or the soles of the feet are dirty instead of being unstained and rounded, the animal was not stillborn!

Iodine deficiency is a possible cause of abortion or stillbirth. The normal weight of the combined thyroids is less than 0.04% of the body weight.[1] Enlarged thyroids (goiter) usually result from failure to supply dietary iodine, but feeding of cruciferous plants during gestation and inherited thyroid diseases are other possible causes.

Copper deficiency can lead to abortion or weak neonates and a deficiency of selenium or vitamin E will predispose to slow parturition, poor colostrum intake and poor immune response to infectious agents. When losses are otherwise poorly explained, or for routine monitoring, trace mineral analysis of neonatal livers is valuable.

Dystocia

A lamb that becomes anoxic during the birth process will defecate in utero and become stained yellow from the meconium. The staining is less evident on kids, as hair does not seem to hold the feces as readily as wool does. A swollen head and tongue are good indications that the fetus was stuck part way out long enough for pressure from vulva or vagina to restrict venous return from the head. A lamb or kid that is compressed during a dystocia or is stepped on afterwards may experience a rupture of the liver capsule. Blood leaks into the abdomen, causing hemoperitoneum and killing the lamb, presumably from hypovolemia. Ribs may be fractured during a dystocia or if the lamb is stepped on after delivery. Closer supervision, training of personnel to recognize dystocia, and selection for lambing ease are possible responses to excess dystocias. Cache Valley lambs with arthrogryposis will cause dystocia; the ewe or doe will be immune the next year. Losses can be limited by not breeding during the mosquito vector season.

Hypothermia and Starvation

The lamb or kid that dies of hypothermia before starvation has time to develop is difficult to diagnose with certainty or to differentiate from infectious postnatal losses. Some brown fat remains, seen on the kidney and pericardium. Usually the abomasum is empty except for a little amniotic fluid or scant colostrum. Some meconium may remain in the intestines. The lamb may have a wet coat because the ewe did not lick it dry. Subcutaneous hemorrhages over the limbs, visible if the skin is removed, are evidence of hypothermia before death.[5] Small lambs or kids, triplets or quadruplets, and neonates from sick or inexperienced dams are at greatest risk. A history of cold or rainy weather heightens the suspicion of hypothermia.

The brown fat is rapidly metabolized for nonshivering thermogenesis if the neonate does not get colostrum. Instead of almost completely hiding the kidney, it will be reduced to small remnants of red tissue. The abomasum and intestines are usually empty in the starved neonate, but may contain milk if the caretaker tube fed the animal shortly before it died. Early and adequate colostrum (an ounce per pound three times the first day or 180 to 210 ml/kg during the first 24 hours,[2] tube fed if the neonate is weak) and monitoring subsequent milk intake by evaluation of abdominal fill and behavior of the lamb or kid will prevent these conditions. As part of a flock problem investigation, total protein can be determined by refractometry on 10 to 20 lambs at one day of age, with plasma values greater than 6.5 g/dl indicating adequate colostrum absorption.[7] Less information is available on desirable total protein values in day old kids, but 5.4 g/dl in serum has been suggested as a cut-off.[8] Claiming pens may improve bonding and lamb coats and hovers decrease the risk of chilling. If the lamb or kid is both chilled and starved it will need intraperitoneal dextrose before warming and feeding.[2,5,7]

Pneumonia

Cranioventral bronchopneumonia from which *Mannheimia haemolytica* can be isolated is a common cause of death of lambs and kids. Inhalation pneumonia from improper bottle feeding or white muscle disease or a cleft palate will appear similar. The right cranial lobe is involved first and often most severely, as it has a separate bronchus off the trachea. In an acute, active pneumonia the involved lung lobes are firm and swollen. A fibrinous pleuritis may also be present. If the lung is not firm, no matter what color it is, there is no pneumonia. As the lesion resolves, previously pneumonic lung may be depressed relative to normally inflated portions.

Umbilical Infections

Abscesses may involve the remnant of the umbilical vein that goes to the liver, with exudate or a scab visible on the overlying skin. Large *Fusobacterium* abscesses in the liver should prompt you to check if the navel was properly dipped with iodine (7% tincture of iodine remains the gold standard) and lambing jugs are clean and dry. Smaller milliary abscesses in half of the liver might also have come from the umbilicus but spared part of the liver because of laminar blood flow.

Septicemia

Lambs that have been septicemic with *Listeria monocytogenes* due to infection crossing the placenta or passed through the milk frequently develop fever and diarrhea before dying. A classic granular multifocal necrosis of the liver may be visible grossly in some lambs, or may be detected only by histologic examination.

Failure of passive transfer can also lead to septicemia. The presence of fibrin strands in the thorax or abdomen is suggestive of such an infectious process. Septic arthritis in multiple lambs or kids should prompt a review of feeding of the dam (relative to colostrum production), management of lambs and kids in jugs, and colostrum delivery protocols.

Diarrheal Diseases

Numerous agents can cause diarrhea in the neonate but laboratory support will be required for diagnosis. Enterotoxigenic strains of *Escherichia coli* are rarely involved in diarrhea of lambs and kids unless conditions are unhygienic and crowded. However, a condition termed watery mouth (because of profuse salivation) does occur in twin and triplet lambs 24 to 36 hours old with *E. coli* colonization of the intestine; these lambs are often constipated.[7]

Cryptosporidiosis is a relatively common cause of herd outbreaks of diarrhea in young lambs and kids, often beginning at three to seven days of age. Oocysts can be demonstrated with an acid fast stain of fecal smears or by examination with a high dry lens after a sugar flotation. Stress improvements in sanitation, colostrum provision and milk intake to prevent cryptosporidiosis and supply supplemental oral electrolytes to prevent death by dehydration. Also remind farm workers that this parasite is zoonotic.

Abomasal Bloat

Artificially reared lambs and kids occasionally bloat and die rapidly at several weeks of age. The abomasum will be massive distended and sometimes the wall is emphysematous. Prevention may entail smaller meals, cold milk replacer, more attention to hygiene of the milk replacer and feeding equipment, or selection of a low lactose milk replacer.

Conclusions

When a herd problem with neonatal losses exists, gross necropsy of as many lambs or kids as possible will permit categorization as to probable cause of death. The number dying of abortion, stillbirth, dystocia, hypothermia, starvation, pneumonia, umbilical infections, diarrhea and abomasal bloat can be tallied, with less sure estimates made for hypothermia and septicemia. The total losses and the number in each category should be compared with the number of lambs or kids delivered during the time period under investigation. This will allow the veterinarian and caretaker to prioritize problems to be addressed by laboratory testing, improved nutrition of the dam, colostrum management, umbilical care, hygiene and bedding in the claiming pens and similar interventions.

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Anti-parasitic use of sericea lespedeza and copper oxide wire particles in small ruminants

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Abstract

Management of gastrointestinal parasitism in sheep and goats is a major challenge in many parts of the world, particularly in the current age of multi-drug anthelmintic resistance. *Haemonchus contortus* has gained substantial notoriety for its pathogenicity, as well as for its ability to develop resistance to all currently available classes of anthelmintics. As conventional pharmaceuticals continue to lose efficacy, alternative anti-parasitic strategies, such as feeding sericea lespedeza, a plant rich in condensed tannins, and administration of copper oxide wire particles, are gaining popularity in the United States.

Key words: sericea, lespedeza, anthelmintic, parasites, small ruminants

Résumé

La gestion du parasitisme gastro-intestinal chez le mouton et la chèvre représente un grand défi dans plusieurs parties du monde surtout dans le contexte de l'émergence de multi-résistance aux anthelminthiques. Le nématode *Haemonchus contortus* est bien reconnu pour sa pathogénicité et son aptitude à développer une résistance contre toutes les classes d'anthelminthiques présentement disponibles. Alors que les produits pharmaceutiques continuent de perdre de leur efficacité, des stratégies alternatives de contrôle des parasites, comme l'utilisation de particules de métal d'oxyde cuprique et l'inclusion de la lespedeza de Chine (une plante riche en tannins condensés) dans l'alimentation, gagnent en popularité aux États-Unis.

Introduction

Gastrointestinal nematode parasites are the most important health threat to small ruminants in many parts of the world.[15] Many gastrointestinal nematodes infect sheep and goats, but *Haemonchus contortus* is by far the most pathogenic and prevalent nematode in parts of the United States where there is sufficient warmth and moisture to support its life cycle. *Haemonchus contortus* causes blood loss during feeding activity in the abomasum. When infection intensity is high in vulnerable hosts, symptoms such as anemia, weakness, weight loss, and death can ensue. This disease state is referred to as haemonchosis. The 2 next most prevalent nematode parasites in small ruminants are *Trichostrongylus colubriformis* and *Teladorsagia circumcincta*; appetite reduction, loose feces, and weight loss occur in heavily parasitized hosts.[15]

Over the past 16 years, anthelmintic resistance has increased rapidly in both prevalence and magnitude, particularly in *H. contortus* populations. From 2000 to 2003, multi-drug resistant (benzimidazole, imidazothiazoles/tetrahydropyrimidine, and ivermectin[a]-resistant (but moxidectin[b]-sensitive) *H. contortus* were documented in goat herds in Virginia and Georgia.[22,25,32] In 2008, a study conducted on 48 small ruminants in the southeastern United States demonstrated that *H. contortus* was the most prevalent parasite on 44 of the 46 farms.[14] Resistance to all 3 classes of anthelmintics was present on 22 (48%) of the farms, and resistance to all 3 anthelmintic classes and moxidectin[b] was detected on 8 farms (17%).[14] Since that study was published, total anthelmintic resistance has been recognized with increasing frequency.[15] In response to the rapid evolution of anthelmintic resistance, renewed interest in alternative parasite control solutions has stimulated research efforts to characterize the efficacy and safety of condensed tannins, copper, nematophagous fungi, and *H. contortus* vaccines.

Condensed Tannins

Plants such as sulla, sainfoin, birdsfoot trefoil, big trefoil, chicory, and sericea lespedeza contain condensed tannins which have been shown to have antiparasitic benefit.[13] Tannins are plant polyphenols that are divided into 2 groups based on their structure: hydrolyzable and condensed tannins.[13] Hydrolyzable tannins are degraded in the ruminant digestive tract to absorbable, potentially toxic metabolites. In contrast, condensed tannin metabolites are poorly absorbed after degradation in the digestive tract. Condensed tannins remain in the ingesta bound to macromolecules such as protein and polysaccharides. Consumption of low to moderate concentrations of condensed tannins has nutritional benefit because the protein binding allows some dietary protein to bypass the rumen, and undergo digestion in the small intestines. However, consumption of high levels of condensed tannins can negatively impact rumen microbiota, and cause a decline in appetite.[13] Other benefits of condensed tannins in ruminant nutrition included decrease in bloat and reduction in methane gas formation.[26] Condensed tannins bind and disrupt the protein-rich parasitic cuticle in vitro and, presumably, in vivo.[13] Anti-parasitic benefits include reduction in nematode numbers, reduced worm fecundity, and decreased fecal egg output.[13]

Sericea lespedeza (SL) is a non-bloating perennial legume that is rich in condensed tannins.[26] It is especially well adapted to the southeastern United States. It grows well in a variety of soils, including otherwise infertile acidic soils. In addition, SL is also drought tolerant and insect resistant. For the past century, SL has mainly been used for soil stabilization, and as a livestock forage.[27] Many SL cultivars exist, but AU Grazer®[c] is the primary cultivar used in the United States for feeding livestock.[27] The anti-parasitic benefits of SL were only recently discovered. Min et al published one of the first reports that highlighted this anthelmintic effect.[21] Naturally parasitized goats on SL-rich pasture had had a 57% reduction in fecal egg count (FEC) compared to goats grazing grass pasture.[21] In a subsequent experiment, Angora does that grazed on SL pasture for 81 days had a 76% reduction in their total adult worm burden compared to controls on crabgrass/fescue pasture.[20] Adult *H. contortus* were reduced by 94%, *T. circumcincta* by 100%, and *Trich. colubriformis* populations by 45% in goats on SL pasture.[20] Min's research group later demonstrated that goats ingesting SL pasture not only had decreased FEC, but parasitic larval development was also impaired. In addition, goats grazing SL had higher packed cell volumes (PCV), and improved immunologic function, compared to goats on crabgrass/tall fescue pasture.[19] Lambs grazing SL pasture also had lower FEC than their counterparts on bermudagrass pasture.[5] Unlike goats, sheep appear to require an adjustment period to acclimate to the astringency of fresh SL.[5,26]

Further studies were conducted to evaluate whether the condensed tannins in SL would retain anti-parasitic benefits when fed as hay and as pellets. Shaik et al[23] trickle-infected 20 Boer bucks with *H. contortus* larvae to mimic natural infection, and fed the goats a diet that consisted of either 75% Bermuda grass hay (control group) or 75% SL hay, in confinement for 7 weeks.[23] The ration was balanced between groups for protein and calories with a supplemental feed that made up the remaining 25% of the diet. By the last 2 weeks of the trial, goats eating SL had an 88% decrease in FEC from pre-trial data.[23] The SL group maintained higher PCV than the control group, and ova collected from the SL group were less likely to develop into infective larvae. At slaughter, significantly fewer abomasal worms (*H. contortus* and *T. circumcincta*) and intestinal worms (*Trich. colubriformis*) were recovered from the SL group compared to the control group; the anthelmintic effect was highest against *H. contortus*.[23] Similarly, lambs fed SL hay had 67 to 98% lower FEC during the feeding trial, and the FEC remained significantly lower than controls on Bermuda grass hay throughout the feeding period.[18] The FEC increased quickly after SL feeding ceased, indicating that the reduction in FEC was in part stemming from reduced worm fecundity.[18] These studies demonstrated that SL maintains its anti-parasitic properties after being dried and made into hay, and that the hay was highly palatable to goats and sheep. A subsequent titration study in goats concluded that 75% of the diet needed to be comprised of SL hay to achieve the greatest benefit, but feeding it as 50% of the diet also reduced FEC compared to controls.[24]

Since pellets are more convenient to store and ship than hay, research was conducted determine if pelleting diminished the anti-parasitic effect of SL hay. Terrill et al compared the effect of SL hay and pellets in goats, using a bermudagrass hay control group.[28] The SL hay and pellets effectively lowered FEC compared to controls, and the effect was most pronounced in the goats receiving the SL pellets. Worm burdens, especially *H. contortus*, were significantly reduced in the SL groups compared to controls.[28] These studies showed that SL effectively reduced gastrointestinal nematodes when fed fresh, as hay or as a pelleted preparation.

Recent studies discovered that feeding sericea lespedeza also provides significant anti-coccidial benefit in kids and lambs. Lambs naturally infected with nematodes and coccidia that received SL pellets 30 days before and 21 days after weaning, had lower FEC, and shed up to 98% fewer *Eimeria* oocysts than controls on a conventional creep feed.[6] In addition, none of the lambs on the SL pelleted rations needed treatment for clinical coccidiosis, whereas 33% of controls had symptoms significant enough to warrant treatment.[6] Similarly, feeding SL leaf meal pellets to recently weaned goats significantly reduced both the FEC (66%) and fecal oocyst count (FOC) (91%).[17] In contrast to what was noted with FEC, the FOC did not increase when the SL feeding was discontinued, indicating a direct and permanent effect on the coccidian parasites.[6]

In summary, SL is a non-bloating legume that can provide substantial benefit for control of gastrointestinal nematodes, as well as *Eimeria* spp in small ruminants. For this reason, it has been referred to as "smart man's alfalfa (lucerne)".[27] For control of *H. contortus*, and to a lesser extent other gastrointestinal nematodes, SL can be fed at approximately 50% (or more) of the diet in any of its various forms (fresh forage, hay, pellets, silage) during periods of high risk. Once SL feeding is discontinued, however, small ruminants should be closely monitored for signs of parasitism from gastrointestinal nematodes. When using it for natural coccidian control, SL can be fed to youngsters as 50% or more of the diet, 2 weeks before weaning. The SL creep feed can be continued for up to 6 weeks after weaning, but not indefinitely, as micronutrient deficiencies have been noted in youngsters with long-term feeding.[27] This micronutrient issue has not been noted in adults on long-term SL supplementation.[27] Practical obstacles to feeding SL are availability and cost. Sericea lespedeza grows well in warm climates, and it can be grown separately, or mixed with other forages. Certified AU Grazer® sericea lespedeza seed and pellets are commercially available.[d] Demand for the products continues to increase, so manufacturer supplies are often limited.[e]

Copper Oxide Wire Particles

Copper oxide wire particles[c] (COWP) are currently marketed as 12.5 g boluses for cattle, and as 2 and 4 g boluses for small ruminants to treat copper deficiency. Over 15 years ago, researchers noted that COWP also had an anthelmintic effect.[1] Administration of 5 grams of COWP to 10-week-old lambs 5 days prior to inoculation with either *H. contortus*, *T. circumcincta*, and *Trich. colubriformis* reduced parasitic establishment by 96, 56, and 0%, respectively.[1] This study indicated that COWP has the most profound impact on *H. contortus*. After administration, copper oxide wire particles mix with ingesta in the forestomachs, and subsequently lodge in the abomasal mucosa. Copper dissolves from the particles in the acidic environment.[1] Dissolved copper interacts with susceptible parasites, causing expulsion or death. If abomasal pH is raised to 3 to 4 by *Teladorsagia circumcincta* infection, dissolution of copper from COWP is significantly decreased.[2] Ionic copper released from COWP is absorbed in the small intestine. Copper concentration peaks at day 4 in the proximal duodenum, and after 10 days it steadily declines.[2]

In 2000, research on dairy goats demonstrated that COWP (2 and 4 g) reduced experimentally established *H. contortus* infections by 75%, and lowered fecal egg counts up to 95%.[11] *Teladodorsagia circumcincta* and *Trich. colubriformis* burdens were only reduced by 28% and 15%, respectively, at necropsy.[11] Copper oxide wire particle treatment was not very effective at preventing establishment of new *H. contortus* infections, however.[11] Similarly, COWP treatment (either 2.5 or 5 g) significantly reduced established *H. contortus* infections in yearling sheep, but did not effectively limit establishment of experimental new infections over the 8-week study period.[16] In a subsequent experiment on 4-month-old Zulu goat kids, neither a 2 or 4 g COWP treatment prevented establishment of new *H. contortus* infections.[31] These findings indicate that COWP treatment is most effective against established *H. contortus* infections, and has minimal prophylactic benefit. Anthelmintic benefit of COWP only persists for 28 days.[30]

Administration of copper from any source, including COWP, increases hepatic copper concentration. Depending on individual, nutritional, and environmental factors, copper supplementation can potentially lead to copper toxicity in small ruminants, especially sheep.[29] Hepatic copper stored safely in lysosomes is slowly released into bile, and excreted in feces. If the liver becomes overloaded with copper, any stressor can lead to release of free copper from lysosomal storage. Unbound copper wreaks oxidative damage on the liver and other tissues, and causes hemolysis in in circulation.[29] Sheep are more prone to copper toxicity than goats because they are less efficient at eliminating stored hepatic copper.[29] In order to reduce the risk of copper toxicity, several research efforts focused on identifying the lowest COWP dose that would provide anthelmintic benefit in sheep and goats. In 2004, Burke et al administered 0, 2, 4, or 6 g COWP to 6-month-old lambs, 28 days after administration of *H. contortus* third stage larvae.[4] All doses of COWP resulted in much lower FEC, higher PCV, and a significant reduction in abomasal worms at necropsy compared to untreated controls.[4] Liver copper concentrations 28 days after COWP administration were 62.2, 135.7, 161.1, and 208.4 ppm (wet matter basis) in the 0, 2, 4, and 6 g groups, respectively.[4] Although none of lambs showed signs of copper toxicity in this study, the hepatic copper was twice as high as controls at 28 days, and above the normal hepatic copper reference levels. A subsequent study in weaned lambs showed that even lower doses (0.5 and 1 g COWP) had anti-parasitic benefit.[3] Further, these lower doses were safely administered 3 times at 6-week intervals to lambs within the same grazing season.[3] In goat kids, 0.5 and 1 g COWP improved FEC and PCV, compared to untreated controls.[10] The 0.5 g dose was considered the optimal dose for goat kids.[10]

A COWP dose titration trial was performed in mature Polypay ewes with natural parasite infections (70% *H. contortus*) to determine the lowest effective dose.[8] The ewes received either 0, 0.5, 1, or 2 g doses of COWP 60 days after lambing.[8] Seven days after administration, ewes treated with 1 or 2 g COWP had lower FEC than ewes treated with either 0 or 0.5 g COWP. Although PCV declined in all groups, ewes that received either the 1 or 2 g COWP bolus were less anemic than the sheep in the control and 0.5 g dose groups. Hepatic copper concentrations were not measured; aspartate aminotransferase activity did not differ among groups. The 0.5 g COWP dose had little anti-parasitic effect in the ewes. The 1 and 2 g COWP doses were deemed effective, but the 2 g dose gave slightly better results.[8] Unfortunately, extensive dose titration studies have not been performed in mature goats. Interestingly, Chartier et al were 1 of the few researchers to take body size into account when dosing COWP. In that study, mature Saanen goats weighing 141 to 167 lb (64 to 76 kg) received 4 g COWP, and goats weighing 92 to 101 lb (42 to 46 kg) received 2 g COWP; both doses achieved anthelmintic benefit.[11]

Copper oxide wire particles are typically administered within a gelatin capsule, using a balling gun. Since this method of administration involves individual handling, a simpler delivery method would provide a practical advantage. Burke et al demonstrated that administration of 2 g COWP in feed was as effective at reducing FEC in goats as 2 g COWP administered in a gelatin capsule.[9] The researcher advised that treatment be given on an individual basis rather than free choice to a group of animals to avoid inadvertent over- or under-dosing. This more convenient route of administration could be particularly advantageous to handlers of exotic hoof stock that are susceptible to *H. contortus*. Copper oxide wire particle treatment of oryx, roan antelope, blackbuck, and blesbok reduced FEC by over 90% for up to 28 days.[23]

In summary, COWP treatment effectively reduces established *H. contortus* infections in sheep and goats, based on decrease of FEC of up to 97%. However, it does not have much activity against other abomasal or intestinal parasites. Benefit appears to persist only about 28 days, and treatment does not effectively limit re-establishment of new infections. Treatment with COWP appears to have greater anti-parasitic benefit in lambs and kids than in mature sheep and goats, for reasons that are unclear.[10] Even though copper is slowly and incompletely released from COWP, studies demonstrated that treatment elevates hepatic copper concentration.[1,2,4,11,30,31] Although clinical copper toxicity was not induced in test subjects by COWP administration in any of the published studies, use of COWP in client-owned animals should be undertaken carefully. Assessment of copper and other minerals in hepatic tissue submitted from healthy animals, or from animals that die suddenly on farms, is recommended to determine if COWP benefits outweigh potential risks. The lowest effective dose of COWP should be used, and repeated dosing within the same grazing season discouraged if the micronutrient status of the herd or flock is unclear. Research supports the use of 0.5 to 1 g COWP in lambs and kids for anthelmintic effect.[3,8,10] In adult sheep, doses of 1 to 2 g COWP appear sufficient.[8] Doses of 2 to 4 g COWP are indicated for use in goats.[11] The lower end of the dosage range can be used for smaller breeds, and for animals where risks for copper toxicity are unknown. Treatment efficacy can be assessed using a fecal egg count reduction test. Researchers currently recommend selective (rather than whole herd or flock) use of COWP for anthelmintic purposes.[10] Since some worms survive exposure, it is possible that resistance to COWP treatment (as has been seen with conventional anthelmintic treatment) could develop.[10] Use of COWP can be combined with an anthelmintic to make treatment more broad-spectrum when infections are mixed.[18] The FAffa MAlan CHArt (FAMACHA) System can be used to detect small ruminants with clinically significant *H. contortus* burdens based on their degree of anemia.[7]

Conclusions

Alternative anti-parasitic strategies, such as use of sericea lespedeza and copper oxide wire particles, are promising additions to parasite control strategies on small ruminant farms. In particular, organic producers welcome non-pharmaceutical approaches to worm control. Sericea lespedeza's nutritional and parasite control advantages have few downsides other than product availability. Production of SL is an emerging agricultural opportunity, as demand for seeds, pellets and hay often exceeds supply, and demand is likely to continue to increase in the United States. In contrast, COWP are easily obtained through commercial channels. Although COWP products[c] are marketed as a treatment for copper deficiency, clear benefit has been demonstrated against established H. contortus infections. Producers require education in order to safely implement COWP into their integrated parasite management strategies to avoid copper toxicity. Since the smallest Copasure® bolus[f] on the market is 2 g, capsule content will have to be divided up in order to use lower doses, which is inconvenient for producers. Selective use of COWP at the lowest effective dose, and periodic assessment of micronutrient levels in hepatic tissues from healthy animals that are harvested for meat are several strategies that can be used to mitigate this risk.

Endnotes

[a]Ivomec®, Merial Ltd., Duluth, GA
[b]Cydectin®, Boehringer Ingelheim Vetmedica, Inc., St. Joseph, MO
[c]AU Grazer®, Auburn, AL
[d]Sims Brothers, Union Springs, AL
[e]Sims Brothers, personal communication
[f]Copasure®, Henry Schein Animal Health, Dublin, OH

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Anti-parasitic benefit of nematophagous fungi and *Haemonchus contortus* vaccine in small ruminants

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Abstract

As anthelmintic resistance continues to escalate, the need for alternative parasite control methods in small ruminant has increased. Copper oxide wire particles and sericea lespedeza are commercially available in the United States. Several other novel control methods, such as feeding nematophagous fungal chlamydospores, and vaccination against *Haemonchus contortus*, hold great promise for control of gastrointestinal nematode infections in small ruminants. The *Haemonchus contortus* vaccine is licensed for use in sheep in Australia, but is not yet available in the United States. Experiments conducted around the world have demonstrated the excellent nematode controlling advantages of feeding *Duddingtonia flagrans* chlamydospores to grazing livestock. A commercially available product is expected to be available in the near future.

Key words: small ruminant, parasites, nematophagous fungi, haemonchus

Résumé

Comme antihelmíntico la résistance continue de s'aggraver, la nécessité de trouver d'autres méthodes de contrôle des parasites en petits ruminants a augmenté. Les particules d'oxyde de cuivre et fil lespedeza Sericea sont disponibles dans le commerce aux États-Unis. Plusieurs autres méthodes de contrôle des nouveaux, tels que l'alimentation des chlamydospores, champignons nématophages et vaccination contre Haemonchus contortus, très prometteuses pour le contrôle des nématodes gastro-intestinaux chez les petits ruminants. L'Haemonchus contortus vaccin est autorisé pour utilisation chez les moutons en Australie, mais n'est pas encore disponible dans les États-Unis. Des expériences menées dans le monde ont démontré l'excellent contrôle de nématodes avantages alimentation Duddingtonia flagrans chlamydospores à du bétail au pâturage. Un produit commercialement disponible devrait être disponible dans un proche avenir.

Introduction

Producers in many parts of the world struggle to manage parasitic nematodes such as *Haemonchus contortus* infection in sheep and goats. As anthelmintic resistance continues to rise in prevalence as well as magnitude, this undertaking is becoming more daunting.[12] Nontoxic biological control strategies, such as feeding the nematode-trapping microfungus *Duddingtonia flagrans*, have been shown to effectively reduce pasture larval contamination and worm burdens in many grazing species.[13,15] Efforts directed at developing a viable way to deliver the beneficial chlamydospores in a practical manner could soon result in release of a commercial product.[17] Another alternative parasite control strategy that has received research attention is the use of immunizing agents to induce protection against *Haemonchus contortus*. Currently a *H. contortus* vaccine[a] licensed in Australia is showing excellent protection in sheep under field conditions.[26]

Nematophagus Fungi

Nematophagous fungi occur naturally in soil and fecal material in many parts of the world.[15] Over 200 species are recognized, all of which utilize nematodes as an energy source. Of the known nematode-trapping varieties, *D. flagrans* has emerged as the most successful candidate for use in parasite control because it is the only nematophagous fungus studied thus far that significantly reduces infective trichostrongyle larvae in feces of grazing animals such as horses, cattle, pigs, small ruminants, giraffe, antelope, and gerenuk.[13,15,30] Sufficient numbers (approximately 10%) of the thick-walled chlamydospores survive transit through the digestive tract.[21] Once deposited in feces, the chlamydospores germinate, and form predacious traps on their hyphae, varying from sticky knobs, branches, 3-dimensional nets, to constricting rings.[13,15,17] The traps ensnare parasitic larvae as they migrate in feces, then fungal hyphae penetrate the cuticle and digest the larvae. As a result of this fungal activity, less larvae escape the fecal material, resulting in lower pasture infectivity. Nematode-trapping efficacy of *D. flagrans* is determined by measuring larvae in feces or in the herbage around feces, and by assessing acquired parasitic burdens in tracer animals.[17] Trap formation occurs at temperatures from 50 to 95 °F (10 to 35 °C), and gradually declines over 2 to 3 weeks.[11]

Several projects provided insights into dosage, and optimal treatment intervals of fungal spores in small ruminant systems. Peña et al evaluated doses of 50,000, 100,000, 250,000, 500,000, and 1,000,000 spores/kilogram body weight (kg BW) in feed for 7 days in adult sheep predominantly infected with *H. contortus*.[22] Larvae were reduced by 97.5% in feces from all treatment groups by day 3. In a second trial on lambs with significant parasitic burdens, 500,000 spores/kg BW were fed daily for 7 days.[22] Fecal larvae were decreased in all fungus-fed groups by 95 to 96% on days 4 through 7. The effect was transient, however, as larval numbers rebounded once spore feeding ceased.[22] A dose titration experiment was conducted in Georgia on goats infected with *H. contortus*, *Trichostrongylus colubriformis*, and *Cooperia* spp.[29] Goats were fed spores each day at doses ranging from 500,000 to 50,000 spores/kg BW. By day 2 until day 8 (when treatment was stopped), larvae in feces were reduced by 93.6, 80.2, 84.1, and 60.8% in the 500,000, 250,000, 100,000, and 50,000 spores/kg BW treatment groups, respectively. Within 3 to 6 days, larval reduction was no longer apparent.[29] An experiment conducted in Malaysia on sheep and goats indicated that feeding spores at a daily dose rate of 250,000 spores/kg BW reduced fecal larval recovery by over 99%, compared to an 80 to 90% reduction when a lower dose was fed.[7] Waghorn et al also conducted a dose titration study using both goats and sheep.[31] The lambs and kids were experimentally infected with *H. contortus*, *Ostertagia* (*Teladorsagia*) *circumcincta* or *Trich. colubriformis.* Once the infections were patent, animals were dosed with 250,000 or 500,000 spores/kg BW for 2 consecutive days.[31] Average larval recovery was reduced by 78% in both sheep and goats; no species differences were noted. Interestingly, both the lower and higher dose were equally effective at reducing *H. contortus* and *Trich. colubriformis* larvae, but *O. circumcincta* reduction was higher when the 500,000 spores/kg BW dose was used.[31] In summary, doses of 250,000 to 500,000 spores/kg BW appeared to provide the most consistent and substantial broad spectrum benefit, but feeding 500,000 spores/kilogram BW improved efficacy against *O. circumcincta*. Terrill et al compared daily spore feeding with intermittent spore feeding, in goats. His work demonstrated that daily feeding was more effective at maintaining larval reduction than intermittent (every second or third day) feeding of *D. flagrans* spores.[29]

Fontenot et al studied the effect of feeding 500,000 spores/kg BW to grazing sheep that were naturally infected with *H. contortus.*[10] During the 18-week trial, infective larvae were reduced by 78.9 to 99.1% in feces, and gastrointestinal nematode burdens were reduced by 96.8% in tracer animals. No significant differences were noted in fecal egg count (FEC), packed cell volume (PCV), or animal weight between the naturally infected control and fungus-fed sheep.[10] These data illustrated that feeding *D. flagrans* provides benefit by reducing exposure to infective larvae, and not by reducing established parasitic infections. In an experiment where lambs were first cleared of their natural infections by anthelmintic treatment prior to going into a long-term feeding trial in Malaysia, fungal-fed lambs had lower FEC and better weight gain than untreated controls on pasture.[6] Similarly, animal benefit was noted in grazing sheep in Brazil that received anthelmintics prior to entering the trial.[25] Sheep that received *D. flagrans* spores in feed daily for a year had lower FEC and required fewer anthelmintic treatments than control sheep on pasture that received the same supplemental feed, but no spores.[25]

One of the biggest obstacles to practical application of nematophagous fungal spores in a field setting is finding a suitable delivery system. The ideal delivery method needs to be convenient, palatable, cost-effective, and have a reasonable shelf life. Most fungal spore trials were conducted by mixing spores in a feed supplement, or by using an oral dose syringe to deliver individual treatments. However, other delivery methods have been investigated, such as use of spore-impregnated feed or mineral blocks, and administration of spores in a slow-release device.[14] The main problems with feed or mineral blocks were 1) intake was too variable, and 2) the moisture content of the preparations limited shelf life to less than a week. Although sustained-release products were under investigation at one time, the Danish Company developing *D. flagrans* products stopped production about 10 years ago, so investigations ceased. Currently, daily feeding is the most feasible delivery option. Nutritional pellets containing *D. flagrans* chlamydospores were developed in Mexico for use in sheep.[9] Storage of the pellets under various conditions (refrigerated or room temperatures, within or outside of plastic bags) for 8 weeks did not reduce the larval trapping ability of the fungus.[9] Another promising recent development is that International Animal Health Products (IAHP) in Australia has established a *D. flagrans* strain that can provide larval control at a dose as low as 30,000 spores/kg BW, which will make the cost of commercialization reasonable.[17] International Animal Health Products is working with federal agencies in the United States to get the fungal feed additive registered for commercial use in zoos and small ruminant farms.[17]

***Haemonchus contortus* Vaccine**

Studies have been conducted in sheep to investigate the immunoprophylactic potential of *H. contortus*-derived hidden gut antigens (H-gal-GP and H11),[18,27,28] cysteine proteinases,[23,24] and excretory-secretory products.[1,8] All these experimental vaccines caused a reduction in FEC and *H. contortus* worms in vaccinated animals. However, use of "hidden" somatic antigens in vaccines offer an advantage over soluble and exposed antigens, because the hidden antigens are not recognized by the immune system during natural infection.[20] As a result, no natural selection pressure is imposed, so blood-feeding worms should remain highly susceptible to antibodies in the vaccinated host's blood.[20] However, repeated vaccination within the same grazing season is necessary to maintain the protective effects when using hidden gut antigens.[16] Despite the remarkable success achieved by the experimental hidden gut antigen vaccine, commercialization was only thought feasible if a recombinant version of the antigen proved to be effective. Mass production of enough native antigen to meet market demand did not appear to be feasible. Unfortunately, recombinant antigens failed to achieve the reductions in FEC and worm counts attained by native antigen vaccines.[5,19] However, it was recently discovered that a much lower dose than what was used in the initial field trials also induced a protective response in sheep. This finding renewed interest in commercial vaccine development. Material obtained from 1 infected sheep could provide sufficient worm antigen to make several thousand doses.[2] In addition, a worm-harvesting machine was developed that could efficiently harvest worms from slaughtered lambs without reducing the carcass value.

A field trial was conducted in western Australia from October 2010 to January 2011 using the vaccine produced by Moredun Research Institute scientists to determine an optimal dosage and injection regimen in crossbred lambs.[2] The lambs were dosed with *H. contortus* larvae twice a week during the first half of the trial, then at weekly intervals for the remainder of the trial. The mean FEC of control lambs was 7,000 eggs/gram, despite the fact 7 of the 20 controls received anthelmintic treatment for haemonchosis. Treated sheep received a 2, 5, 10, or 50 microgram vaccine dose. A second dose was given 3 weeks later, and a third dose was given either 6 or 8 weeks after the second dose. The sheep that received the "early" 3rd dose at 6 weeks, received a 4th dose 6 weeks after the 3rd dose. A significant reduction in FEC was seen in sheep that received the 3rd dose of vaccine at 6 weeks compared to 8 weeks after the 2nd dose. The researchers concluded that a dose as little as 5 micrograms of *H. contortus* native gut antigen vaccine was sufficient to provide a high level of protection during periods of intense larval challenge.[2] The mean fecal egg count (FEC) was reduced by over 85% in vaccinates compared to controls.[2] Further, vaccinated animals gained more weight, had higher PCV, and fewer animals required anthelmintic treatment compared to controls.[2] Study results indicate that 2 priming doses should be given 3 weeks apart, and that vaccine boosters should be given at 6-week intervals to maintain protective effect during periods of high parasitic challenge.[2] Use of the vaccine confers between 75 and 95% protection.[3]

As a result of the successful collaboration between Moredun Research Institute scientists in Scotland and the Department of Agriculture and Food in western Australia, Barbervax® was released in October 2014 for use in lambs.[3] It is now approved for use in sheep of all ages.[3] The first batch of Barbervax® consisted of 30,000 doses, which were sold in 1 week by word of mouth, in Australia. Barbervax® is marketed in 250 mL containers, and unopened containers have a refrigerated shelf life of 2 years.[3] Each 1 mL dose consists of 5 *ug* native antigen and 1 mL of saponin adjuvant. Current recommendations in previously unvaccinated suckling lambs is to give 2, 1-mL doses subcutaneously, 3 weeks apart, followed by a booster 6 weeks later at weaning time. Re-vaccination (1 mL, subcutaneously) every 6 weeks is recommended during periods of high *H. contortus* exposure. An anamnestic response occurs in vaccinated sheep, so priming doses are not necessary the following grazing season. Vaccinations are given at 6-week intervals during "*Haemonchus* season" (warm, wet times of the year) in subsequent years.[3] The manufacturer plans to increase Barbervax® vaccine production over the coming years, and anticipates marketing the vaccine in other countries in the future.[3] Applications have been made to South African regulatory agencies to allow use of the vaccine in that country, marketed under the name, Wirevax®.[4] Barbervax® vaccine is currently undergoing 33 field trials in various species around the world.

Conclusions

Novel parasite control strategies will benefit producers by reducing reliance on conventional anthelmintics. Biological control methods such as nematophagus fungi, and use of *H. contortus* vaccines will not replace the need for judicious use of anthelmintics, sensible pasture management practices that break the parasitic life cycle, and genetic selection for traits such as resistance and resilience. Instead, these tools will need to be used as part of an integrated parasite control plan. Nematophagous fungi should provide a safe, nontoxic way to reduce infective larvae on pasture, but spores will need to be administered to each animal on a daily basis for maximum benefit. The cost could limit use of the product to farms with small numbers of animals, and to use in valuable collections such as grazing zoo animals. Experiences in the field with Barbervax in Australia have shown the vaccine reduces morbidity, the need for rescue anthelmintic treatments, and pasture infectivity when the recommended protocol is followed. Although the vaccine is not expensive, some producers will be unwilling or unable to vaccinate their animals themselves, or hire a veterinarian to vaccinate their animals every 6 weeks. However, in parts of the United States, and elsewhere around the world where total anthelmintic failure is currently threatening the future of the small ruminant industry, these new parasite management tools will be a welcome addition.

Footnotes

[a]Barbervax**®**, Albany Laboratory of the Department of Agriculture and Food, Western Australia

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Beef Session

Moderators: *Tiffany Lee, Travis Hill, Pete Ostrum*

Economics of dry lotting beef cows

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Abstract

Three experiments evaluated cow and calf performance in alternative production systems; 1) early weaning on feed use; 2) a sensitivity analysis investigating profit potential of confinement cow management to changes in production prices and weaning rates, and; 3) investigate a winter management system incorporating winter cornstalk residue grazing on cow and calf performance in a summer-calving herd. In experiment 1, cows were limit fed and used two weaning time, early (EW**;** 91 days old) or conventionally-weaned (CW**;** 203 days old). Nursing pairs were fed an equivalent amount of DM that the early weaned calf plus the dams were fed. Cows limit-fed in confinement resulted in no negative impact on reproduction and early-weaning did not reduce feed energy requirements. In experiment 2, production parameters were obtained from the summer-calving cowherd in a dry lot year-round. Greater returns were projected as weaning percentage increased and a positive return for systems using distillers grains and crop residues. For experiment 3, two wintering systems on cow-calf performance in a summer-calving cowherd were evaluated. Grazing cow-calf pairs on cornstalks had lower ending weights of cows and gains of calves. Incorporating winter cornstalk grazing into the system were $137 more profitable compared to cows wintered in the drylot.

Key words: beef cows, dry-lotting, production, economics

Résumé

Trois expériences évaluées vache et veau performance dans de nouveaux systèmes de production ; 1. Sevrage précoce sur l'utilisation fourragère ; 2. Une analyse de sensibilité sur la rentabilité potentielle de l'accouchement de la gestion de la vache à l'évolution des prix de production et les taux de sevrage, et ; 3. Enquêter sur un système de gestion de l'hiver l'incorporation de résidus sur le pâturage d'hiver cornstalk veau vache et performance dans un troupeau d'élevage. Dans l'expérience 1, les vaches étaient nourries et limite utilisée deux fois, au début du sevrage (EW ; 91 jours) ou conventionnellement-sevré (CW ; 203 jours). Paires de soins infirmiers ont reçu un montant équivalent de DM que le veau sevré plus tôt les barrages ont été nourris. Limite de vaches-fed en confinement, a donné lieu à aucun impact négatif sur la reproduction et le début-sevrage n'a pas réduit les besoins en énergie. Dans l'expérience 2, les paramètres de production ont été obtenus à partir de l'été-mise bas bouvier dans un terrain sec toute l'année. Un plus grand rendement avait été prévu que le sevrage pourcentage a augmenté et un rendement positif pour les systèmes utilisant des drèches et des résidus de récolte. Pour l'expérience 3, deux systèmes d'hivernage dans les exploitations de la performance dans un été-mise bas bouvier ont été évalués. Paires de vaches-veaux de pâturage sur les tiges ont des poids de vaches et se terminant un gain de veaux. L'intégration de cornstalk hiver dans le système de pâturage ont été de 137 vaches plus rentable par rapport à l'hiver dans le solide.

Introduction

In beef cow-calf production systems, weaning most often occurs when calves reach a conventional age of 6 to 8 month, independent of season of birth.[25,35] Situations like reduced forage availability, decreased milk production by the dam, age of dam, or low cow BCS may arise in which early calf weaning is a viable management strategy. The benefits of sparing available forage,[4,19] enhancing reproduction[11] and reducing cow maintenance energy requirements[24] by early-weaning are well documented. Given that early-weaned calves are inherently efficient at converting feed to gain;[22] early-weaning is often regarded as a more feed efficient management practice by reducing the total feed energy required by a cow-calf pair.[27] Peterson et al[27] measured this efficiency by feeding different diets to pairs and weaned calves and calculated energy intakes with assumed feedstuff energy values. An alternative approach that would minimize variation in diet energy content would be to feed a common diet to all cows and calves at a similar DMI.

Achieving operation profitability requires a clear understanding and analysis of the various economic factors driving profitability. Feed cost has frequently been reported as the greatest variable cost associated with cow-calf production.[16,28] Thus, considerable effort has historically been placed on evaluating methods to reduce harvested or purchased forages and feeds, but the price of forages/feeds relative to other inputs (i.e., grazing costs, land values) varies significantly depending on year and location.

Reproduction, expressed as calves weaned per female exposed for breeding, influences profitability of the cow-calf system because the breeding female incurs all expenses of calf production. Furthermore, Griffin et al[10] noted that seasonal variability exists for cattle prices depending on size and class, potentially creating opportunities for production systems to match the timing of marketing to periods of stronger market prices. Stockton et al[33] documented that moving the calving season changes the timing of production and marketing which may prove economically beneficial.

Numerous economic factors have led to strengthened land values and stimulated the conversion of pasture and other grasslands to cropland.[41] When such changes in land use are combined with other events that decrease forage availability (i.e., drought), the price of grass and other forages increases and the cowherd must be maintained using alternative resources. However, increased corn and ethanol production in major crop production areas has resulted in a greater abundance of other feedstuffs, primarily residues and distillers grains. Alternative cow-calf production systems involving partial or total intensive management (confinement) of cows utilizing crop residues and distillers grains may be viable alternatives to conventional cow-calf systems. Alternative cow-calf production systems including dry lot and/or corn residue grazing need investigation. Therefore three objectives:

1) Evaluate the impact of calf age at weaning on: a) cow-calf performance and reproduction, and b) the feed utilization by the cow-calf pair of developing a weaned calf to 205 day of age when pair-fed a common diet;
2) Model profitability through the weaning phase of production of an intensively managed cow-calf production system located in the Midwest and evaluate the sensitivity of profitability to changes in annual cow feed costs, feeder cattle prices, replacement female purchase costs, and reproductive rate (number of calves weaned per cow exposed for breeding);
3) Investigate a winter management system incorporating winter cornstalk residue grazing on cow and calf performance in a summer-calving intensively managed cow-calf production system.

Material and Methods

For experiment 1, multiparous (4.6 ± 1 year of age), crossbred (Red Angus × Red Poll × Tarentaise × South Devon × Devon), lactating beef cows (total n = 156) with summer-born calves were utilized in a 2 year experiment conducted at two University of Nebraska-Lincoln Research locations, eastern and western in their feedlot facility. Annual precipitation at the east location is approximately 28 inches (72 mm) and for the west location 13 inches (34 cm). The trial was a randomized complete block design with a 2 × 2 factorial arrangement of treatments. Each year, cows within each location were blocked by pre-breeding BW (heavy, medium, and light), stratified by calf age, and assigned randomly within strata to one of two calf weaning treatments with three replications (pens) per treatment per year per location (total n = 24 pens; 5 to 7 pairs per pen). Location was considered part of the treatment design given the difference in climate, therefore treatment factors included: 1) calf age at weaning; early-weaned (EW) at an average age of 91 ± 18 d or conventional-weaned (CW) at an average age of 203 ± 16 d ; and 2) research location; eastern or western Nebraska. Cows remaining in the herd for two consecutive year were assigned to the same treatments each year. Cows removed upon completion of year 1 of the experiment were replaced with pregnant, multiparous (4 years of age) females of similar genetic composition and calving date from a commercial ranch in southwest Nebraska. Reasons for cow removal from the experiment between the completion of year 1 and the beginning of year 2 included: failure to become pregnant (n = 10), calf death during the calving season (n = 4), undesirable teat or udder conformation (n = 2), poor disposition (n = 1), and death (n = 1).

Prior to the beginning of the experiment each year, cows within locations were managed as a common group while calving in June and July in earthen feedlot pens without access to shade. Cows were vaccinated approximately one month prior to calving against bovine rotavirus, bovine coronavirus, *Escherichia coli*, and clostridium perfringens type C.[a] Post-calving, cows were limit-fed (9.1 kg DM/cow daily) high energy diets (Table 1) to meet nutrient requirements for early-lactation. Within 24 hour of parturition, calving date, calf birth weight, and sex were recorded, male progeny were band castrated, and all calves were vaccinated against clostridium chauvoei, septicum, novyi, sordellii, perfringens types C and D, and haemophilus somnus.[b] All calves received a second vaccination of Vision® 7 Somnus and were vaccinated against infectious bovine rhinotracheitis, bovine viral diarrhea (types 1 and 2), parainfluenza 3, and bovine respiratory syncytial virus[c] concurrent with the time of early-weaning. Upon trial initiation approximately October 6 each year, cow-calf pairs assigned to the EW treatment were separated at an average calf age of 91 days, after which cows and calves were managed and fed independently for the duration of the trial. Cows and calves assigned to the CW treatment remained together throughout the trial and these calves were weaned approximately January 28 at an average calf age of 203 days. Cow BCS (1 = emaciated; 9 = obese) was assessed visually by the same experienced technician across locations at trial initiation and completion.[39] Two-day consecutive cow and

Table 1. Ingredient and nutrient composition of diets fed to all cows and calves from October to January by location and year.[1]

	Yr 1		Yr 2	
Ingredient, %	**EAST[2]**	**WEST[3]**	**EAST[2]**	**WEST[3]**
Corn silage	--	--	40.0	40.0
MDGS[4]	56.5	--	36.5	--
WDGS[5]	--	58.0	--	38.0
Cornstalks	40.0	--	20.0	--
Wheat straw	--	40.0	--	20.0
Supplement[6]	3.5	2.0	3.5	2.0
Calculated composition				
DM, %	61.9	47.0	45.4	39.3
CP, %	19.0	18.8	16.1	15.3
TDN, %	80.0	80.0	78.0	78.4
NE_m, mcal/kg	1.94	1.94	1.87	1.90
NE_g, mcal/kg	1.52	1.52	1.46	1.48
NDF, %	47.3	54.9	47.1	51.1
ADF, %	25.2	21.6	25.3	22.0
Ca, %	0.75	0.77	0.58	0.81
P, %	0.50	0.49	0.44	0.41

[1]All values presented on a DM basis.
[2]EAST = Agricultural Research and Development Center.
[3]WEST = Panhandle Research and Extension Center.
[4]MDGS = modified wet distillers grains plus solubles.
[5]WDGS = wet distillers grains plus solubles.
[6]Supplements contained limestone, trace minerals, vitamins and formulated to provide no greater than 200 mg/cow daily monensin sodium (Elanco Animal Health, Greenfield, IN).

calf BW measurements[33] were recorded to determine cow weight change and calf gain from October to January. Prior to collecting weights at the beginning of the trial, all pairs were limit-fed (20 lb DM/pair daily or 9.09 kg DM/pair daily) a diet (Table 1) for 5 day to minimize variation in gastrointestinal tract fill.[40] At trial completion, both CW (following separation from their dams) and EW calves were limit-fed (approximately 10 lb•calf-1•day-1 or 4.5 kg•calf-1•day-1; DM basis) the same diet for 5 day before taking weights. All cows were limit-fed 15 lb DM (6.8 kg DM) (Table 1) for 5 day prior to weighing.

From October through January, EW cows within each location were limit-fed 15 lb (6.9 kg) DM/cow daily a diet designed to meet maintenance energy requirements for a nonlactating cow in mid-gestation (Table 1). Concurrently, the EW calves within each location were offered *ad libitum* access to the same diet as the cows. Feed refusals (if present) by the calves were collected, sampled, and DM determination was conducted using a 60°C forced air oven for 48 hour to calculate DMI. The CW cow-calf pairs that remained together were then limit-fed the equivalent amount of DM consumed in total by the EW cows and calves, accomplished by summing the intakes of the two groups. Intakes for the CW cow-calf pairs were adjusted once weekly based on the average consumption of the EW calves from the prior wk. No attempt was made to measure intake between the CW cow and her calf. Consequently, the total DMI between either the separated EW cows and calves or the CW pairs together was intended to be equal by design and increased throughout the experiment due to growth and diet consumption by the EW calf. The ratio of calf BW gain to the total feed energy intake by the cow-calf pair was subsequently calculated as a measurement of the feed efficiency of early weaning. All cattle were maintained in earthen feedlot pens and received their diets as a TMR once daily in concrete fence-line feed bunks with the following bunk space allotments: 2 ft (0.6 m) per EW cow, 1 ft (0.3 m) per EW calf, and 3 ft (0.9 m) per CW cow-calf pair.

Cows were exposed to Simmental × Angus bulls at a bull:cow ratio of 1:10 for 60 d beginning approximately September 26 each year, and breeding occurred in the pens. Cows were vaccinated approximately 1 month prior to the start of the breeding season against infectious bovine rhinotracheitis, bovine viral diarrhea (types 1 and 2), parainfluenza 3, bovine respiratory syncytial virus, and leptospirosis.[d] All bulls passed a breeding soundness examination administered by a licensed veterinarian. Pregnancy was diagnosed via transrectal ultrasonography 60 day after bull removal.

All data were analyzed as a randomized complete block design using PROC MIXED of SAS[e] with pen as the experimental unit. Model fixed effects included calf age at weaning, location, and the weaning × location interaction. Because the proportion of steer and heifer calves was unequal among treatments, calf sex was initially included as a covariate for all variables tested and was subsequently removed if not significant. Block and year were included in all analyses as random effects, and significance was declared at $P \leq 0.05$.

For experiment 2, production data were obtained from Experiment 1. For the Economic Analysis, a Microsoft® Excel[f] spreadsheet budget was constructed to model profitability of the intensively managed cow-calf system. Base production parameters and economic assumptions made are presented in Tables 2 and 3, respectively. An arbitrary number of cows (100) were used as an initial inventory of exposed females each year. Data from experiment 1 were used to establish length of the breeding season and calf age at weaning. Given the efficiency of feed use was not significantly different between nursing pairs and weaned cows and calves, the current analysis evaluated the system in which calves were weaned and marketed at 7 month of age.

Prices for all feeds were entered into the spreadsheet on an as-is basis. Base distillers grains price was calculated as 100% of the value of $3.50/bu corn on a DM basis. Base price for crop residue was $50 per ton ($50 per 907 kg) based on reported values as of September 2015.[37] Additional costs added to feeds included $5 per ton ($5 per 907 kg) for delivery, $15 per ton ($15 per 907 kg) for grinding of baled crop residue, and 5% shrink on all ingredients. Feed prices were converted to a 100% DM basis for calculation of ration costs. Interest was charged to both cows and bulls based on average lifetime value under the assumption that cattle required financing.[13] Base replacement female price was determined using the Midwest average price for bred cows as of September 2015.[6] This price was multiplied by the average female replacement rate to determine the capital cost of the replacement female. The average base cull cow market price was determined using the national 5-yr average price from 2010 to 2014[6] and corresponded to the first week of February as cull animals would be marketed at that time. This price was increased $0.20 per lb ($0.20 per 0.45 kg) to establish the average base cull bull market price. Base market BW for cull cows and bulls were assessed at 1,250 lb (567 kg) and 2,000 lb (907 kg), respectively. Marketing costs were charged at $30 per cow per year. Likewise, expenses for animal health and identification were assessed at $30 per cow per year. Yardage was charged at a common rate for cows and bulls to cover expenses for labor, equipment, utilities/fuel, and land/loans.[12]

Bulls were considered purchased by the cowherd owner at a one-time base cost and maintained in confinement year-round. The average productive life of bulls was considered to be 4 year and a 1:25 bull:cow ratio was assumed. Costs of bull ownership were calculated by dividing initial purchase cost by the number of cows serviced over the bull's lifetime. Feed amounts for bulls were considered to be equal to that for either lactating or nonlactating cows depending on if bulls were in service. Because the cow was considered the productive unit, all bull expenses for feed, yardage, and interest were prorated so each cow was charged 1/25th of the cost of the bull.

Base calf marketing BW was from experiment 1. The average base market price for 450 lb (204 kg) feeder steers was determined using the national 5-yr average price from 2010 to 2014[6] corresponding to the first week of February when calves would be sold. A discount of $0.10 per lb ($0.10 per 0.45 kg) was applied to derive the average base price for heifers. Total revenues from the sale of weaned calves were calculated using the percentage calf crop weaned relative to the number of exposed females, weaning BW, and corresponding prices for steers and heifers assuming each sex comprised 50% of the resulting calf crop. A base value of 85% was assessed for calf crop weaned based on cows exposed for breeding. Total annual costs per cow per year were determined as the sum of feed, interest, and yardage for cows and bulls, bull ownership costs, capital costs of the replacement female, animal health/identification, and marketing less credits for cull animals and manure. Credits for cull animals were calculated by multiplying the value of the cull animal by replacement rate adjusted for death loss. Cows

Table 2. Base annual production inputs for intensively managed system.

Item	Value	Unit
Total mature cow inventory exposed for breeding	100	cows
Length of breeding season	60	d
Average calf age at weaning	210	d
Average productive bull lifetime	4	year
Cows serviced over bull's lifetime	100	cows/bull
Average cull cow market BW	1,250 (567)	lb (kg)
Average cull bull market BW	2,000 (907)	lb (kg)
Calf crop weaned based on cows exposed	85	%
Average calf weaning BW	450 (204)	lb (kg)
Average female replacement rate	15	%
Cow DMI, nonlactating period[1]	15 (6.8)	lb (kg)/d
Cow DMI, lactating period[1]	23 (10.4)	lb (kg)/d
Bull DMI, breeding period[2]	23 (10.4)	lb (kg)/d
Bull DMI, nonbreeding period	15 (6.8)	lb (kg)/d

[1]Based on feeding a 60:40 distillers grains:crop residue diet (DM basis).

[2]Assuming equal DMI to that of cows during the breeding season.

were credited $50.00 per cow per year from the fertilizer value of manure produced, which is similar to that reported by Anderson et al.[2] Total annual costs per cow per year were multiplied by the number of cows exposed to calculate total costs for the system. Total system costs were subtracted from total revenues to determine net system profit or loss, which was then divided by the number of cows exposed to calculate profit or loss on a per cow per year basis.

System profitability was first modeled using initial base input prices and then under 4 different price and production analyses. In each analysis, two price or production parameters were changed at a time, while remaining parameters were held constant at initial base values. Therefore, projected profitability was influenced solely by the change in the parameters selected. The first analysis evaluated the effect of varying both the cost of replacement females ($1,600 to $3,000 per cow) and the percentage of calves weaned per cow exposed (75 to 95%) on profitability. In the second analysis, both calf marketing price $1.76 to $3.16 per lb ($1.76 to $3.16 per 0.45 kg) and weaning rate (75 to 95%) were varied. The price of distillers grains in relation to different corn price levels (85, 100, or 115% of $2.00 to $5.00 per bu corn) and weaning rate (75 to 95%) were altered in the third analysis. The final analysis evaluated the influence of both distillers grains (85, 100, or 115% of $2.00 to $5.00 per bu corn) and feeder calf prices $1.76 to $3.16 per lb ($1.76 to $3.16 per 0.45 kg) on profitability.

Experiment 3 was conducted at the two locations described in experiment 1 and using the same breed composition of as described in experiment 1 (n= 47 in the east location and n= 29 at west location) lactating beef cows with summer-born calves were utilized in the study. Within each location, cow-calf pairs were blocked by cow BW, stratified by calf age, and assigned randomly to one of two treatments: 1) dry lot feeding (DL) or, 2) cornstalk grazing (CS). Prior to trial initiation, cows were grouped in a single drylot pen within location during the summer calving season (mean calving date: July 9). A distillers and corn residue based diet was limit-fed to cow-calf pairs during this time. Trial initiation corresponded to the beginning of cornstalk grazing within each location (east = Nov 11 and west = Dec 4). Cow-calf pairs assigned to the CS treatment were transported to irrigated cornstalk fields, while cow-calf pairs assigned to DL treatment remained in drylot pens. Drylot pairs within location were limit-fed a common diet (Table 4) formulated to maintain a lactating cow in early gestation. Dry matter offered increased monthly throughout the study to account for the increasing intake of the growing calves.

Stocking rate for cow-calf pairs grazing cornstalks was calculated using estimated residue intakes of the cow and calf assuming 8 lb (3.6 kg) of husk and leaf residue (DM) were available per bushel of corn yield.

A dried distillers grain based pellet (Table 5) was supplemented in bunks (space: 2 linear feet per pair or 0.61

Table 3. Base production input and marketing prices.

Item	Value	Unit
Average bull purchase price	6,000	$/bull
Cattle interest rate	3.5	%
Average cull cow market price	0.74	$/0.45 kg[3]
Average cull bull market price	0.94	$/0.45 kg[3]
Manure value credit	50	$/cow/yr
Animal health and identification expenses	30	$/cow/yr
Marketing expenses	30	$/cow/yr
Cow yardage	0.35	$/cow/d
Bull yardage	0.35	$/bull/d
Average steer calf market price	1.76	$/0.45 kg[3]
Average heifer calf market price	1.66	$/0.45 kg[3]
Average purchase cost of replacement cow	2,300	$/cow
Average WDGS[1] price[2] as-is	51.47	$/907 kg[4]
Average baled crop residue price	50.00	$/907 kg[4]
Average supplement price	400.00	$/907 kg[4]

[1]WDGS = wet distillers grains plus solubles.
[2]Equal to 100% the price of $3.50/bu corn DM basis.
[3] $0.45 kg = $/lb.
[4] $907 kg = $/ton.

Table 4. Ingredient and nutrient composition of diets fed to cow-calf pairs in drylot by location.[1]

	Location	
Ingredient, %	**EAST**	**WEST**
Modified wet distillers grains plus solubles	55.0	
Wet distillers grains plus solubles	–	58.0
Wheat straw	40.0	40.0
Supplement	5.0	2.0
Calculated composition		
DM, %	62.4	47.0
CP, %	19.3	18.8
TDN, %	79.1	81.0
NDF, %	54.0	54.9
ADF, %	31.0	21.6
Ca, %	0.79	0.77
P, %	0.52	0.49

[1]All values presented on a DM basis
[2]Supplements included limestone, trace minerals, and vitamin A, D, E premix

Table 5. Supplement fed to cow-calf pairs grazing cornstalks.

Ingredient, %	
Dried distillers grains plus solubles	94.06
Limestone	5.49
Pelleting binder (urea formaldehyde polymer and calcium sulfate)	0.21
Vitamin A,D,E	0.12
Trace mineral[3]	0.11

[1]All values presented on a DM basis
[2]Fed at 5.3 lb (2.4 kg) per pair per d (DM)
[3]Cobalt, Copper, Manganese, Zinc, Iodine, Limestone Carrier

linear meters per pair) to pairs wintered on cornstalks at a rate of 5.3 lb (range of 3.7 lb to 7.1 lb; 2.4 kg; range 1.6 to 3.2 kg) DM/pair daily. The amount supplemented each day was calculated to provide the pairs on cornstalks the same energy intake of the DL pairs. Estimated DM intake of the cow and calf and estimated digestibility values of the cornstalk residue throughout the grazing period were used to calculate supplementation rate. Supplemental feed was only fed to grazing pairs if snow cover prevented grazing. The trial was completed when winter cornstalk grazing ended on April 13. Weaning of the calves also coincided with the completion of the corn residue grazing season.

Cow BW and body condition score (BCS) were recorded over two consecutive days at trial initiation and completion to determine changes in BW and BCS (feeding pre-weighing criteria described in experiment 1). Calf weights were also collected over two consecutive days at trial initiation and completion to calculate gain (feeding pre-weighing criteria described in experiment 1).

Cows were exposed to bulls (approximately 1 bull: 10 cows) from Sept 25 to Nov 30 for a 66 day breeding season at both locations. All bulls were examined for breeding soundness and approved by a licensed veterinarian prior to breeding season.

Results include 2 years of data from the east location and 1 year of data from the west location. Data was analyzed as a randomized block design using the mixed procedure of SAS. The model included pen or paddock as the experimental unit, wintering system as the fixed effect, and block as a random effect. Significance was declared at $P \leq 0.05$.

Results and Discussion

Experiment 1

Early-weaned calves across both year had a daily DMI of 9.0 lb (4.1 kg; east) and 8.6 lb (3.9 kg; west) per calf from October through January (Table 6). This amount was adjusted weekly, and added to the 15 lb/d (6.9 kg/d DM) fed to the EW cows to derive the total amount fed daily to the CW pairs. The combined total intake of the EW cows and calves was about 24 lb (11.0 kg). The CW pairs consumed 24 lb (10.9 kg DM/d). As a result, on average approximately 19.0 lb•pair-1•day-1 (8.7 kg•pair-1•day-1) of TDN was supplied to both EW and CW treatments, respectively, regardless if pairs were separate or together. Unlike Peterson et al,[27] the same diet was fed in the current study to all cows and calves regardless of weaning treatment within each year and location. This was done to eliminate potential variation in the energy value of the diet. A review of the literature indicates that this method to compare the feed efficiency between early- and conventional-weaned pairs has not been previously attempted.

In the current experiment, DMI of the EW calves was comparable to, but slightly lower than reported in previous studies for calves of similar BW and age.[22,23] Previous research has focused on feeding grain-based finishing diets to young calves upon early-weaning in an effort to increase DMI, and thus energy intake. Our diets contained more forage (40%, DM basis) from either crop residue or corn silage than the diets in the aforementioned studies.

As intended, cow BW was not different ($P \geq 0.05$) among treatment means in October (Table 7). The weaning age by location interaction was not significant for cow BW change, but EW cows gained more BW ($P < 0.01$) than their CW counterparts, and cows at west location outgained those at east ($P < 0.01$). Our observation for cow BW change in response to early-weaning agrees with previous data. Angus × Brahman cows gained less BW compared to cows whose calves were weaned 60 d earlier.[25] Early calf removal improved cow BW at the time of conventional-weaning in two additional studies using crossbred cows.[21,22] Similarly, total BW gain was greater for mature cows and first-calf heifers when calves were weaned at 108 compared to 205 d of age.[30] This positive change in cow BW from early weaning is logical given calf removal diverts intake energy from lactation towards maintenance and gestation.

There was no weaning age by location interaction or weaning age effect for January cow BCS ($P = 0.60$) or BCS change ($P = 0.38$; Table 8) although did not respond in a

Table 6. Daily DMI lb ± SD (kg ± SD) by location and weaning treatment across year.

	EAST[1]		WEST[2]	
Item	**EW[3]**	**CW[4]**	**EW[3]**	**CW[4]**
Cow	15.2 ± 0.11 (6.9 ± 0.05)	--	15.2 ± 0.07 (6.9 ± 0.03)	--
Calf	9.0 ± 2.25 (4.1 ± 1.02)	--	8.6 ± 2.09 (3.9 ± 0.95)	--
Cow-calf pair	--	24.0 ± 2.5 (10.9 ± 1.13)	--	23.8 ± 2.2 (10.8 ± 1.00)
Total	24.2 (11.0)	24.0 (10.9)	24.0 (10.9)	23.8 (10.8)

[1]EAST = Agricultural Research and Development Center.

[2]WEST = Panhandle Research and Extension Center.

[3]EW = early-weaned at 91 d of age.

[4]CW = conventionally-weaned at 203 d of age.

Table 7. Performance of cows by location and weaning treatment.

	EAST[1]		WEST[2]			*P*-value		
Item	EW[3]	CW[4]	EW[3]	CW[4]	SEM	Wean[5]	Loc[6]	W × L[7]
Cow BW, lb (kg)								
October	1,202 (545)	1,179 (535)	1,228 (557)	1,213 (550)	115 (52)	0.26	0.08	0.85
January	1,206 (547)	1,166 (529)	1,303 (591)	1,232 (559)	104 (47)	0.02	<0.01	0.51
Cow BW change, lb (kg)	4 (2)	-13 (-6)	75 (34)	20 (9)	22 (10)	<0.01	<0.01	0.15
Cow BCS[8]								
October	5.5	5.5	5.2	5.2	0.3	1.00	<0.01	0.59
January	5.4	5.3	5.6	5.6	0.4	0.60	0.03	0.60
Cow BCS change[8]	-0.1	-0.2	0.4	0.4	0.2	0.38	<0.01	0.38
Pregnancy, %	89.9	85.4	92.5	95.2	6	0.88	0.25	0.50

[1]EAST = Agricultural Research and Development Center.
[2]WEST = Panhandle Research and Extension Center.
[3]EW = early-weaned at 91 d of age.
[4]CW = conventionally-weaned at 203 d of age.
[5]Fixed effect of calf age at weaning.
[6]Fixed effect of location.
[7]Calf age at weaning × location interaction.
[8]BCS on a 1 (emaciated) to 9 (obese) scale.

similar manner by location. Why BCS did not respond in a similar manner as did BW is interesting. Calf removal has been frequently reported to either enable females to gain BCS or minimize the extent of BCS losses.[3,21,22] Other researchers have also demonstrated that removing the energy need for lactation improves BCS.[18,30] In most studies, early-weaned cows received *ad libitum* access to grazed pasture, such that forage quantity or quality was sufficient to support BCS improvements. In our study, cows were limit-fed to meet requirements, and BCS data indicate that energy intakes were adequate for maintenance.

There was no weaning age by location interaction (P = 0.50) for cow pregnancy rate nor were there effects of either location or calf weaning age (Tables 7 and 8). The dates for early-weaning coincided with the start of the breeding season, and approximately two week after the onset of breeding in year 1 and 2, respectively. Previous[15] and more recent data[3,4] indicate that early-weaning prior to the breeding season may increase cycling activity and conception rates in thin primiparous cows, and can reduce the duration of postpartum anestrus.[11] This agrees with work by Story et al[34] in which early-weaning did not influence pregnancy rates when cows were at a BCS of at least 5.0 before calving.

The conception rates in the current experiment also add to a limited body of research demonstrating the reproductive performance of cows when limit-fed high energy diets throughout the entire breeding season. Several trials[14,29,31,36] have found that limit-feeding high energy diets comprised of corn or ethanol co-products to cows in late-gestation or early-lactation does not hinder reproductive performance. In many of these trials the limit-feeding period ended at the start of the breeding season.

By design, calf BW was similar among treatments in October at the time of early-weaning (Table 4). Weaning age by location interactions were observed ($P < 0.01$) for both calf ADG and ending January BW. At the west location, EW calves gained more resulting in greater ($P \leq 0.05$) January BW than CW calves. At the east location, calves that nursed their dams had improved ($P \leq 0.05$) gain and ending BW over those weaned at 91 d of age. A weaning age by location interaction existed ($P < 0.01$) for calf BW per d of age at conventional-weaning in January. Suckling calves had greater ($P \leq 0.05$) BW per d of age at the east location, whereas EW and CW calves were not different at the west location. Gains of early-weaned calves prior to a traditional weaning age appear to be strongly dependent on the diet fed. Several studies have reported that early-weaned calves have increased ADG and BW at a conventional-weaning time when fed grain-based finishing diets.[5,8,34] Likewise, early-weaned calves supplemented on pasture had similar gains and BW to those nursing cows.[3,30] In our study, diets were formulated to provide adequate energy and protein intakes to allow the EW calf to gain BW at a rate comparable to that of the CW calves.

The ratio of calf BW gain to the total feed energy intake by the cow-calf pair may be an appropriate expression of the feed efficiency of early-weaning. It is a comparison of calf gain as a result of either direct diet consumption by the calf or the partitioning of feed between the cow and her calf plus the conversion of cow feed energy intake to milk production. Because diet energy levels were equal between weaning treatments, and DMI was measured for all animals, this relationship can be accurately described. Consistent with calf BW and ADG, a weaning age by location interaction was observed ($P < 0.01$) for cow-calf pair G:F (Table 8). Total pair G:F was greater ($P \leq 0.05$) for CW than EW pairs at the east location, while weaned and nursing pairs were not different at the west location. In contrast, Peterson et al[27] reported that early-weaned pairs converted feed energy into calf

Table 8. Performance of calves by location and weaning treatment.

	EAST[1]		WEST[2]			*P*-value		
Item	**EW[3]**	**CW[4]**	**EW[3]**	**CW[4]**	**SEM**	**Wean[5]**	**Loc[6]**	**W × L[7]**
Initial age[8], d	91	91	91	89	--	--	--	--
Ending age[9], d	205	205	206	202	--	--	--	--
Calf BW[10], lb (kg)								
October	280 (127)	278 (126)	289 (131)	267 (121)	9 (4)	0.13	0.92	0.22
January	474[b,c] (215)	509[a] (231)	498[a,b] (226)	461[c] (209)	11 (5)	0.90	0.19	<0.01
Calf ADG, lb (kg)	1.7[b,c] (0.78)	2.1[a] (0.93)	1.9[b] (0.84)	1.7[c] (0.77)	0.22 (0.1)	0.09	0.02	<0.01
BW•d•age[11], lb (kg)	2.3[b] (1.04)	2.5[a] (1.15)	2.4[a,b] (1.08)	2.2[b] (1.04)	0.67 (0.03)	0.16	0.17	<0.01
Pair G:F[12]	0.090[c]	0.109[a]	0.098[b]	0.091[b,c]	0.007	0.06	0.09	<0.01

[1]EAST = Agricultural Research and Development Center.
[2]WEST = Panhandle Research and Extension Center.
[3]EW = early-weaned at 91 d of age.
[4]CW = conventionally-weaned at 203 d of age.
[5]Fixed effect of calf age at weaning.
[6]Fixed effect of location.
[7]Calf age at weaning × location interaction.
[8]Age at the time of early-weaning across both yr.
[9]Age at the time of conventional-weaning across both yr.
[10]Actual weights.
[11]Weight per d of age at January conventional-weaning time.
[12]Calf gain per lb (kg) of total pair feed TDN intake.
[a-c]Within a row, least squares means without common superscripts differ at $P \leq 0.05$.

ADG 43% more efficiently. The use of different diets among treatments, an inconsistent manner in which cows were fed (i.e., *ad libitum* vs restricted intake), and the lack of accounting for gastrointestinal fill when weighing may represent limitations with these data. Data from Moe et al[20] indicate that the efficiency of the conversion of ME towards lactation and maintenance in the cow is similar. In agreement, energy balance studies with primiparous cows,[9] reported that the efficiency of conversion of ME to lactation energy was 72%. The efficiency of transferring ME to tissue energy and then to lactation energy was 78%. This is verified from other previous data.[20,38] If the efficiency of energy use for lactation or maintenance in the cow is similar, then the conversion of total feed energy intake to calf gain, between early and conventional weaning, is mainly a function of calf performance.

Experiment 2

For the year-round intensively managed cow-calf system, modeled profitability was -$346 per cow per year under base price levels. This suggests that if 450 lb (204 kg) steers are priced at $1.76 per lb ($1.76 per 0.45 kg) and base inputs and prices held constant, revenue generated is clearly not sufficient to overcome system costs. However, the costs of replacement females, the value of calves, feed prices, and reproductive rates collectively have the greatest influence on cowherd economics irrespective of production system. Thus, these factors were evaluated in the current analysis.

Replacement females represent a significant capital investment, and the cost to bring replacements into the cowherd has important ramifications on system profitability.[17] The purchase price for replacement cows dictates interest expense and the share of the capital cost of the replacement that is allotted to the remaining cows in the herd. The difference between the capital cost of the replacement and the cull cow credit value is depreciation. At base price levels, the capital cost of the replacement represents ≥ 30% of the total annual cow cost. Therefore, replacement cow purchase values were priced against different weaning rates to evaluate profitability (Table 9). Regardless of cow purchase price, profitability was most negative at 75% calf crop and improved as calf crop percentage increased. This is because weaned of exposed percentage directly influences gross revenue. As replacement cow price decreased from $3,000 to $1,600 per cow, profitability improved regardless of weaning percentage largely because the capital cost of the replacement female declined. This indicates that while female replacement cost is an important determinant of profitability, overall profit potential may be less sensitive to changes in replacement cost.

Various calf marketing prices were priced against different weaning rates to evaluate profitability when all other input parameters and price levels were held constant at base (Table 10). As observed with replacement cow prices, projected profitability was the least at 75% calf crop, and improved as percentage weaned per cow exposed increased regardless of calf price level. Likewise, irrespective of weaning rate, profitability improved as calf prices increased. This indicates that potential profitability of an intensively managed system will largely be a function of the price received for calves because of the direct effect it has on gross revenue.

Returns to any intensively managed cow-calf system which relies on harvested forages and feeds to meet cowherd nutrient requirements are strongly dependent on feed price. For the system analyzed in the current study, primary feed ingredients include distillers grains and baled crop residue, and total feed expenses represented ≥ 50% of total annual expenses. Distillers grains represent the majority of the diet and the price of distillers grains has historically been a function of corn price. Distillers grains were priced at either 85, 100, or 115% of corn price (DM basis), when corn was priced from $2.00 to $5.00 per bu. This indicates that if 450 lb (204 kg) steer calves are priced at $1.76 per lb ($1.76 per 0.45 kg), revenues from calves are not sufficient to cover production costs in an intensively managed system, even if distillers grains are priced in relation to $2.00 per bu corn.

Table 9. Projected profitability ($ per cow per yr) by replacement cow purchase price and percentage of calves weaned per cow exposed[1].

	% weaned of exposed				
Price, $/cow	**75**	**80**	**85**	**90**	**95**
3,000	-540	-502	-463	-425	-387
2,900	-523	-485	-447	-408	-370
2,800	-507	-468	-430	-392	-353
2,700	-490	-452	-413	-375	-336
2,600	-473	-435	-396	-358	-320
2,500	-456	-418	-380	-341	-303
2,400	-440	-401	-363	-325	-286
2,300	-423	-385	-346	-308	-269
2,200	-406	-368	-329	-291	-253
2,100	-389	-351	-313	-274	-236
2,000	-373	-334	-296	-258	-219
1,900	-356	-318	-279	-241	-202
1,800	-339	-301	-262	-224	-186
1,700	-322	-284	-246	-207	-169
1,600	-306	-267	-229	-191	-152

[1]All other prices and inputs held at base values.

Table 10. Projected profitability ($ per cow per year) by calf marketing price and percentage of calves weaned per cow exposed.[1]

	% weaned of exposed				
Price, $1lb[2] ($/0.45 kg)	**75**	**80**	**85**	**90**	**95**
3.16	51	121	191	261	331
2.96	-17	49	114	180	245
2.76	-84	-23	38	99	160
2.56	-152	-95	-39	18	74
2.36	-219	-167	-115	-63	-11
2.16	-287	-239	-192	-144	-97
1.96	-354	-311	-268	-225	-182
1.76	-422	-383	-345	-306	-268

[1]All other prices and inputs held at base values.

[2]Steer price only, heifer price discounted $0.10 per 1.0 lb (0.45 kg).

The price of calves has the greatest impact on gross revenue of the system, and distillers grains represent the greatest component of overall feed costs. Perhaps evaluating the response in profitability to concomitant changes in both calf and distillers grains price will provide the most information regarding economic feasibility of the intensively managed system (Table 11). In this analysis, the price of distillers grains as a proportion of corn price was varied against steer calf prices of $1.76 to $3.16 per lb ($1.76 to $3.16 per 0.45 kg) with all remaining inputs and values constant at base levels. As expected, projected profitability improves as calf price increases, irrespective of distillers grains price. Collectively, these data suggest that under the assumptions made in this study, positive returns to an intensively managed cow-calf system may be realized if calves are priced above $2.36/lb ($2.36 per 0.45 kg) and the price of corn is $3.50 per bu or less.

Additional expenses contribute to total annual cow costs in any production system. Changes in such costs were not evaluated in the current analyses, but have critical effects on economic outcomes. For example, bulls represent a significant investment for a cowherd and add $60 per cow per year in ownership cost alone at the base bull purchase price used in the current study. Expenses for cattle marketing and animal health/identification each represent an additional $30 per cow per year, but must be accounted for in an operation budget. Yardage is an important consideration in intensively managed cow-calf systems. At $0.35 per d, yardage charged per cow unit is approximately $133 annually if cows are in intensive management year-round. It is necessary to include yardage in a cowherd economic analysis, or otherwise directly account for those costs that are included in a yardage value (labor, equipment, utilities/fuel, land/loans). The value used in the current study ($0.35 per day) may be greater than usually assessed for many operations, but is consistent with that reported for commercial feedlots[12] and intensively managed cowherds.[2]

While economic analyses of conventional cow-calf production systems are common in the literature,[1,26,33] studies involving alternative intensively managed systems are limited. Certainly, this is because intensively managed systems have historically been less common. Three year of data directly comparing intensively managed and conventional cow-calf production in North Dakota indicated that total net cost per pair per year was approximately $22 greater for intensively managed pairs.[2] This equated to a $0.23 advantage for total cost per 1 lb (0.45 kg) of calf weaned for the conventional system. In another recent analysis, Close[7] estimated production costs and returns for total intensive management systems at 3 different price levels ($2.20, $2.70, or $3.50 per lb or 0.45 kg) for 550 lb (250 kg) calves sold at weaning. If aged cows were purchased as replacements and produced 2 calves, returns above costs were reported from $88 to $800 per cow per year depending on calf price received. If young females were purchased as replacements, producing 7 calves on average, profitability per cow per year ranged from -$22 to $693.

Table 11. Projected profitability ($ per cow per year) by distillers grains price as a proportion of corn price and calf marketing price[1].

Corn Price, $/bu	Calf price, $1 lb[2] ($/0.45 kg)							
5.00	1.76	1.96	2.16	2.36	2.56	2.76	2.96	3.16
115%	-552	-476	-399	-323	-246	-170	-93	-17
100%	-483	-407	-330	-254	-177	-101	-24	52
85%	-414	-337	-261	-184	-108	-31	45	122
4.50								
115%	-499	-423	-346	-270	-193	-117	-40	36
100%	-437	-360	-284	-207	-131	-54	22	99
85%	-375	-298	-222	-145	-69	8	84	161
4.00								
115%	-446	-370	-293	-217	-140	-64	13	89
100%	-391	-314	-238	-161	-85	-8	68	145
85%	-335	-259	-182	-106	-29	47	124	200
3.50								
115%	-393	-316	-240	-163	-87	-10	66	143
100%	-344	-268	-191	-115	-38	38	115	191
85%	-296	-219	-143	-66	10	87	163	240
3.00								
115%	-340	-263	-187	-110	-34	43	119	196
100%	-298	-222	-145	-69	8	84	161	237
85%	-257	-180	-104	-27	49	126	202	279
2.50								
115%	-287	-210	-134	-57	19	96	172	249
100%	-252	-176	-99	-23	54	130	207	283
85%	-217	-141	-64	12	89	165	242	318
2.00								
115%	-234	-157	-81	-4	72	149	225	302
100%	-206	-129	-53	24	100	177	253	330
85%	-178	-102	-25	51	128	204	281	357

[1]All other prices and inputs held at base values.
[2]Steer price only, heifer price discounted $0.10 per 0.45 kg.

While these data suggest that strong profits may be realized, there are several important distinctions between the current analysis and the analysis by Close.[7] In that analysis, costs for yardage, capital cost of replacement females, and marketing expenses were not included when calculating total annual cow costs. However, of greater importance, Close[7] assumed a calf weaning BW of 550 lb (250 kg) as compared to 450 lb (204 kg) based on published data in the current analysis, and calf prices were greater than this analysis resulting in greater projected revenue.

This analysis is one of only few conducted on a total intensively managed cow-calf system relying principally on feed resources from corn and ethanol production. It provides a model for producers to estimate profitability of such a system when production and price parameters are known.

Experiment 3

Cow-calf pairs at the eastern location grazed from November 11 to April 19 (160 d). An ammoniated corn stalk bale was fed approximately 147 lb (67 kg) DM per pair due to snow cover. The cornfield at the east location produced a grain yield of 217 bu per acre. Estimated removal of available corn residue was 32%. At west location, the grazing period was 133 days (Dec 4 to April 15) and the average yield for the cornfield was 245 bu per acre. Cow-calf pairs removed approximately 20.0 % of the available residue.

Drylot cow-calf pairs were limit-fed 28 lb (12.7 kg) DM during this trial. Drylot cows had a greater ending BW and BCS compared to cows grazing cornstalks. Cows wintered on cornstalks lost BW and had a 0.7 unit (Table 12) decrease in BCS, while cows in the drylot gained BW and had a 0.5 unit increase in BCS. Calves in the drylot had a greater ending BW compared to calves grazing cornstalks. Similarly, DL calves had greater ADG and BW per d of age compared to CS calves (Table 13). The breeding season was nearly complete before the experimental treatments were applied. Therefore, the effect of treatment on reproduction could not be measured until the following breeding season. Overall, pregnancies was 90%, but the number of cows is too small to make a treatment comparison.

The cost of each wintering system was also evaluated. Winter production inputs (Table 14) for grazing cornstalks

Table 12. Performance of cows by wintering system.[1]

Item	CS[2]	DL[3]	SEM	*P*-value
Cow BW, lb (kg)				
Initial	1183 (537)	1187 (538)	62 (28)	0.93
Ending	1121 (508)	1322 (600)	57 (26)	<0.01
Cow BW Change, lb (kg)	-64 (-29)	132 (60)	16 (7)	<0.01
Cow BCS[4]				
Initial	5.3	5.3	0.3	0.92
Ending	4.6	5.9	0.2	<0.01
Cow BCS change[4]	-0.7	0.5	0.2	<0.01

[1]Two years of data from EAST and 1 year of data from WEST.
[2]CS= pairs wintered on cornstalks.
[3]DL= pairs wintered in drylot.
[4]BCS on a 1 (emaciated) to 9 (obese) scale.

Table 13. Performance of calves by wintering system.[1]

Item	CS[2]	DL[3]	SEM	*P*-value
Initial age, d[4]	125	129	5	0.49
Ending age, d[5]	282	284	3	0.51
Calf BW, lb (kg)				
Initial	331(150)	326 (148)	9 (4)	0.68
Ending	541 (245)	642 (291)	13 (6)	<0.01
Calf ADG, lb (kg)	1.33 (0.60)	2.04 (0.93)	0.1 (0.05)	<0.01
BW•d•age, lb[6] (kg)	1.96 (0.89)	2.32 (1.05)	0.1 (0.05)	<0.01

[1]Two years of data from EAST and 1 year of data from WEST.
[2]CS= pairs wintered on cornstalks.
[3]DL= pairs wintered in drylot.
[4]Initial age= age at initiation of cornstalk grazing period.
[5]Ending age= age at collecting weights following weaning.
[6]Weight per d of age at collecting weights following weaning.

Table 14. Winter production inputs by wintering system.

Inputs, $/pair/day	CS[1]	DL[2]
Cornstalk rent[3]	0.20	–
Yardage	0.30	0.50
Ration[4]	–	1.66
Supplement[4]	0.37	–
Net cost, $/pair/day	0.87	2.16
Net cost, $/pair/wintering season	144.55	356.40
Net cost difference, $/pair	212.85	

[1]CS= pairs wintered on cornstalks.
[2]DL= pairs wintered in drylot.
[3]Cornstalk rent = $12 per acre (0.404 hectares).
[4]Distillers priced at 100% of corn assuming $3.50 per bu of corn.

were estimated to be approximately $0.87 per pair per day, resulting in a total of $144 per pair for a 165 day winter grazing season. In contrast, the DL wintering system was estimated at $2.16 per pair day or $356 per pair per grazing season.

A partial budget (Table 15) was utilized to economically compare the reduced performance, as well as decreased winter production cost of the CS wintering system. The reduced winter production input is observed under reduced cost. In the CS wintering system, additional feed would be required for the cow to compensate for BW and body condition reductions observed throughout the winter. Consequently, additional post-weaning feed for the CS cow would cost approximately $16. The lighter weaning weight of CS calves would result in a reduced return of $60 per calf when a $20/cwt price slide is used between the calf weaning weights of the CS and DL wintering systems. A net change of $137 per pair was observed when winter cornstalk grazing was incorporated into an intensive production system. Lower winter production inputs may be significant enough to compensate for the reduced performance of calves when cow-calf pairs are wintered on cornstalks.

Conclusions

Weaning calves at 90 day of age appears to have marginal effect on cow BW and BCS change and pregnancy rates when cows are limit-fed high energy diets to meet requirements, provided BCS is acceptable (≥ 5.0) prior to the beginning of the breeding season. Because calf ADG per unit of feed energy intake for the cow and calf combined were relatively

Table 15. Partial budget of winter cornstalk grazing.

Additional costs		Additional returns	
Post weaning feed[1]	$16		
Reduced returns		**Reduced costs**	
Lighter weaning wt[2]	60	Winter production inputs	$213
Total	$76	Total	$213
Net change	$137		

[1] Cost to feed an additional 3.6 lb (1.6 kg). (DM) of ration at $0.06 per lb. ($0.03 per kg). for 165 days to compensate for body condition reduction of cow.
[2]The difference in calf value at weaning between treatments; calf price, April 30; $20/cwt ($20/45 kg) price slide.

similar, the total energy requirements for weaned cows and calves or nursing pairs do not appear to be markedly different. Thus, decisions regarding early-weaning should be made on the discretion of management as opposed to feed efficiency. Cow-calf systems are complex, but the economic feasibility of a cow-calf production system is ultimately a function of the costs of replacement females, the value of calves, feed prices, and reproductive rates. These same fundamentals also determine profitability of alternative systems centered around feeding cows in intensive management. Incorporating corn residue grazing into the cow-calf production system that doesn't include grass pasture as a grazing component makes this system economical to conventional cow-calf production systems.

Endnotes

[a]ScourGuard® 4KC, Zoetis, Florham Park, NJ
[b]Vision® 7 Somnus, Merck Animal Health, Summit, NJ
[c]Bovi-Shield Gold® 5, Zoetis, Florham Park, NJ
[d]Bovi-Shield Gold® FP® 5 VL5 HB, Zoetis, Florham Park, NJ
[e]SAS Inst. Inc., Cary, NC
[f]Microsoft®, Redmond, WA

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Applied feedlot immunology

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Abstract

Outcomes such as health performance, growth performance, and feed efficiency – outcomes that are clinically relevant and economically important to beef cattle producers and veterinarians involved in production medicine are the most clinically relevant and economically important outcomes by which to evaluate immune function in beef cattle populations. Although substitution indicators like serum antibody titers, lymphocyte proliferation assays and other laboratory assays may be indirectly related to the health and performance of the populations of interest, they are not directly correlated with the economically important outcomes essential to the financial health of the beef cattle businesses for which food animal veterinarians provide service.

A number of factors or events impact immune function of cattle that are received and fed in North American feedlots. These include, but are not limited to, weaning, commingling, transportation, arrival processing surgical procedures, nutritional status and environmental conditions. The expression of immune function in terms of health performance, growth performance, and feed efficiency, during the feeding phase is affected by not only arrival conditions and procedures conducted at feedlot arrival or management during the feeding phase, but the background and history of management prior to feedlot arrival. These are the most economically important measures of immune function.

Key words: beef, feedlot, immunology

Résumé

Les résultats comme la performance sanitaire, la performance de croissance et l'efficacité de l'alimentation sont importants d'un point de vue clinique et économique pour les producteurs de bovins de boucherie et pour les vétérinaires en médecine de population. Ils sont donc les plus pertinents cliniquement et économiquement afin d'évaluer la fonction immunitaire dans les populations de bovins de boucherie. Bien que d'autres indicateurs, tels les titres sériques d'anticorps, le dosage de la prolifération des lymphocytes et d'autres analyses de laboratoire, puissent être indirectement reliés à la santé et à la performance dans des populations d'intérêt, ils ne sont pas directement corrélés avec les résultats économiquement importants qui sont essentiels à la santé financière des élevages de bovins de boucherie auprès desquels les vétérinaires offrent leurs services.

Plusieurs facteurs ou évènements ont un impact sur la fonction immunitaire chez les bovins accueillis et engraissés dans les parcs d'engraissement en Amérique du Nord. Parmi ceux-ci on retrouve le sevrage, le regroupement, le transport, les procédures chirurgicales à l'arrivée, l'état nutritionnel et les conditions environnementales. L'expression de la fonction immunitaire durant l'engraissement au niveau de la performance sanitaire, de la performance de croissance et de l'efficacité de l'alimentation n'est pas seulement affectée par les conditions lors de l'arrivée, les procédures menées à l'arrivée au parc d'engraissement ou par la régie durant l'engraissement mais aussi par le contexte et le type de régie adopté avant l'arrivée au parc d'engraissement. Ce sont les mesures de la fonction immunitaire qui sont les plus pertinentes économiquement.

Introduction

Immune function is a term often used interchangeably with serum antibody response, leukocyte or lymphocyte responses, responses of endogenous immunomodulatory molecules such as interleukins or tumor necrosis factor (TNF), among others. However, these are actually substitution indicators for actual immune function, which is expressed as health performance, growth performance, and feed efficiency – outcomes that are clinically relevant and economically important to beef cattle producers and veterinarians involved in production medicine.[26,30] Although substitution indicators may be indirectly related to the health and performance of the populations of interest, they are not directly correlated with the economically important outcomes essential to the financial health of the beef cattle businesses for which food animal veterinarians provide service.

Immunity is often categorized as innate (non-specific) or acquired (specific). Innate immunity is inherent and is not enhanced through stimulation following exposure to antigen, while acquired immunity elicits a response that is quicker and increasingly stronger following exposure. Recent developments in understanding protective immunity have been described. These developments are intriguing and help to elucidate the biological mechanisms underlying protective immune function.

A number of factors or events impact immune function of cattle that are received and fed in North American feedlots. These include, but are not limited to, weaning, commingling, transportation, arrival processing surgical procedures (dehorning, castration), and environmental conditions (dust, weather, extreme temperatures). The expression of immune function in terms of health performance, growth performance, and feed efficiency, during the feeding phase is affected by not only arrival conditions and procedures conducted at feedlot arrival or management during the feeding phase, but the background and history of management prior to feedlot arrival. This involves not only the antigens included in vaccines given, but also the timing and routes of the vaccines administered. Specifically, management of the vaccination program is as important as the vaccines themselves.

Technological approaches to diagnosis of disease relevant to feedlot production have been described.[32,36] The objective of these technologies is to enhance sensitivity and specificity of diagnosis of infectious disease in order to fine-tune treatment selection and timing of treatment. Diagnosis of disease is made by measuring feeding behavior and core body temperature changes using infrared thermography.

Also important in the ability of an animal to respond to an antigen is the metabolic status associated with the status of minerals essential to protective immune function. Selenium, copper, cobalt, and manganese have been shown to be important in the ability of an animal to respond to antigens exposed to in the form of vaccination or natural exposure.

It is interesting that vaccine technology has evolved and applications have been developed for a number of species. However, although technologies are available, bovine medicine has not taken advantage of these advances. Recently, we've seen approval of an immunomodulator[a] that may provide an opportunity for further advancement of technology in relation to enhancing or filling gaps in normal immune function.

Protective immune function is complex and involves management of immune responses through sound nutrition, timing of presentation of antigens, and management of procedures that minimally inhibit normal, protective responses.

Recently described immune responses

Immune function has been categorized as innate and acquired immunity. Innate immunity consists of physical and chemical barriers, non-specific phagocytes, macrophages and neutrophils, the complement system, interferon, natural killer (NK) cells, and TNF. Acquired, specific immunity is comprised of humoral and cell-mediated functions. Humoral immunity is found in fluids such as serum, tears, mucus, and bronchial secretions. Cell-mediated immunity (CMI) may be a misnomer, since humoral immunity is also mediated through cellular function, albeit a separate cell line, specifically B-cells. However, CMI is described as "trained" T-lymphocytes that eliminate and provide protection against intracellular pathogens and tumor cells.[16]

Cellular signaling in the form of pathogen receptor recognition (PRR) has been described.[37,41] PRRs comprise a group of cellular signaling pathways, which includes the highly studied toll-like receptors (TLRs). TLRs reportedly play important, and potentially critical roles in both innate and acquired branches of immune function.[13,37] While understanding these mechanisms helps to elucidate normal immune function, they are indirectly related to outcomes most directly relevant to cost-effective beef cattle production.

Management Practices

Hay et al[21] reported reduced risk of bovine respiratory disease development during the feeding phase if calves had been weaned in a yard vs pasture-weaned, had been fed grain ("bunk broke"), and had been vaccinated against BVDV1 or *Mannheimia haemolytica* prior to feedlot entry in Australian feedlots.

Passive Transfer

Dewell et al[12] reported that calves with lower (<2,400 mg/dl) serum IgG1 had 1.6 times higher likelihood of morbidity, 2.7 times higher likelihood of mortality, and weighed 7.38 lb (3.35 kg)/hd less at weaning than calves with serum IgG1 > 2,700 mg/dl during the pre-weaning period. No significant association was reported between perinatal serum IgG1 and feedlot health or growth performance.

Earlier, Wittum et al[45] had reported that calves with inadequate plasma protein (<4.8 g/dl) had 3.0 times higher likelihood of overall morbidity and 3.1 times higher likelihood of respiratory tract morbidity during the feedlot phase.

While the feedyard doesn't have control over cow-calf practices, such as colostrum and passive transfer management, calves coming from sources with attention to detail in this area have a higher probability of better health and growth performance. Therefore, the feedyard and the consulting veterinarian can use historical health and feeding performance to make current and future purchasing decisions.

Commingling

The scientific literature is sparse on the immunologic impact of commingling cattle populations. Step et al[39] reported that commingling reduced growth performance and increased risk of development of respiratory disease with increased treatment cost and numerically higher mortality due to infectious causes (i.e., respiratory disease). However, statistical power was not reported in the event failure to find statistically significant differences, and the study only covered a 42-day receiving period.

Weaning

A 2-step weaning process reportedly reduced weaning stress and enhanced immune response when measured using the laboratory outcomes BHV-1 shedding, serum haptoglogin levels, interferon-gamma, and leukocyte tumor necrosis factor following experimental BHV-1 challenge when compared to abrupt weaning and transportation.[20]

Weather

Month, year placed, days on feed (DOF), arrival body weight, BRD risk code, gender, size of cohort, wind chill temperature, temperature change, and maximum wind speed have been reported to be associated with morbidity in feeder cattle.[2,7] Briefly, September and October placements had significantly higher BRD morbidity than November placements, lighter placements (500 to 600 lb (227 to 271 kg)/hd) were at greater risk of BRD treatment than heavier placements (700 to 800 lb (318 to 363 kg)/hd), high-risk placements were about 3X more likely to require BRD treatment than low-risk placements, and smaller placement cohorts (< 91 hd) were at lower risk of BRD treatment than larger cohorts. Additionally, interactions between wind speed, temperature change, and wind chill were reported to be associated ($P < 0.05$) with BRD morbidity, as measured by number of daily treatments for BRD.

Transportation

Arthington et al[1] reported that transported calves had greater weight loss and an increase in acute-phase proteins compared to non-transported calves. Reporting clinically relevant outcomes, Cernicchiaro et al[8] found that shrink following transportation was associated with morbidity, mortality, hot-carcass weight, and average daily gain which were significantly modified by gender, season, and mean arrival body weight.

Vaccination

Traditionally, it had been accepted that vaccinated cattle populations would be effectively protected against challenge pathogens; however, it has since been shown that other factors, such as commingling, nutrition, period of time since weaning, weather, and transportation conditions play a role in the health of the population that may compliment or overwhelm protection provided through vaccination.

Herd immunity is an important principle that affects the health of a population based on reduced numbers of susceptible animals, reduced pathogen load due to shedding, duration of pathogen shedding, and a higher infectious dose required to cause disease.[40]

Antigens

Respiratory vs other pathogens

Vaccination against respiratory pathogens – both viruses and bacteria – has been the central theme for providing immunity to calf, feeder, and feedlot cattle populations. Ancillary antigens administered include, but are not limited to, clostridial agents, leptospiral antigens, anaplasma antigens, mycoplamal antigens, among others that may vary by region, history, and anecdotal effects.

MLV vs KV

Modified-live (MLV) BHV-1 has been shown to be more effective in protection against IBR than killed virus vaccines. This has also been extrapolated for BVDV vaccination, with the basis being protection of the fetus in a simulated challenge mode.[19,33] The onset of immunity has been reported to be dramatically reduced for MLV vaccines, with protection provided in 3 days post-vaccination in 1 study and by 5 days post-vaccination in another.[46] Alternatively, killed vaccines generally require a booster and rely on antibody production, which requires more time to provide protection.[40]

Route of Administration

Vaccines in beef cattle production are generally administered parenterally, i.e. subcutaneously. This is done more for ease of delivery than for effectiveness. Immunity following parenteral administration of vaccines varies with the antigen, the disease targeted for protection, and conditions of vaccination. Immunologically and biologically, it may make more sense to deliver antigen at the site of natural challenge, i.e., mucosal surfaces.[40]

Parenteral

Perino and Hunsaker[30] provided a thorough review of the scientific literature that reported clinically relevant outcomes using sound scientific methods such as blinding, a contemporaneous control group, randomization, and appropriate statistical analysis of results, among others. In this review of 22 reports that met these criteria, 10 reported field efficacy of the vaccines investigated. Positive results were reported for BRSV, *Mannheimia haemolytica*, *Pasteurella multocida*, and *Histophilus somni*.

Hunsaker and Tripp[23] later reviewed the scientific literature to update the previously published review article. In this later review, it was reported that 21 articles met the criteria of the review, which were the same as those outlined above for the previous review. Of the qualifying articles, 10 were from studies done in beef cattle. Of these, 7 reported efficacy under field conditions for cattle vaccinated against BRSV, *Clostridium* spp, bovine coronavirus, *Fusobacterium necrophorum*, *Mannheimia haemolytica*, and *Moraxella bovis*. Results for antigens that showed field efficacy were often equivocal, i.e., there may have been multiple studies done wherein some reported efficacy, while others did not.

Intranasal

Ellis et al[15] reported that clinical efficacy of immune response to intranasal vaccination in an experimental challenge study may be equal to that of parenterally delivered vaccine. Onset of immunity for antigens delivered by the intranasal route was reported to be established by day 3 post-vaccination in a dual challenge model with bovine herpesvirus-1 and *Mannheimia haemolytica*; however, the challenge exposure began on day 3, so prior protection could not be stated.[24] Todd[43] stated that calves vaccinated intranasally with BHV-1 were protected against experimental IBR challenge as early as 48 hours post-vaccination; however, no data were provided to support this finding, only statements of findings. In a study designed to compare IN vaccination with parenteral vaccination (IM), it was reported that no difference was found in ADG, DMI, or morbidity as measured by the number of BRD treatments; however, feed:gain ratio was increased in cattle vaccinated by the IM route.[14] Although this study was done under natural challenge conditions, the duration of the study was only for the 28-day receiving period. Therefore, economic outcomes relevant to feedyard production could not be calculated.

In summary, intranasal vaccines have been available for nearly 5 decades, but there are no reports in the public domain of field efficacy under conditions of natural challenge. Nonetheless, as stated by Stokka,[40] it makes biologic and immunologic sense to deliver antigen at the site of challenge. There are in-house data from studies done in large pens, under commercial feeding conditions, investigating protection against natural challenge that support this hypothesis.[b]

Intradermal

Hunsaker et al[22] provided a thorough review of the scientific literature on the intradermal route of vaccination in domestic animals. ID vaccination is reported to be an appealing alternative to other routes of administration based on beef quality issues, without compromising effectiveness. However, reliable and consistent delivery of the antigen to a consistent depth in the dermis may not be achievable in a commercial setting. Dean et al[11] reported that intradermal vaccination against tuberculosis challenge using a CMG-primed adenoviral vectored vaccine provided more consistent and strongest immune response of the different routes of administration examined.

Oral delivery

Oral vaccines have been investigated experimentally, using genetic engineering to develop recombinant bovine pathogen sequences into plant genome. To date, these vaccines are not available commercially since efficacy has not been shown.

Timing of Vaccination

Exposure to antigens prior to disease exposure has been documented to be most effective in reducing infection and disease, which is logical considering the time requirement for development of a protective immune response. Furthermore, antibody response requires the most time to develop when compared to other components of protective immunity, such as innate immunity and cell-mediated responses. This is particularly important for immunity against bacterial agents and associated leukotoxins.[40] Hence, it may require an adjustment in expectations for protection immediately following vaccination at arrival to the feedlot, unless previous natural exposure or exposure through vaccination has occurred.

Kirkpatrick et al[25] reported that vaccination with IBRV, BVDV1, BVDV2, PI3, BRSV, *M. haemolytica*, and *P. multocida* antigens was effective in improving health performance when compared to unvaccinated control calves, with no difference seen between calves vaccinated at 67 days of age at the time of primary vaccination vs 167 days of age. This implies that vaccination at the time of branding is not detrimental in terms of eliciting a protective immune response at a time when maternal immunity would expected to be present.

Revaccination has been well-defined and described by Stokka et al[40] in a review of the scientific literature relevant to vaccination of cattle populations. Little benefit has been reported for re-vaccination as an isolated effect.

Nutrition

Mineral status

Chromium has been reported to reduce morbidity, as measured by numbers of treatments for respiratory disease, and modulate weight loss in the face of LPS challenge.[4] *Copper* has been reported to play an important, if not crucial, role in immune function; however, Galyean[16] reviewed the literature to find little compelling evidence of benefit to copper supplementation in stressed calves. *Selenium* has been reported to be essential in supporting adequate immune function;[29] however, review of the literature for reports of clinically relevant outcomes in selenium-supplemented cattle being prepared for feedlot entry is unrewarding.

Zinc-supplemented cattle reportedly had improved growth performance, but no change in clinically relevant health performance outcomes.[14]

Energy

Duff et al[14] reported in a review of the literature that a higher-concentrate ration fed during the receiving period had a negative impact on health performance as measured by clinical morbidity, but a positive effect on feeding performance. They indicated that it was not cost-effective over the entire feeding period to reduce concentrate and increase roughage during the receiving period, even with the benefit found in morbidity. However, Gifford et al[18] reported that growth performance and feeding performance could be compensated with additional days on feed.

Gifford et al[18] also reported that the metabolic cost of inflammatory responses and immune function had a liability on feeding performance and carcass characteristics, measured by hot-carcass weight and marbling.

Protein

Galyean et al[16] indicated that protein deficiency has negative implications on protective immune function. This position was based largely on substitution indicators (e.g. serum antibody responses) reported in protein-supplemented cattle vs non-supplemented cattle prior to feedlot entry. These authors describe a paradoxical response, using clinically relevant outcomes, wherein crude protein (CP)-supplemented cattle have greater dry matter intake, greater gain, but also greater rectal temperature and clinical signs of respiratory disease. However, no mortality outcomes (crude mortality, BRD mortality, infectious mortality, etc.) were reported. Little has been reported since this time to dissect the question of immune function impact of protein-supplementation in studies reporting clinically relevant outcomes. However, Gifford et al[18] described the metabolic protein demand based on inflammatory response.

Biotechnology

Genetically engineered vaccines

In the peer-reviewed refereed scientific literature, there are reports of efficacy of experimental vaccines developed using genetic engineering technology against bovine herpesvirus-1 (BHV-1), bovine respiratory syncytial virus (BRSV), *Brucella abortus*, and *Salmonella* spp using experimental challenge models and reporting substitution indicators, such as serum antibody response and reduction in viral shedding. In some cases, clinically relevant outcomes, such as reduction in severity of clinical illness scores under experimental challenge conditions, are reported.

Recombinant

A recombinant vaccine was reportedly developed by integrating BVDV sequences into ginseng plant DNA. However, although humoral and cell-mediated responses were reported following vaccination, no clinically relevant outcomes were reported under natural-challenge field conditions.[17] Although recombinant technology has been used to elicit immune responses to foot-and-mouth disease virus (FMDV),[27] *Brucella abortus*[42] and *Mycoplasma mycoides* when laboratory outcomes or substitution indicators are measured under experimental challenge conditions, there are no reports in the peer-reviewed, refereed scientific literature investigating field efficacy in feedlot cattle populations. Prysliak et al[31] reported that conserved protein sequences of *Mycoplasma bovis* failed to protect feedlot cattle from experimental challenge as measured by weight gain, rectal temperature, survival proportion, and lung lesion development.

There have been recent advances in experimental plant-made viral bovine vaccines against foot-and-mouth disease virus (FMDV), bovine rotavirus (BRV), bovine viral diarrhoea virus (BVDV), bluetongue virus (BTV), and bovine papillomavirus (BPV). However, there have been no commercially available recombinant vaccines developed for use in feedlot cattle.[35]

Gene-deleted mutant

Chowdhury et al[10] reported that a gene-deleted mutant experimental vaccine with deletions or modifications at 3 gene loci provided superior protection and immunologic substitution indicators following experimental challenge compared to unvaccinated control calves or an experimental vaccine with a gene-deletion at only 1 locus.

Subunit vaccines

Babiuk et al[3] presented a novel vaccine approach in 1996 and predicted that subunit BHV-1 vaccines would launch a new generation of vaccines and revolutionize vaccine regimes used in cattle. While this seemed promising, based on developed technology, limited progress has been made after 20 years in commercializing genetically engineered vaccines such as recombinant strains, gene-deleted mutant strains, and subunit sequences. However, recent work has been done to investigate genetically engineered vaccines under experimental conditions, reporting substitution indicators, and in some cases, protection against experimental challenge.

A commercially available *Mannheimia haemolytica* bacterial extract-toxoid has been developed and made commercially available. This vaccine is comprised of subunit *M. haemolytica* outer membrane protein and recombinant leukotoxin. Clinical efficacy investigating clinically relevant outcomes under field challenge conditions is underway.

Immunomodulators

Van Engken et al[44] reported that oral meloxicam had negative impact on immune indicators such as interleukins, interferon production, CD surface molecule expression, and expansion of T-cell subsets; however, no clinically relevant outcomes were reported.

Zelnate DNA immunostimulant[a] is a non-antibiotic DNA sequence that mimics infection, thereby stimulating non-specific innate immune responses. Results of manufacturer-sponsored studies designed to investigate field efficacy are equivocal. A third-party, independent field trial designed to investigate field efficacy of Zelnate DNA immunostimulant and report clinically relevant outcomes under field conditions has recently been published.

Conclusions

Immune function in cattle received at the feedlot can be optimal based on attention to detail regarding prior management including adequate passive transfer, weaning practices, effective immunization based on timing and appropriate vaccination, transportation, season and associated weather during the receiving period, commingling, and nutrition. The driving question becomes whether it is cost-effective for the feedlot to pay premiums for cattle managed to enhance immune function prior to feedlot arrival at a level that warrants implementation of these management practices for the cow-calf producer.

Seeger et al[38] reported results of a study designed to find the actual market value of management practices that enhance immune function during the feeding period. This study used reports of sales of calves sold on a video livestock auction service from 1995 to 2009. Calves in the sale are categorized as having been vaccinated once or vaccinated and re-vaccinated, vaccinated and weaned, or unvaccinated. Calves designated and marketed as having pre-sale management including vaccination, weaning prior to feedlot arrival, and bunk breaking yielded a premium of 3.7 to 7.3% of the base price. In today's marketing environment, assuming a 500 lb (227 kg) calf is valued at $150/cwt, this returns an additional $2.06 to 10.95/100 lb (45 kg) bodyweight to the producer. However, this does not come at no additional cost or risk to the producer. Using elementary calculations to estimate these costs, without feed mark-up or interest, but including a basic yardage charge to cover additional labor, fuel, and repairs, and an estimate of mortality for the backgrounding period, it likely costs the producer approximately $12/100 lb (45 kg) BW to manage calves at weaning time in a manner that enhances immune function, based on reports in the literature cited in this review.

Participation in pre-feedlot management programs varied in the study reported by Seeger et al[38] from 3.2 to 53%, depending on the level of management and the year of the study. From the feedlot's perspective, it makes sense to purchase cattle that have been managed to enhance the probability of optimal immunity prior to sale. However, from the producer's perspective, implementation of additional management practices must return on investment. Based on the results of this study, even for years with the highest return vs baseline, the management practices that enhance immune function prior to feedlot entry are unlikely to return on the investment of the cow-calf producer. Hence, the cow-calf producer must rely on more intangible benefits of these management practices, such as reputation and buyer relationships.

Endnotes

[a]Zelnate DNA immunostimulant, Bayer Animal Health, Shawnee Mission, KS

[b]Feedlot Health Management Services, Okotoks, AB, Canada. Unpublished data.

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Dairy Session

Moderators: *Michael Capel, Greg Johnson*

Prudent drug use for the dairy practitioner

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Abstract

As consumers become more savvy about the food they eat, dairy farmers and their veterinarians must be progressively vigilant to make sure that public health is protected. These protections come not only from residue prevention, but also in the implementation of prudent drug practices that minimize the risk of development of antimicrobial resistance, which may be passed on to humans who consume animal-based food products. Throughout the last decade, the FDA has issued several guidance policies and implemented prohibitions in drug use in attempts to reduce the risk of development of antimicrobial resistance in humans. As dairy farms become larger, veterinarians are spending less time doing individual animal treatments and more time directing those treatments on farms. Whether animals are treated on-farm by veterinarians or by farm personnel, there are specific expectations that must be in place in order to reduce the risk of antimicrobial resistance development and drug residues in meat or milk.

Key words: dairy, drug use, stewardship

Résumé

Alors que les consommateurs deviennent de plus en plus exigeants en ce qui concerne leur alimentation, les producteurs laitiers et leurs vétérinaires doivent être des plus vigilants afin de s'assurer que la santé publique soit bien protégée. Cette protection implique non seulement la prévention des résidus mais aussi la mise en place de méthodes judicieuses d'utilisation des drogues afin de minimiser le risque de développement de résistance antimicrobienne qui pourrait être passée aux humains qui consomment des produits alimentaires d'origine animale. Au cours de la dernière décennie, le *FDA* a émis plusieurs directives et mis en place des programmes de restriction dans l'utilisation des drogues afin de réduire le développement de résistance antimicrobienne chez les humains. Alors que les fermes laitières deviennent de plus en plus grosses, les vétérinaires passent moins de temps à prodiguer des soins individuels aux animaux et plus de temps à régir ces traitements à la ferme. Peu importe si les animaux sont traités à la ferme par les vétérinaires ou par le personnel de la ferme, il y a des attentes bien particulières qui doivent être rencontrées afin de réduire le risque de développement de résistance antimicrobienne ou de minimiser la présence de résidus de drogues dans le lait ou la viande.

Introduction

Antimicrobial residues in milk and meat from dairy cattle have long been scrutinized by the US public and governmental agencies. There are also increased concerns about the presence of elevated levels of antimicrobial resistance in both veterinary medicine and human medicine. Additionally, there is heightened fear that certain antimicrobial use practices in veterinary medicine are leading to decreased treatment efficacy in human medicine. Dairy farmers and their veterinarians must be progressively vigilant to make sure that public health is protected following consumption of products from dairy animals, and that perception of milk and dairy beef remains as high as possible.

Antimicrobial Residues in Dairy Beef

Cull dairy cows have the highest incidence of confirmed meat residue violations at slaughter of all food animal classes, with 568 violations noted in the Red Book during FY11.[11] According to this document, the percentage of cull dairy cows with violative meat residues is approximately 10 times higher than in cull beef cows. This correlates to cull dairy cows accounting for approximately 90% of all of the violative residues found in beef animals harvested for meat each year. In recent years, publication of the Red Book lags substantially beyond completion of the fiscal year they summarize. However, the USDA has now started publishing Residue Quarterly Reports online (USDA FSIS-Residue Quarterly Reports).[12] The reports currently available for the most recent year (July 2014 – June 2015) indicate that there have been 515 dairy cull cows identified as violative, with 600 residues identified in those animals. Of the residues identified, ceftiofur, penicillin, and the sulfonamide family were the most common violative residues identified. During this time period, USDA conducted 192,746 in plant tests on all animal classes, of which 105,295 (54.6%) were conducted on cull dairy animals. As a result of these tests, there were 871 animals with confirmed violative residues, of which 59% were dairy animals. This is particularly shocking when taking into account the small percentage that cull dairy cows represent among the total animal marketings across all species.

It becomes pretty obvious why the USDA and FDA are paying so much attention to the dairy industry. In general, inspector-generated sampling is completed at a higher rate in cull dairy cattle than in cull beef cattle for a couple of reasons. Inspector-generated sampling targets *individual suspect animals* and suspect *populations of animals*.

1. The rate of inspector-generated sampling is determined by the incidence of previous residue-positive sampling. Since cull dairy cows have a 10-fold increase in positive samples vs cull beef cows, there are more samples collected from cull dairy cows as a percentage of the total animals that are marketed.
2. Residue testing is also triggered by the presence of a carcass defect. Observations of animals that are marketed with mastitis, metritis, pneumonia, peritonitis, surgical incisions, or active injection-site lesions may generate a suspect test for antimicrobial residues.

This rate of sampling is based on professional judgment of the plant veterinarian and public health criteria.[11]

Another contributor to increased violative residues in dairy cattle is that they are treated with antimicrobials at a much higher rate than beef cull cows or beef feedlot cattle, thus presenting more risk for mistakes to occur. This cannot be used as an excuse for the startling high incidence of antimicrobial residues in cull dairy beef. We must continue to work with dairy producers to assure that all products are used in compliance with the labels, including stated withdrawal times. In addition, when products are utilized in an extra-label manner, proper withdrawal times must be established and maintained to prevent adulteration of the food supply.

Preventing Antimicrobial Residues in Milk

The US Pasteurized Milk Ordinance (PMO) states that every load of milk that is shipped in the United States must be tested for the presence of β-lactam antibiotics.[8] This practice has reduced antibacterial residues from β-lactam antibiotics in milk to less than 0.1% per year from 13% in 1962.[2] Figure 1 shows the annual pounds of milk that is dumped and the percentage of all samples that were found to be positive. For fiscal year 2015, the percentage of violative samples was 0.012%, which was the lowest in history.[3]

When the causes for these remaining residues are investigated, the majority were caused by mistakes in management. Examples include failing to mark treated cows or treated cows being mixed with non-treated cows. Therefore, it would seem prudent to develop testing strategies that focus on testing the bulk-tank or tanker-truck milk leaving the farm in addition to individual treated cows, as testing individual cows will often not catch the mistakes that occur.

FDA Guidance on Antimicrobial Resistance and Residue Prevention

Since 2003, the FDA has issued 3 guidance policies that are intended to direct drug use on US livestock farms. The first was Guidance for Industry (GFI) 152 entitled *Evaluating the Safety of Antimicrobial New Animal Drugs with Regard to Their Microbiological Effects on Bacteria of Human Health Concern*.[4] This document was published to outline the risk assessment approach the FDA will undertake to determine if new antimicro-

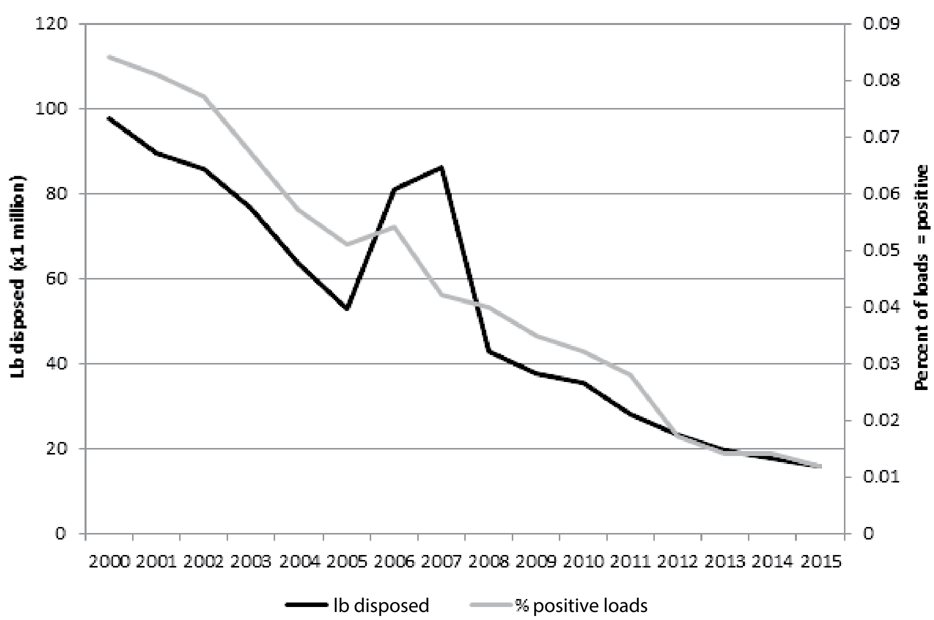

Figure 1. Milk disposition due to drug residues in the US (Fiscal 2000-2015). National Milk Drug Residue Database FY 2000-2015.

bials submitted for FDA approval have impact on the development of antimicrobial resistance in non-target bacterial species, and the risk of human health issues related to transmission of food-borne pathogens to humans. Within the document, the FDA states "that food-borne human exposure to antimicrobial resistant bacteria is complex and often involves the contributions from other sources of exposure" but feel that assessing the food-borne pathway of resistance development is the most significant pathway for resistance development in humans. As a result of this process, the FDA has classified antimicrobial classes as critically important, highly important, or important to human medicine. It is not surprising that many drugs or drug classes that are listed as critically or highly important to human medicine are valuable drugs in veterinary medicine.

In 2012, the FDA released GFI 209 *The Judicious Use of Medically Important Antimicrobial Drugs in Food Producing Animals*.[5] This document was developed to provide practitioners guidance on proper use of drugs that are currently approved in order to minimize the development of antimicrobial resistance. Within the document, the FDA lists the following two principles regarding judicious use of drugs in food-producing animals:

> "**Principle 1**: The use of medically important antimicrobial drugs in food-producing animals should be limited to those uses that are considered necessary for assuring animal health.
>
> **Principle 2**: The use of medically important antimicrobial drugs in food-producing animals should be limited to those uses that include veterinary oversight or consultation."

It is my opinion that there is much work to be done by the dairy veterinary community to uphold these principles, especially number 2.

The final guidance policy was GFI 213, *New Animal Drugs and New Animal Drug Combination Products Administered in or on Medicated Feed or Drinking Water of Food-Producing Animals: Recommendations for Drug Sponsors for Voluntarily Aligning Product Use Conditions with GFI #209*, which provided drug sponsors with a roadmap for complying with the GFI 209. This has led to feed efficiency and growth promotion claims being removed from feed-grade antimicrobials considered to be medically important. Additionally, over-the-counter labels have now been removed, leading to the need for veterinary prescription of these products for their remaining therapeutic purposes.[5]

Citing concerns stated within these guidance policies, essentially that antimicrobial use in food-producing animals combined with husbandry practices that likely lead to exposure of resistant bacteria to humans, the FDA has issued prohibitions and/or restrictions on the use of certain antimicrobials. The first is a prohibition on extra-label use cephalosporin products, excluding cephapirin, in major food-producing species.[6] The second is the Veterinary Feed Directive, released in its final form in June 2015.[9] The justification for these prohibitions was increased presence of multi-drug-resistant organisms in US and Canadian survey programs, the risk of these organisms being transmitted to humans through consumption of contaminated food, and a fear that consumption of these bacteria may reduce efficacy of first-line drugs for human medical practitioners. In the document announcing the prohibition on cephalosporins, the FDA cited high levels of ceftiofur residues found in cull dairy cattle and the high quantitative levels of those violative residues. The FDA cites several factors that lead to the misuse of ceftiofur products. These include: "(1) poor or nonexistent animal treatment records for adequately monitoring treated animals; (2) inadequate animal identification systems for monitoring treated animals; (3) animal owners' lack of knowledge regarding withdrawal times associated with the animal drug product; (4) the animal drug product was administered by a route not included in the approved labeling; (5) the animal drug product was administered at a dose higher than stated in the approved labeling; and (6) the animal drug product was administered to a type of animal (e.g., veal calves) not listed in the approved labeling."[6]

Developing Protocols and Maintaining Records

Data from the 2007 USDA National Animal Health Monitoring System (NAHMS) survey of the US dairy industry showed that 18.2% of all cows were treated for mastitis during the previous 12 months. In addition, 23% of all of the animals that were sold from the surveyed farms left due to mastitis or udder problems.[10] This estimate does not include cows that died from mastitis, thus underestimating the percentage of cows that leave dairies from mastitis as compared to other conditions like reproductive failure, which would likely result in few dead cows.

In the US, Doanes Market Research places yearly intramammary tube sales at approximately $24 million (US), with approximately $15 million spent on dry cow products (including Orbeseal) and the balance being lactating products.[1] Extrapolating from the NAHMS Dairy 2007 data, mastitis treatments are the most common reason for the use of antimicrobial agents on US dairy farms, with 85.4% of all cows that are affected with mastitis receiving antimicrobial therapy.[10] According to Doane's research referenced above, the largest majority of antibacterials used for the treatment of mastitis in the United States are from the penicillin and cephalosporin classes, which is not surprising considering that most intramammary tubes marketed in the United States are from the β-lactam family.[1]

With that being said, mastitis therapy seems to be one of the logical choices to begin development of treatment protocols. The FDA expectations are that all drug therapies on farms will be administered by a veterinarian or will be directed by a veterinarian based on a written, farm-specific protocol. Whether these treatment protocols are based on culture results or on generalized knowledge of the dairy, the area of protocol development and treatment record keeping is underdeveloped on most dairies. The treatment protocol should force the dairy employee to concentrate on making the correct diagnosis and to assess the cow to determine severity of the condition.

The difficulty from the dairy veterinarian's perspective is trying to craft treatment protocols that farm employees can comprehend and apply, but not hang too much risk on yourself in taking ownership of the treatment program. Treatment protocols should be developed based on medically relevant treatment practices and the technical ability of the farm's personnel. Currently, expectations from the regulatory personnel are high and many dairy farmers are still reluctant to follow the guidelines put forward. Following personal conversations with FDA personnel, the expectations are that written protocols are a living document that is regularly reviewed and updated by the veterinarian of record and farm management.

Drug Labels

While there is a lot of gray area with new regulations coming forward all the time, i.e., the cephalosporin restrictions, there are a couple of requirements that the dairy industry has been dealing with for a long time due to the requirements of the PMO. According to the PMO, all prescription drugs need to be labeled according to the regulation. Specifically, drug labels must contain the manufacturer's or distributer's name and address for over-the-counter drugs or that of the veterinary practitioner for prescription drugs. If the drugs are dispensed by a pharmacy under the order of a veterinarian, the label must include the name of the prescribing veterinarian and the name and address of the dispensing pharmacy. Drug labels must also contain directions for use, designated withdrawal times for meat and milk, any cautionary statements, and the active ingredients. On farm, drugs that are for lactating cows must be stored separately from those intended for non-lactating animals, with shelves for both groups appropriately labeled. During regular PMO-governed farm inspections, the drug inventory on the farm is often checked for correct labeling and storage.[8] Recently, some farms have been asked to maintain an ongoing drug inventory that can be reconciled with the farm's treatment records.

The Treatment Record

According to the FDA, the treatment record can be either paper or electronic. No matter the form, treatment records must be kept for 2 years after the animal leaves the dairy farm. In order to be a complete record, it must contain:

- The ID of animal. This also mandates that all animals on the farm be uniquely identified.
- Date of therapy.
- The condition being treated.
- The product used.
- The dosage used.
- Route and location of administration.
- The earliest date animals are cleared of violative residues for milk and meat.
- For paper records, the identification of the person administering the treatment.[8]

Veterinarians should also consult their state's practice act, as there may be additional requirements put forth by individual states for protocols, labels, and record keeping.

Conclusions

Violative residues in meat of cull dairy cattle occur at a much higher rate than for cull beef cattle. Many of these problems occur because people try to dump their problems into the cull market instead of alternative solutions such as humane euthanasia. As the industry gathers more information about treatment procedures and as the consumer becomes savvier about the source and safety of their food, increased scrutiny will develop for our clients. Development of treatment protocols and residue prevention protocols allow the herd veterinarian to undertake conversations about prudent drug use on farms, to help their clients develop realistic expectations following treatment, and to develop monitoring programs to track the success (or lack thereof) of herd treatment programs.

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Prudent drug use from the practitioner's viewpoint

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Abstract

With increased scrutiny from government agencies, animal rights groups and consumers, we need to be more vigilant with antibiotic usage on farm. Now more than ever we need to assure that a valid veterinarian-client-patient relationship (VCPR), written protocols and treatment records are in place for drug use documentation. As the veterinarian of record (VOR) it is our responsibility to oversee drug usage on our client's operations and monitor treatment response and protocol drift.

Key words: VCPR, drug usage, protocols

Résumé

Avec une surveillance accrue des organismes gouvernementaux, les groupes de défense des droits des animaux et des consommateurs, nous avons besoin d'être plus vigilant à l'utilisation des antibiotiques à la ferme. Maintenant plus que jamais nous avons besoin d'assurer qu'une relation vétérinaire-client-patient (RVCP), les protocoles écrits et enregistrements de traitement sont en place pour la lutte contre l'utilisation de la documentation. Comme le vétérinaire officiel (VOR) c'est notre responsabilité de superviser l'usage des drogues sur nos opérations du client et de surveiller la réponse au traitement et au protocole de la dérive.

Introduction

Today's dairy producers and veterinarians need to take an increased active role in drug usage and documentation on their operations. Written VCPR's, written treatment protocols and treatment records need to be common place in all operations. As the VOR, it is your responsibility to make sure all areas of prudent drug use are followed and documented. Everything from protocols to drug storage to employee training and oversight need to be reviewed and documented.

Implementation

The first step in the process needs to be a signed VCPR in place. There are several good sites for templates to use to create this. I have decided to make my own simple form that explains the principles of what I expect out of the VCPR from my clients. My approach is a simple statement that says the client has agreed that I am the VOR and that they agree to follow my treatment protocols and recommendations, and that I have agreed to accept the responsibility for herd health and drug usage, and to monitor results and be available for treatment failures or adverse outcomes.

I believe that before drugs can be scripted for a producer that a written protocol has to be in place for proper use of each drug that is on the farm. The owner needs to understand extra label use, route of administration, and withholding for all medicines stored on site. I educate my clients on the restricted uses for the cephalosporins, the need to only administer flunixin by the IV route and have them sign off that they understand and agree to follow those rules. This needs to be taken seriously and not just a rubber stamp signature on a piece of paper. If I do not belief the client is able or willing to follow these protocols than I believe I have the right to limit what drugs I will allow on farm, and if I am even willing to sign a VCPR on that particular farm.

Protocols need to be simple and easy to follow for them to be used routinely. There needs to be a case definition of what we are treating and easy to follow directions for treatment. When making our protocols, we need to be ever cognizant of withholding times and systems to record treatments. Protocols need to be made specific for each farm and what they are capable and willing to do, and not just a one size fits all concept.

Oversight

Treatment records need to be reviewed on a periodic basis and monitored for protocol drift and deviation from accepted practices. My philosophy is to review the records when on farm for routine herd health visits. At that time I go over the records with the owner and/or herdsperson to assure that all treatment are being recorded and properly administered. If problems are seen they can be addressed and possible changes to the protocols can be made. When reviewing the records, I initial on the page to document that I did review the records and everything appears to be within our protocols.

I also routinely inventory the medicine cabinet to assure that every drug on farm is listed on one of our protocols and that supplies are reasonable for disease incident on our farm and herd size.

It is important to record all on farm treatments that we do while on farm as well. We need to show our clients that if this is truly important than we need to take the effort to record what we do on farm in the treatment log.

Treatment logs don't need to be anything extravagant, but there is certain information that needs to be included. That is drug name, route of administration, dose, and name of person administering. These can be as simple as a 3-ring binder to complex computer software, as long as it is recorded.

Conclusion

As the VOR, it is our job to oversee drug use on our clients operations, and assure a safe wholesome product for their consumers. There continued use of antimicrobials on farm is contingent on us being diligent in drug oversight.

Fatty acids and fat supplements in lactating dairy cow rations*

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Introduction

In most Federal Milk Market Orders milk fat and protein yield are the major contributors to the price that producers receive for milk. The addition of supplemental fatty acid (FA) sources to diets is a common practice in dairy nutrition to increase dietary energy density and to support milk production. The ability to understand and model FA, the effects of individual FA, and different FA supplements on production parameters has direct impact on dairy industry recommendations and the usefulness of FA supplementation strategies. The emphasis of the current paper is on biological processes and quantitative changes during the metabolism of FA in the rumen and the effect this has on FA availability to the dairy cow, the digestibility of these FA, and their overall impact on performance. We will focus on recent research supplementing palmitic acid (C16:0) and stearic acid (C18:0)-enriched supplements, on feed intake, digestibility, milk production, and milk composition, and energy partitioning.

Lipid Metabolism in the Rumen and Mammary Gland

As well as being derived from specific supplements, FA in the dairy cow's diet are also present in forages and concentrates. Each feed/fat source is composed of a different mix of individual FA. The majority of FA in dairy cow diets contain 16 and 18-carbons. Generally, most cereal grains and seeds contain a high concentration of linoleic acid (C18:2 n-6), whereas linolenic acid (C18:3 n-3) is typically the predominant FA in forage sources. For example, corn, cottonseed, safflower, sunflower, and soybean oils are high in C18:2 n-6, whereas linseed is high in C18:3 n-3. Unsaturated FA are toxic to many rumen bacteria, thus an extensive metabolism of dietary lipids occurs in the rumen that has a major impact on the profile of FA available for absorption and tissue utilization.[19] The two major processes that occur are hydrolysis of ester linkages in lipids found in feedstuffs and the biohydrogenation of unsaturated FA. Biohydrogenation of unsaturated FA results in the conversion of unsaturated FA to saturated FA, mainly C18:0, through a series of biohydrogenation intermediates (conjugated C18:2 and *trans* C18:1 FA). The major substrates are 18:2 n-6 and 18:3 n-3 and the rate of rumen biohydrogenation is in the range of 70-95% and 85-100%, respectively;[12] thus C18:0 is the predominant FA available for absorption by the dairy cow under typical feeding situations.[1] A series of recent in vitro studies concluded that biohydrogenation occurs to enable rumen bacteria to survive the bacteriostatic effects of unsaturated FA, and that the toxicity of unsaturated FA is probably mediated via metabolic effects rather than disruption of membrane integrity. Furthermore, it appears that the degree of toxicity of different unsaturated FA varies for individual ruminal bacteria species; all the main species that comprise the ruminal cellulolytic bacteria appear vulnerable to inhibition by unsaturated FA.[16,17]

FA supplements are often used as a means to increase the energy density of the diet and many of these are referred to as inert. In this case inertness simply means that the FA supplement has minimal affects on rumen fermentation. Although deemed inert at the level used, they can still be hydrolyzed, if a triglyceride, or biohydrogenated, if unsaturated. Often, Calcium-salts of palm FA or canola are referred to as 'protected'. However, these are not protected from rumen biohydrogenation, but rather are considered to be ruminally inert with regard to their effects on the microbial population.[18]

Lipids in milk are primarily in the form of triglycerides (98%) with phospholipids and sterols accounting for 1.0 and 0.5 % of total lipids, respectively. Bovine milk is extremely complex and contains about 400 FA, a large proportion of which are derived from lipid metabolism in the rumen.[13] Milk FA are derived from 2 sources; <16 carbon FA from de novo synthesis in the mammary gland and >16 carbon FA originating from extraction from plasma. 16-carbon FA originate from either de novo or preformed sources. Substrates for de novo synthesis are derived from ruminal fiber digestion and dietary FA supply preformed FA for direct incorporation into milk fat.[18] Microbial synthesis of branched and odd-chained number FA in the rumen and absorption of biohydrogenation intermediates also contribute to the diversity of FA secreted in milk fat. Under typical conditions, about half of the FA in milk are synthesized de novo, 40 to 45 % originate from FA in the diet, and less than 10% are derived from mobilization of adipose tissue.[20] However, nutrition can substantially alter the balance between mammary de novo FA synthesis and uptake of preformed FA. C16:0, C18:0 and *cis*-9 C18:1 are the major FA in milk fat. The relatively high melting point of C16:0 and C18:0 requires the production of de novo synthesized FA or the conversion of C16:0 and C18:0 to *cis*-9 C16:1 and

*Adapted from paper published in the *Proceedings* of the Cornell Nutrition Conference, 2015.

cis-9 C18:1, respectively, in the mammary gland in order to maintain fluidity.

Overall Impact of FA Supplements

There is a wide range of FA supplements available for lactating dairy cattle. For example, Calcium-salts of free FA and prilled saturated free FA are two common types of supplements used in the dairy industry and they differ in FA content and FA profile. Calcium-salt supplements typically contain 80-85% FA and these typically provide approximately 50% saturated and 50% unsaturated FA. By comparison prilled saturated free FA contain approximately 99% FA which are approximately 90% saturated, 10% unsaturated. A summary of the FA profile of some commonly used supplements is provided in Table 1. Although in general FA supplementation has been shown to increase milk yield, milk fat yield, and the efficiency of milk production, great variation has been reported in production performance for different FA types, and indeed the same supplement across different diets and studies. This is evident in a meta-analysis examining the effect of FA supplementation to diets of dairy cows.[23] In general milk production and milk fat % and yield increased, DMI and milk protein % decreased, and milk protein yield was not affected by FA supplementation. There was a wide range of responses (~5 standard deviations) for all variables, indicating varied and marked biological effect of the different FA supplements.[23]

Utilizing a larger data set than Rabiee et al,[23] we recently performed a meta-analysis of production responses to commercially available FA supplements.[3] Available data were collected from 133 peer-reviewed publications of which 88 met our selection criteria, comprising 159 treatment comparisons. Calcium-salts of palm FA distillate (PFAD; n=73), saturated prilled FA (PRILLS; n=37), and tallow (n=49) supplemented at ≤ 3% diet DM were compared to non FA supplemented diets used as controls. Treatment comparisons were obtained from either randomized design (n=99) or crossover/Latin square design experiments (n=60). Preliminary results from the meta-analysis are shown in Figure 1.

Overall, FA supplementation increased yield of milk and milk components and reduced DMI. However type of supplement influenced response with PRILLS not reducing DMI, tallow having no effect on milk fat yield, and PFAD having no effect on milk protein yield. It is important to note that the majority of the studies reported in Figure 1 simply compared a single commercial FA supplement with a non FA supplemented control diet. This makes direct comparisons between different FA supplements difficult to interpret and importantly provide accurate answers to commonly asked questions (by farmers and nutritionists) as to which are the best FA supplements to use. There are limited reports in the published literature that have undertaken direct comparisons

Table 1. Fatty acid composition of common fat supplements (Data from our laboratory).

Fatty acid, g/100 g	Tallow	Ca-salt PFAD	Saturated free FA	C16:0-enriched
C14:0	3.0	2.0	2.7	1.6
C16:0	24.4	51.0	36.9	89.7
C18:0	17.9	4.0	45.8	1.0
C18:1	41.6	36.0	4.2	5.9
C18:2	1.1	7.0	0.4	1.3

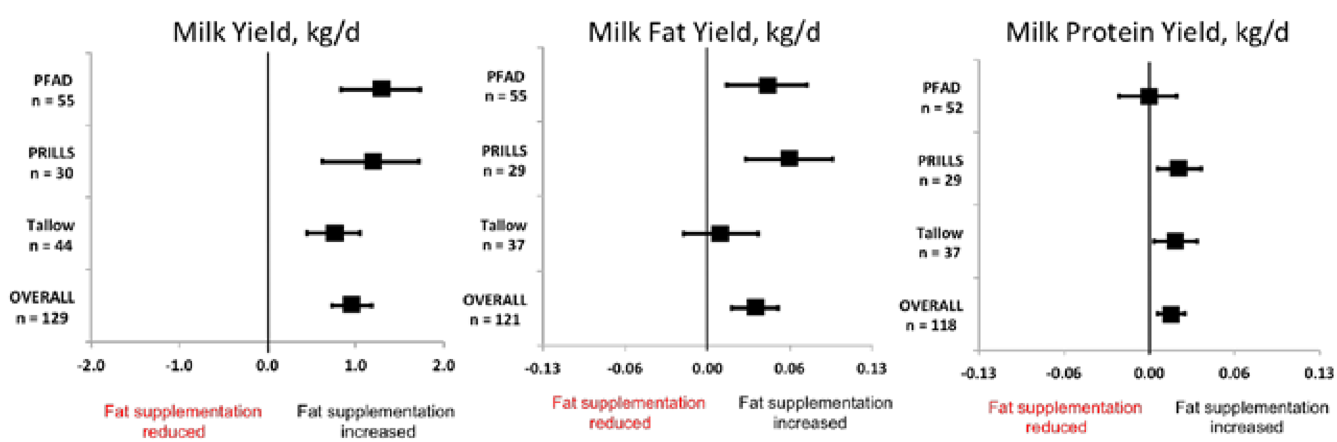

Figure 1. Effect of commercially available FA supplements on yield of milk, milk fat, and milk protein (Boerman JP, Lock AL. Feed intake and production responses of lactating dairy cows when commercially available fat supplements are included in diets: a meta-analysis. *J Dairy Sci* 2014; 97 (E-Suppl. 1):319). All data reported in peer-reviewed journals in which FA supplements were included at ≤ 3% diet DM compared to control with no added FA supplement. All studies had to have measurements of variance reported. **PFAD** – calcium salts of palm FA distillate (~ 50% 16:0, ~ 50% unsaturated 18-carbon FA); **PRILLS** – saturated FA prills (> 80% saturated FA [16:0 and/or 18:0]); **Tallow** – animal fat labeled as tallow (~ 50% 16:0 and 18:0, ~ 45% 18:1). Data analyzed using Comprehensive Meta-Analysis (CMA) version 2.0 (Biostat, Englewood, NJ), calculating difference between FA supplemented and control diets using a random effects model.

between different commercially available FA supplements. Results from the meta-analysis also suggest that responses to FA supplements interact with other dietary components, and this should be examined further.

Impact of Supplemental 16- And 18-Carbon FA on FA Digestibility

Under typical feeding situations, C18:0 is the predominant FA available for absorption by the dairy cow, regardless of the diet fed. As result, this FA has an important impact on total FA digestibility as recently observed in a recent meta-analysis and meta-regression examining the intestinal digestibility of long-chain fatty acids in lactating dairy cows.[4] We observed a negative relationship between the total flow and digestibility of FA (Figure 2A). Furthermore, the decrease in total FA digestibility appears to be driven by the digestibility of C18:0 because a negative relationship between the duodenal flow and digestibility of C18:0 was also was detected (Figure 2B).

The exact mechanisms for the reduction in digestibility are not understood; however, potential causes include limits in lysolecithin or competition for absorption sites.[7] Lysolecithin also acts as an amphiphile (substance with both water and lipid-loving capacity) and further increases the solubility of saturated FA.[9] During FA digestion in the small intestine, bile secretions supply bile salts and lecithin, and pancreatic secretions provide enzymes to convert lecithin to lysolecithin and bicarbonate to raise the pH. Lysolecithin is an emulsifier compound and together with bile salts desorb FA from feed particles and bacteria, allowing the formation of micelles, which is critical for absorption.[15] Once micelles are formed they facilitate transfer of water-insoluble FA across the unstirred water layer of intestinal epithelial cells, where the FA and lysolecithin are absorbed. Additional research to understand the observed reduction in C18:0 digestibility and how this may be overcome or improved is required.

Our recent FA digestibility research has utilized and focused on C16:0 and C18:0-enriched supplements. Of particular importance, Boerman et al[3] fed increasing levels of a C18:0-enriched supplement (85% C18:0) to dairy cows and observed no positive effect on production responses, which was likely associated with the pronounced decrease in total FA digestibility as FA intake increased (Figure 3A). Similarly, de Souza et al[6] fed increasing levels of a C16:0-enriched supplement (87% C16:0) to dairy cows and even though a positive effect was observed on production response up to 1.5% diet dry matter, we observed a decrease in total FA digestibility as FA intake increased (Figure 3B). Considering the results presented in Figure 3, given that the range on FA intake is similar across both studies, the decrease in total FA digestibility is more pronounced when there is increased intake/rumen outflow of C18:0 rather than C16:0, similar to our observations in Figure 2.

To further understand what factors influence FA digestibility, we recently utilized a random regression model to analyze available individual cow data from 5 studies that fed a C16:0-enriched supplement to dairy cows (unpublished results). We observed that total FA digestibility was negatively impacted by total FA intake, but positively influenced

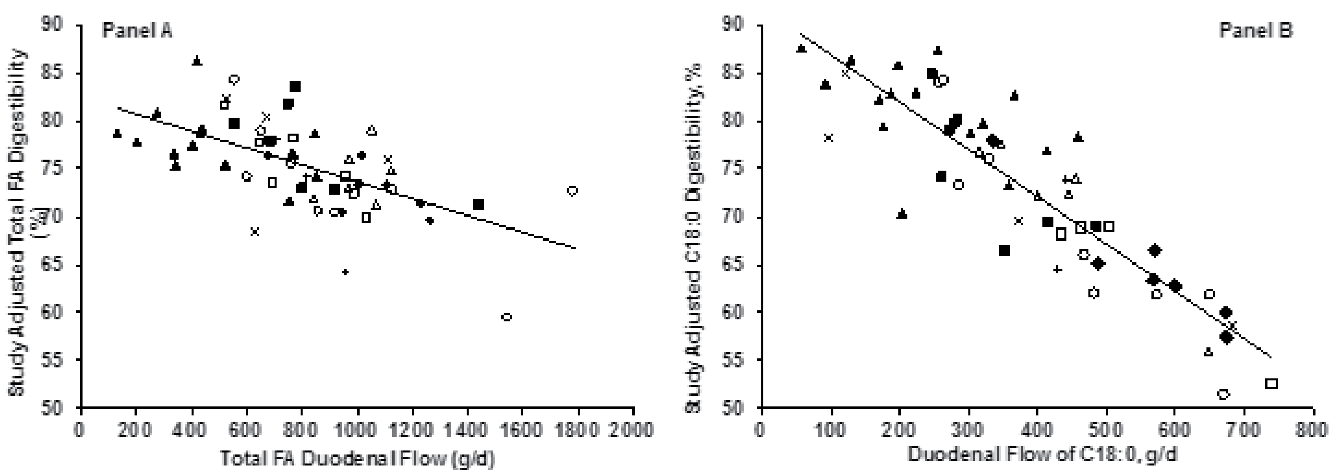

Figure 2. Relationship between study adjusted total FA intestinal digestibility and total FA duodenal flow (Panel A) and study adjusted C18:0 intestinal digestibility and duodenal flow of C18:0 (Panel B). Results from a meta-analysis using 15 published studies that measured duodenal flow and intestinal digestibility of fatty acids in dairy cows (Boerman JP, Firkins JL, St-Pierre N, Lock AL. Intestinal digestibility of long chain fatty acids in dairy cows: a meta-analysis and meta-regression. *J Dairy Sci* 2015; In Press. Available at: http://www.journalofdairyscience.org/inpress). Control treatments represented by black triangles; animal-vegetable fat treatments represented by black diamonds; calcium salt treatments represented by black squares; tallow treatments represented by open circles; vegetable oil treatments represented by open triangles; seed meal treatments represented by open squares; whole seed treatments represented by black addition sign; and other treatments represented by black multiplication sign.

by the intake of *cis*-9 C18:1. This suggests that a combination between 16-carbon and unsaturated 18-carbon FA may improve FA digestibility, but reason for this effect needs to be further determined.

Impact of Supplemental 16- and 18-Carbon FA on Production Responses

In the 1960's Steele and co-workers performed a series of studies using relatively pure sources of C16:0 and C18:0 and and their findings suggested that C16:0 supplementation induces a higher milk fat response (concentration and yield) as compared to C18:0 supplementation. More recent work from Enjalbert et al[8] suggests that the uptake efficiency of the mammary gland is higher for C16:0 than for C18:0 and *cis*-9 C18:1. We recently carried out a series of studies examining the effect of individual saturated FA on production and metabolic responses of lactating cows.[14,21,22,24] These results indicate that C16:0 supplementation has the potential to increase yields of milk and milk fat as well as the conversion of feed to milk, independent of production level when it was included in the diet for soyhulls or C18:0 (Table 2).

Rico et al[24] fed increasing levels of a C16:0-enriched supplement (87% C16:0) to dairy cows and observed a quadratic response with a positive effect on milk fat yield, 3.5% fat-corrected milk and feed efficiency up to 1.5% diet DM (Table 3). Furthermore, we recently utilized a random regression model to analyze available individual cow data from 10 studies that fed a C16:0-enriched supplement to dairy cows (unpublished results). We observed that energy partitioning toward milk was increased linearly with C16:0 intake, as a result of a linear increase in milk fat yield and 3.5% fat-corrected milk with increasing intake of C16:0.

Piantoni et al[22] reported that C18:0 increased DMI and yields of milk and milk components, with increases more evident in cows with higher milk yields, indicating that there was significant variation in response. Reasons why only higher yielding cows responded more positively to C18:0 supplementation than lower yielding cows remains to be determined. However, when we directly compared C16:0 and C18:0 supplementation the yield of milk fat and 3.5% FCM increased with C16:0 regardless of level of milk production (Table 2).[24] In a recent dose response study with mid lactation cows feeding a C18:0-enriched supplement (85% C18:0) increased DMI but had no effect on the yields of milk or milk components when compared to non-FA supplemented control diet (Table 4), which is probably associated with the decrease in FA digestibility (Figure 3A).[3]

There is mechanistic data to support the concept that individual FA can impact milk fat synthesis differently. Hansen and Knudsen[11] utilized an in vitro system and reported that C16:0 stimulated de novo FA synthesis and incorporation into triglycerides whereas other FA were either neutral or inhibitory. In addition, there were only minor differences in the esterification efficiency into triglycerides of various FA, except for C16:0, which was a better substrate than the other FA tested. These results in association with the digestibility results suggest that C16:0-enriched supplement improve performance of dairy cows, while understanding factors that affect the digestibility of C18:0 with increasing intake/duodenal flow may allow the development of strategies to overcome this possible limitation.

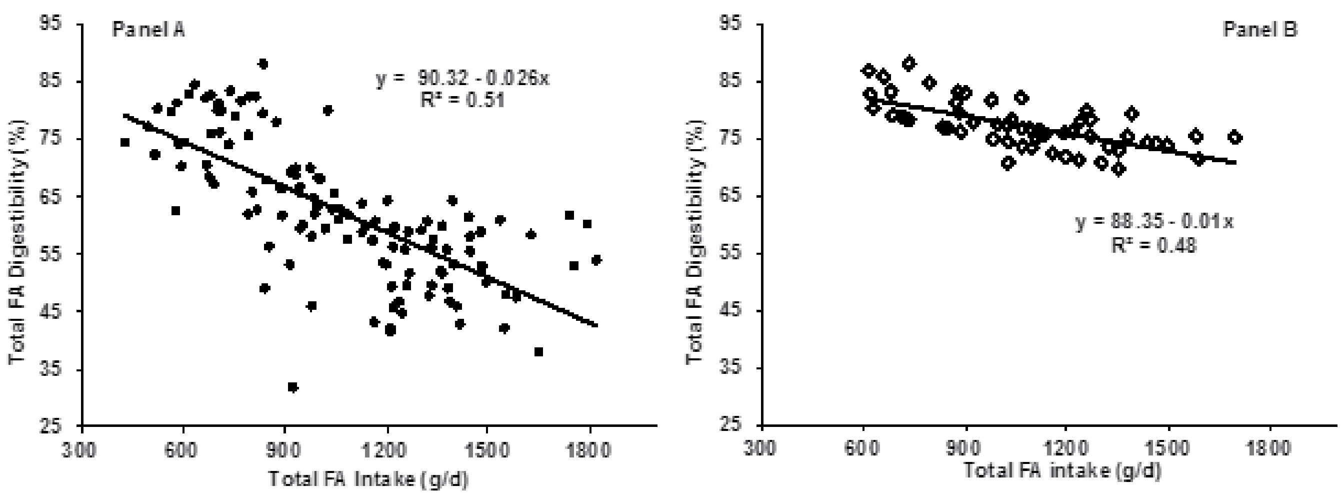

Figure 3. Relationship between total FA intake and total FA digestibility of dairy cows supplemented with either a C18:0-enriched supplement (Panel A) or a C16:0-enriched supplement (Panel B). Results in Panel A utilized 32 mid-lactation cows receiving diets with increasing levels (0 to 2.3% dry matter) of a C18:0-enriched supplement (85% C18:0) in a 4 X 4 Latin square design with 21-d periods (Boerman JP, Lock AL. Milk yield and milk fat responses to increasing levels of stearic acid supplementation of dairy cows. *J Dairy Sci* 2014; 97 (E-Suppl. 1):840). Results in Panel B utilized 16 mid-lactation cows receiving diets with increasing levels (0 to 2.25% dry matter) of a C16:0-enriched supplement (87% C16:0) in a 4 X 4 Latin square design with 14-d periods (de Souza J, Rico JE, Preseault CL, Allen MS, Lock AL. Total-tract fatty acid digestibility responses to increasing levels of palmitic acid supplementation of dairy cows receiving low- and high-fat diets. *J Dairy Sci* 2015; 98 (E-Suppl. 1):867).

Supplemental Fat Interactions with Other Dietary Components

The composition of the basal diet can also be an important element of production responses to FA supplementation. In high producing dairy cows an interaction was observed between forgage:concentrate ratio and response to supplemental FA.[28] In high-forage diets increased energy intake from supplemental saturated FA (mixture of C16:0 and C18:0) was directed mostly to body reserves, whereas in low-forage diets the increased energy intake from the saturated FA supplement was directed mostly to milk production. Using lower producing cows Grum et al compared diets at 2 different forage:concentrate ratios either without or with added saturated FA (mixture of C16:0 and C18:0). At both forage:concentrate levels supplemental saturated FA increased milk fat concentration and yield, whereas saturated FA supplementation had opposing effects on DMI when supplemented in the low and high forage:concentrate diets. In early lactation cows, van Knegsel et al[27] fed either high FA or high starch diets with the same concentrate to forage ratio (40:60). Additional FA in the high FA diet were provided by Ca-salts of palm FA and palm oil. Cows fed the high FA diet partitioned more energy to milk than cows fed the high starch diet and had a higher milk fat yield. No differences were found for energy retained as body protein, but

Table 2. Summary of DMI, milk production and composition, body weight, and BCS for cows supplemented with C16:0 and C18:0 supplements. The C16:0 supplement contained ~ 99% C16:0 and the C18:0 supplement contained ~ 98% C18:0.

	Piantoni et al. (2013)[1]			Piantoni et al. (2015)[2]			Rico et al. (2014)[3]		
Variable	**Control**	**C16:0**	**SEM**	**Control**	**C18:0**	**SEM**	**C16:0**	**C18:0**	**SEM**
DMI, kg/d	27.8	27.8	0.54	25.2[n]	26.1[m]	0.42	32.1	32.3	0.44
Milk yield, kg/d	44.9[b]	46.0[a]	1.7	38.5[n]	40.2[m]	0.71	46.6	45.8	2.02
Fat yield, kg/d	1.45[b]	1.53[a]	0.05	1.35[n]	1.42[m]	0.03	1.68[y]	1.59[z]	0.05
Milk fat, %	3.29[b]	3.40[a]	0.11	3.60	3.59	0.12	3.66[y]	3.55[z]	0.09
Protein yield, kg/d	1.38	1.41	0.04	1.14[n]	1.19[m]	0.02	1.50	1.49	0.05
Milk Protein %	3.11	3.09	0.05	3.00	2.99	0.05	3.24	3.29	0.05
3.5% FCM	42.9[b]	44.6[a]	1.35	38.6[n]	40.5[m]	0.76	47.5[y]	45.6[z]	1.64
3.5% FCM/DMI	1.54[b]	1.60[a]	0.03	1.53	1.55	0.04	1.48[y]	1.40[z]	0.05
Body weight, kg	722	723	14.7	727	730	12.8	720	723	13.6
BCS	2.99	2.93	0.15	2.67	2.67	0.11	2.93[z]	2.99[y]	0.11

[1]Treatments were either a control diet (with 2% of diet DM as added soyhulls) or a C16:0-supplemented diet (with 2% of diet DM as C16:0). Means within a row with different superscripts ([a, b]) differ ($P < 0.05$).

[2]Treatments were either a control diet (with 2% of diet DM as added soyhulls) or a C18:0-supplemented diet (with 2% of diet DM as C18:0). Means within a row with different superscripts ([m, n]) differ ($P < 0.05$).

[3]Treatments were either a C16:0-supplemented diet (with 2% of diet DM as C16:0) or a C18:0-supplemented diet (with 2% of diet DM as C18:0). Means within a row with different superscripts ([y, z]) differ ($P < 0.05$).

Table 3. DMI, milk production and composition, body weight, and BCS for cows supplemented with increasing levels of a C16:0-enriched supplement (Rico et al., 2013). The C16:0 supplement contained 87% C16:0.

	C16:0 supplementation, % diet DM					
Variable	**0%**	**0.75%**	**1.50%**	**2.25%**	**SEM**	***P*-value**
DMI, kg/d	28.8	28.8	28.6	27.4	0.83	0.05
Milk yield, kg/d	43.7	43.5	44.5	42.5	1.73	0.06
Fat yield, kg/d	1.63	1.69	1.78	1.70	0.09	0.01
Milk Fat, %	3.78	3.88	4.01	4.03	0.17	0.01
Protein yield, kg/d	1.36	1.36	1.40	1.32	0.06	0.08
Milk Protein, %	3.17	3.15	3.18	3.16	0.07	0.32
3.5% FCM, kg/d	45.3	46.1	48.0	45.9	1.91	0.02
3.5% FCM/DMI	1.57	1.60	1.68	1.68	0.07	0.21
Body weight, kg	703	705	701	701	25.7	0.76
BCS	2.66	2.48	2.71	2.84	0.05	0.94

energy mobilized from body fat tended to be higher in cows fed the lipogenic diet.[27]

In a recent study using high producing post-peak dairy cows we fed either a high fiber and FA diet (HFF) containing a 50:50 ratio of forage to concentrate containing a C16:0-enriched supplement at 2.5% of diet DM or a high starch diet (HS) containing a 40:60 ratio of forage to concentrate.[5] The two treatments resulted in similar apparent energy densities and intakes but the HS treatment partitioned more energy toward body gain whereas the HFF treatment partitioned more energy toward milk (Table 5). In established lactation, cows are usually in positive energy balance and the goals are to maximize milk and component yields and reduce excessive conditioning. We recently observed that reducing starch concentration (32 to 16% diet DM) reduced BW gain in late lactation cows and diminished the incidence of over conditioning, while supplementation with a C16:0-enriched supplement increased milk fat yield and fat-corrected milk.[10]

Table 4. DMI, milk production and composition, body weight, and BCS for cows supplemented with increasing levels of a C18:0-enriched supplement (Boerman and Lock, 2014b). The C18:0 supplement contained 85% C18:0.

	C18:0 supplementation, % diet DM					
Variable	**0%**	**0.80%**	**1.50%**	**2.30%**	**SEM**	***P*-value**
DMI, kg/d	28.5	29.1	29.6	30.0	0.61	0.13
Milk Yield, kg/d	38.3	38.6	38.2	37.8	1.65	0.51
Fat Yield, kg/d	1.43	1.40	1.40	1.42	0.04	0.61
Fat, %	3.79	3.72	3.74	3.82	0.08	0.29
Protein Yield, kg/d	1.33	1.33	1.32	1.30	0.05	0.49
Protein, %	3.49	3.50	3.48	3.49	0.05	0.91
3.5% FCM/DMI	39.8	39.4	39.3	39.3	1.40	0.77
FCM/DMI	1.43	1.39	1.35	1.33	0.04	0.03
Body weight, kg	738	739	735	737	12.0	0.58
BCS	3.44	3.40	3.39	3.42	0.08	0.37

Table 5. Body weight, body condition score, and calculated energy values for cows fed a high fiber diet containing a palmitic acid-enriched supplement or a high starch diet containing a mixture of dry ground and high moisture corn.[a]

	Treatments[1]			
Variable	**HFF**	**HS**	**SEM**	***P*-value[2]**
DMI, kg/d	26.9	27.4	0.38	0.02
3.5% FCM, kg/d	49.1	47.6	1.59	0.03
Change in BW, kg/d	0.33	0.78	0.10	0.003
Change in BCS, pt/28 d	- 0.01	0.24	0.03	0.001
Calculated energy values[3]				
Apparent NE_L of diet Mcal/kg	1.78	1.79	0.02	0.64
Milk, Mcal/d	32.8	32.6	1.05	0.05
Body Tissue Gain, Mcal/d	1.95	4.90	0.58	0.001
Maintenance, Mcal/d	10.6	10.7	0.17	0.02
Partitioning				
Milk, %	72.8	67.9	1.11	< 0.001
Body Tissue Gain, %	4.03	10.1	1.16	0.001
Maintenance, %	23.2	22.0	0.43	0.01

[1] Treatments were either a high fiber and FA diet (HFF) containing a 50:50 ratio of forage to concentrate containing a palmitic acid-enriched supplement at 2.5% of diet DM or a high starch diet (HS) containing a 40:60 ratio of forage to concentrate containing a mixture of dry ground and high moisture corn.

[2] *P*-value associated with treatment differences (HFF vs. HS; Trt).

[3] From the sum of milk energy output, maintenance energy calculated from metabolic BW, and body energy gain divided by DMI for each cow on each diet throughout the 28-d period.

Boerman JP, Potts SB, VandeHaar MJ, Lock AL. Effects of partly replacing dietary starch with fiber and fat on milk production and energy partitioning. *J Dairy Sci* 2015; 98:7264–7276

Further work is necessary, but higher fiber and FA diets (particularly diets supplemented with palmitic acid) may diminish the incidence of over conditioning in mid and late lactation cows.

Conclusion

The addition of supplemental FA to diets is a common practice in dairy nutrition to increase dietary energy density and to support milk production. Although in general FA supplementation has been shown to increase milk yield, milk fat yield, and the efficiency of milk production, great variation has been reported in production performance for different FA supplements, and indeed the same supplement across different diets and studies. Further work is required to characterize the sources of variation in response to FA supplementation. Just as we recognize that not all protein sources are the same it is important to remember that not all FA supplements are the same. The key is to know what FA are present in the supplement, particularly FA chain length and their degree of unsaturation. Once this information is known it is important to consider the possible effects of these FA on DMI, rumen metabolism, small intestine digestibility, milk component synthesis in the mammary gland, energy partitioning between the mammary gland and other tissues, and body condition. Interactions with other dietary components and the level of milk production are also important in determining the response to various FA supplements. The extent of these simultaneous changes along with the goal of the nutritional strategy employed will ultimately determine the overall effect of the supplemental FA, and the associated decision regarding their inclusion in diets for lactating dairy cows.

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Updates in transition cow health and nutrition

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Abstract

Transition cow nutritional management strategies have evolved significantly over the past 10 years and continue to evolve. Management of subclinical hypocalcemia is important to support high milk yield, excellent reproduction, and decrease subclinical disease. Feeding anionic diets before calving, perhaps using more aggressive strategies, improves blood calcium status post-calving and increases post-calving dry matter intakes and milk yield. Controlling energy intake before calving improves postpartum energy balance and decreases subclinical ketosis; feeding adequate metabolizable protein before calving helps maintain high milk yield after calving. Excellent feeding management (managing chop length of bulky forage and moisture of the (total mixed ration) TMR) of transition rations is critical for on-farm success; many dairy farms have opportunities for improved feeding management. There may be interactions of starch levels pre- and post-calving; cows fed low starch pre-calving rations should be fed lower starch diets after calving, whereas cows fed moderate starch rations pre-calving can likely be fed starch levels more typical of high starch cow rations after calving. Furthermore, there may be opportunities to combine higher fermentability with higher bulk in fresh cow rations to improve feed intakes after calving, as well as to more critically consider metabolizable protein and amino acid formulation of the fresh diet.

Key words: dairy, transition, feeding, health

Résumé

Stratégies de gestion de la nutrition des vaches en transition ont évolué considérablement au cours des 10 dernières années et continuera d'évoluer. Gestion de l'hypocalcémie subclinique est important de soutenir la production de lait, une excellente reproduction, et la diminution des maladies subcliniques. Les régimes alimentaires anioniques d'alimentation avant le vêlage, peut-être en utilisant des stratégies plus agressives, améliore l'état de calcium de sang après la mise bas et de post-mise bas augmente l'apport de matière sèche et la production de lait. Contrôler l'apport en énergie avant le vêlage améliore le bilan énergétique post-partum et la cétose subclinique diminue ; les protéines métabolisable adéquate avant le vêlage permet de maintenir un haut niveau de production laitière après le vêlage. Excellente gestion de l'alimentation (la gestion de la durée de broyage du fourrage encombrant et de l'humidité de la ration totale mélangée (RTM)) de rations de transition est cruciale pour le succès à la ferme ; de nombreuses fermes laitières ont des possibilités d'amélioration de l'alimentation de la gestion. Il peut y avoir des interactions entre les niveaux d'amidon pré- et post-mise bas ; vaches nourries bas amidon pré-mise bas devraient être nourris de rations alimentation amidon inférieure après le vêlage, tandis que vaches nourries de rations d'amidon modérée vêlage pré-peuvent probablement être nourris plus typiques des niveaux d'amidon l'amidon des rations de vache après le vêlage. En outre, il peut être possible de combiner des fermentation avec des rations de vache frais en vrac pour améliorer les prises d'alimentation après le vêlage, ainsi qu'à examiner de façon plus critique et d'acides aminés protéines métabolisable de formulation de l'alimentation.

Introduction

Nutritional management strategies for transition cows have evolved significantly over the past 10 years in the dairy industry, and ongoing research and experience continue to refine our recommendations for nutritional management of dairy cows during both the prepartum and postpartum periods. Our high-performing herds combine high milk production with modest loss of body condition score (no more than 0.50 or so units during early lactation), low incidence of metabolic and immune function-related diseases, excellent reproductive performance during early lactation, and have calves born alive and ready to thrive. In this paper, we will outline several areas that have received significant research attention during the past several years, along with some that are currently very active areas of research that likely will lead to continued evolution of nutritional recommendations for transition cows.

Feeding Strategies for the Dry Cow

Management of hypocalcemia – an old topic made new again

Clinical milk fever is a thing of the past on many dairies. Research over the past 5 years has shifted the hypocalcemia focus to include management of not only clinical cases of milk fever, but also cows that experience subclinical drops in blood calcium postpartum. Even in herds with very low milk fever incidence, subclinical hypocalcemia (SCH) after calving can affect 50% or more of the herd, predisposing cows to infectious and metabolic disease and reducing their productive and reproductive potential.[4,18,21] As these associations continue to be researched, the need for strategies to reduce SCH incidence is becoming more evident. Reducing the dietary cation anion difference (DCAD; Na + K – Cl – S = mEq/100 g DM) of the prepartum ration is a tried and true method for decreasing rates of clinical milk fever.[2,9] Strategies for implementing this approach can range from minimizing the dietary potassium (aiming for a low but still positive DCAD) to varying inclusion rates of anion supplements to reach a negative DCAD.

Recent work by our group at Cornell University aimed to determine if benefits in calcium status and production parameters increased when anion inclusion rate was incrementally increased (and therefore, DCAD decreased) in a low-potassium prepartum ration.[22,23] Three experimental groups included a low-potassium control ration (+18.3 mEq/100 g DM), partial anion supplementation (+5.9 mEq/100 g DM), and full anion supplementation (-7.4 mEq/100 g DM). Diets were managed to maintain urine pH of the full anion supplemented group between the target of 5.5 to 6.0. Ultimately, as prepartum DCAD was decreased in this trial, average postpartum plasma calcium was increased, indicating that the greatest benefit in calcium status postpartum was seen in cows fed the lowest DCAD. Interestingly, an effect of parity was seen such that older cows (3rd+ lactation) benefited the most when fed the lowest DCAD.[22] Increases in postpartum dry matter intake and milk yield were seen for cows fed decreasing DCAD. Cows fed the lowest DCAD ration prepartum produced over 7 lb (3.2 kg)/day more milk in the first 21 days compared to cows fed the low-potassium control ration.[23] This study indicates that implementing a more aggressive DCAD prepartum can yield the greatest benefits postpartum when compared to a low-potassium control approach.

Measuring urine pH is an essential component of monitoring prepartum DCAD, and can also provide valuable information about feeding management.[5,11] Urine pH should be measured in midstream urine samples from approximately 12 to 15 cows weekly. It is important that the time relative to feeding is consistent from week to week, since urine pH response may fluctuate throughout the day. Large variation from cow to cow within a week may indicate undesirable consumption of the ration, whether that be a result of overcrowding, social factors, or sorting due to poor diet mixing. Variation in average urine pH from week to week can indicate inconsistency in ration mixing or changes in feed ingredient composition. This information can be used to improve feeding and management strategies to increase transition cow success.

Dry period plane of energy and effects on health, production, and reproduction

Since the early 2000s we have largely abandoned the historically proposed "steam up" approach to dry cow feeding. With increasing evidence from research conducted at the University of Illinois, a controlled energy strategy to feeding dry cows was proposed.[8] Lower postpartum concentrations of non-esterified fatty acids (NEFA) and ketone bodies (e.g. ß-hydroxybutyrate or BHB) were observed with these controlled energy diets and the incidence of metabolic disease was decreased.[6,10] However, detrimental effects on early postpartum milk production were observed in some studies, particularly in those that restricted energy intake below requirements. Relatively little attention was paid to controlling for adequate protein supply when controlling energy intake.

Cornell research investigated the effects of 3 different dietary energy strategies during the dry period: a bulky, high-fiber controlled energy diet (approximately 100% of energy requirements); a high-energy diet (approximately 150% of energy requirements); and a step-up approach where the controlled energy diet was fed during the first 28 days after dry-off, after which cows were fed an intermediate diet (approximately 125% of energy requirements) for the remainder of the dry period (28 days before expected calving). All diets were fed ad libitum and predicted metabolizable protein (MP) supply was formulated for approximately 1300 g/d. Our observations confirmed that feeding a controlled energy diet prepartum was associated with lower postpartum concentrations of markers of negative energy balance, such as NEFA and BHB, whereas milk production was not different between the groups. In addition, as previously observed by others,[3,10] glucose and insulin concentrations remained higher post-partum in the controlled energy group.[17] This is of great importance for the fresh cow, as glucose is necessary for normal immune cell function and insulin prevents excessive breakdown of adipose and muscle tissue due to its direct inhibitory effects on these processes. Furthermore, high concentrations of BHB and NEFA, as well as lower circulating concentrations of glucose and insulin as observed in cows overfed energy prepartum, have been associated with decreased reproductive success in a number of studies.[3,14,20]

Metabolizable protein (MP) in the dry period

The drop in dry matter intake around the time of calving as well as the relatively slow increase in intakes in early lactation do not only affect the energy balance of fresh cows, but also their protein balance. Protein and amino acids are instrumental to many physiological functions, particularly cell renewal and immune system function, both of which are particularly important in the transition cow as this is the highest at risk period for infectious diseases like metritis and mastitis. Research shows that protein mobilization starts in the last 2 weeks before calving and carries on until about week 6 post-partum. A majority of mobilized protein is used for milk protein synthesis, with a smaller proportion being used for glucose synthesis. Our current recommendation for an adequate protein supply during the close-up period is 1,200 to 1,400 g/d of predicted MP. Particularly with controlled energy diets, adequate sources of rumen undegradable protein (RUP) should be included in the diets to achieve this goal. No beneficial effects on post-partum performance or health have been observed when higher than recommended amounts of MP were fed. When considering the cost of protein feed sources and environmental implications of excess nitrogen excretion, feeding protein in great excess of requirements is unwarranted.

Effects of dry period plane of energy on colostrum composition

Most of the research on the effect of prepartum diet on colostrum composition of cattle stems from research in beef cattle. Few studies have evaluated the effect of feeding dairy cows either a controlled or higher energy diet on colostrum quality and quantity while controlling for adequate protein supply. Our research showed that cows fed a controlled energy diet for the whole duration of the dry period (approximately 57 d) had a greater concentration of IgG in colostrum (96 g/L) than those fed a higher energy diet (72 g/L) during the dry period. At the same time colostrum volume was not significantly different (13 vs 16 lb; 6 vs 7.3 kg).[16] Higher concentrations of IgG in colostrum allow for a higher amount of antibodies to be administered to the calf in 1 feeding, which we consider beneficial for passive transfer of immunity. In our opinion and according to experience shared by others, it is important to allow for an adequate supply of MP prepartum while controlling the diet for energy to prevent a drop in colostrum volume.

Feeding management of dry cow rations

Even the best formulated rations will not be effective if they are not well-implemented. Bulky rations with the forage base consisting of either straw or mature, low-potassium hay blended with corn silage and a grain mix can be easily sorted by cows if the straw or hay is not chopped, ideally prior to mixing into the TMR. In new research conducted by our group[13] and involving 72 commercial dairy farms in New York and Vermont, only 25% of the prefresh TMR had particle size within recommended ranges (10 to 20% on the top screen; 50 to 60% in the middle; < 40% in the pan) using the Penn State Particle Separator (PSPS). We recommend chopping the straw or hay such that the long particles are no more than 1.5 inches (3.8 cm) (33% on each of the 3 sections of the PSPS). Often, addition of water or another wet ingredient to decrease the ration dry matter into the 46 to 48% range is also required for optimal effectiveness of these rations. Accuracy and consistency in feed delivery and composition are paramount to a successful transition feeding program.

Emerging concepts in feeding the fresh cow

Ironically, the vast majority of transition cow nutritional management research conducted over the past 20+ years has focused almost exclusively on the dry cow. In most studies focused on transition cow nutrition, dietary treatments were imposed during the prepartum period only and cows were fed a common diet during the post-calving period. Fresh cow rations are common in the dairy industry, although often they are modest variations of the high cow ration, perhaps with slightly higher fiber content and/or the inclusion of modest amounts (1.5 lb (0.7 kg) or less) of straw or hay, lower starch content, additional rumen undegradable protein, increased amounts of supplemental fat, or targeted inclusion of other nutrients or additives (e.g., rumen-protected choline, additional yeast or yeast culture, additional monensin). Success of these strategies was gauged largely at the farm level, because until recently very few controlled research studies examined these factors in the ration fed during the immediate post-calving period.

Starch and fiber interactions during the pre-calving and post-calving periods

The research groups at Cornell and the Miner Institute have completed 3 experiments evaluating starch content of the post-partum diet and starch content of the postpartum diet and monensin supplementation throughout the periparturient period.[7,19,24] Dann and Nelson[7] fed 72 multiparous Holstein cows a controlled energy diet during a shortened (40 d) dry period and then 1 of 3 dietary starch regimens during early lactation–a low starch (21.0% starch) diet for the first 91 d postpartum, a medium starch (23.2% starch) diet for the first 21 d post-partum followed by a high starch (25.5% starch) diet through 91 d post-partum, and a high starch diet (25.5% starch) for the first 91 d post-partum. Cows fed the low starch and medium-high starch diets after calving had similar DMI and performance post-calving, whereas cows fed the higher starch diet post-calving had lower DMI and lower milk yield.

McCarthy et al[19] fed primiparous (n = 21) and multiparous (n = 49) Holstein cows diets containing either 26.2% or 21.5% starch from calving through d 21 postpartum; beginning on d 22 postpartum all cows were fed the diet containing 26.2% starch through d 63 postpartum. Cows were also fed either 0 or 400 mg/d of monensin beginning 21 d before expected calving and either 0 or 450 mg/d of monensin beginning at calving and continuing through d 63 post-partum. In contrast to the Miner Institute study, cows fed higher starch diets had faster increases in milk yield and DMI along with lower plasma NEFA and BHBA consistent with better energy status. Cows fed monensin had higher post-partum DMI and milk yield and lower plasma BHBA, regardless of starch level in the post-partum diet.

The Miner and Cornell studies suggest apparently opposite responses to feeding low- and high-starch diets during the fresh period. However, the pre-calving diets were very different between the 2 studies. In the Miner study, cows were fed a typical low starch (13.5% of DM), controlled energy diet for the entire 40-d dry period whereas in the Cornell study, cows were fed a moderate starch close-up diet (17.4% of DM). We speculate that the differences in starch levels between pre-calving and post-calving diets should be no more than 8 to 10 percentage units; cows fed lower starch diets (12 to 14%) immediately before calving should be transitioned onto a fresh diet containing no more than 21 to 22% starch. On the other hand, cows fed higher starch rations before calving (16 to 18% starch) likely can be transitioned onto fresh rations containing 26 to 27% starch as long as there is sufficient physically effective fiber in the fresh cow diet.

Based upon some case study work as part of a controlled experiment,[19] we also speculate that there are interactions between starch and fiber levels in the post-calving diet. When we had insufficient physically effective fiber in the fresh diet, DMI was higher for cows fed a lower starch diet. However, when straw was increased to levels higher than typical (~ 11% of diet dry matter compared to typical 2 to 4%), DMI was higher for cows fed the higher starch diet. We are currently following up this work with controlled research to further understand the role of fiber in the fresh cow ration.

Additional requirements for metabolizable protein and amino acids in fresh cows?

In addition to being in negative energy balance, cows also are in negative protein balance during early lactation. This negative protein balance reaches its low point at about 7 days after calving, and cows likely reach positive protein balance by about 21 days after calving.[1] Cows compensate for this negative protein balance in part by mobilizing body protein post-calving, although we understand this process much less than we do the mobilization of body fat during early lactation.

Recently, Larsen et al employed an innovative experimental approach in which they estimated the negative MP balance in cows during the postpartum period and then infused casein into the abomasum in order to eliminate the deficit in MP.[12] Controls received a water infusion, and treatment cows received casein planned to supply 360 g at 1 d postpartum and 720 g at 2 d postpartum, followed by daily reductions of 19.5 g/d ending at 194 g/d at 29 d postpartum. The casein infusion resulted in a high and nearly constant supply of MP from 2 to 29 d postpartum. Although the number of cows in this experiment was very small (n = 4 per treatment), cows infused with casein produced an impressive 7.2 kg/d (~ 16 lb/day) more milk than controls during the experimental period. Further research is needed to evaluate cow responses to supplies of both total MP and individual amino acids during the postpartum period.

Conclusions

Nutritional management strategies for transition cows have evolved significantly over the past 10 years and continue to evolve. Formulation and implementation of anionic diets pre-calving improves both calcium status and performance (feed intake and milk production) post-calving. Controlled energy diets pre-partum moderate the dynamics of DMI, BCS, and fat mobilization; effective implementation of these diets through excellent feeding management improves metabolic health of fresh cows. Although research focused specifically on nutrition of the fresh cow is limited, new results suggest that there are interactions between starch levels pre-calving and post-calving along with opportunities to combine higher fermentability with higher effective fiber levels to maintain rumen stability. Furthermore, there appear to be opportunities to focus on metabolizable protein and amino acid nutrition not just during the pre-calving period, but also during the immediate post-calving period.

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New techniques: TMR Audit® – a systematic approach to evaluating feeding systems to enhance production and health

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Abstract

Feeding systems need to be monitored and evaluated just like milking systems. A TMR Audit® is a systematic approach designed to evaluate the feeding program. The objectives are to look for ways to minimize variation between the formulated and consumed ration, minimize shrink, and to improve the efficiency of the feeding system. Areas evaluated include silage and feedstuff management, TMR load preparation, TMR consistency within and between loads, and feedbunk management. Management procedures should be in place to minimize top spoilage of silage stored in bunker silos and with other feedstuffs, and feeding personnel should be trained that spoiled feed needs to be discarded, not fed. Due to variation in DM and nutrient content across the face of the silo and across bales of hay or balage, it is best to premix an individual forage prior to using that forage in preparing a load of TMR. The Penn State Particle Separator can be used to evaluate TMR consistency. We have identified 10 primary factors that can lead to variation within and between loads of TMR. These factors include the following: worn equipment, mixing time, load size, levelness of mixer during mixing, loading position on the mixer box, hay or straw quality and processing, loading sequence, liquid distribution, vertical mixer auger speeds, and hay restrictor plate settings in vertical mixers. Feed efficiency can be improved by feeding multiple times per day as opposed to once daily. Feed push-ups need to be done frequently enough to ensure easy access to feed along the entire feed bunk. TMR Audits can help to improve performance and health on the dairy.

Key words: dairy, TMR, audit, production

Résumé

Les systèmes d'alimentation doivent être surveillés et évalués comme le sont les systèmes de traite. Le *TMR Audit®* est une approche systématique servant à l'évaluation des programmes d'alimentation. Les objectifs sont de trouver des moyens de minimiser la variation entre la ration prescrite et consommée, de minimiser les pertes alimentaires et d'améliorer l'efficacité du système d'alimentation. Les composantes concernées inclus la régie de l'ensilage et du fourrage, la préparation de la ration totale mélangée (RTM), l'uniformité des RTM dans le lot et entre les lots et la régie des mangeoires. Des pratiques de gestion devraient être mises en place pour minimiser la détérioration de la partie supérieure de l'ensilage remisé dans le silo-couloir et avec d'autres fourrages. Le personnel chargé de l'alimentation devrait aussi être formé pour s'assurer que les aliments souillés soient laissés de côté plutôt que donnés aux animaux. En raison de la variation dans les matières sèches et des teneurs en éléments nutritifs à travers le silo et aussi de la variation qui existe d'une botte de foin ou d'une balle d'ensilage à l'autre, il est préférable de prémélanger l'aliment avant l'utilisation de cet aliment dans la préparation d'un lot de RTM. Le *Penn State Particle Separator* peut être utilisé pour évaluer l'uniformité de la RTM. Nous avons identifié 10 facteurs qui peuvent contribuer à la variation dans un lot et entre les lots d'une RTM. Parmi ces facteurs, on retrouve les suivants : le délabrement de l'équipement, le temps de mélange, la grosseur du lot, le niveau du mélangeur durant le mélange, la position de chargement dans le mélangeur, la qualité et le traitement du foin ou de la paille, la séquence de chargement, la distribution du liquide, la vitesse de la vis d'alimentation dans le mélangeur vertical et le réglage du réducteur de foin dans le mélangeur vertical. L'efficacité de l'alimentation peut être améliorée en alimentant les animaux plusieurs fois au lieu d'une fois par jour. La redistribution des aliments doit être faite assez souvent pour faciliter l'accès aux aliments sur toute la surface de la mangeoire. L'inspection de la RTM peut améliorer la performance et la santé dans une ferme laitière.

Introduction

Much effort and emphasis is often placed on the milking system, and for good reason – every cow is exposed to it at least 2 times daily. Dairies typically have specific milking protocols, vacuum levels and pulsators are monitored, and equipment maintenance routinely performed. The feeding system, however, often does not receive nearly as much attention. While the diet may be formulated with the most advanced nutrition software, the implementation of the feeding program is often far from rigorous. A TMR Audit uses a systematic approach to evaluate the implementation of the feeding program. The objectives are to look for ways to minimize variation between the formulated and consumed ration, and to improve the efficiency of the feeding system. Areas evaluated include silage and feedstuff management, TMR load preparation, TMR consistency within and between loads, and feedbunk management.

TMR Audits

A TMR Audit consists of an intensive evaluation of the feeding system.[4] One of its primary objectives is to reduce the amount of variation between the formulated and consumed ration. The Diamond V Technical Services team has conducted several thousand TMR Audits on dairies across the United States. Anecdotally, we have observed an improvement in performance as feeding routines were changed and TMRs became more consistent.

Keys to collecting, analyzing, and feeding a consistent forage

Forage within a bunker silo varies in DM and nutrients primarily across the vertical, but also somewhat across the horizontal, aspect of the silo. To minimize this variation, forages should first be defaced (starting from the bottom and working up), and then pushed into a central pile with the loader bucket and further mixed with the loader bucket. Forages can also be loaded into the mixer wagon, mixed for 2 minutes, and moved to a convenient loading location. The feeder should be careful to include any forage at the bottom of the silo that was not removed with the defacer. This basic procedure, which should be a standard operating protocol in all feeding systems, helps to make the TMR consistent throughout all loads of feed.

Forages should always be premixed prior to feeding or collecting a sample for analyses. This is a critical management technique that can result in more uniform DMI, improvements in cow health, and reduced variation in feed analytical results over time. Ensiled forages can be premixed by defacing or uniformly scraping across the entire face of the silo, pushing the forage into a central pile, and then mixing by either turning with the loader bucket, or loading onto the mixer wagon and mixing for 2 minutes before discharging at the desired location for load preparation. Now the forage can be used for feeding or a sample collected for analysis.[5]

Discard all spoiled feed

Moldy and/or rotting feed, and silage that has undergone clostridial fermentation can cause indigestion, reduced intakes and ruminal digestibility, and possibly abortions. Feeders should be trained in the importance of avoiding the feeding of spoiled feed.

Evaluating TMR mixing and consistency

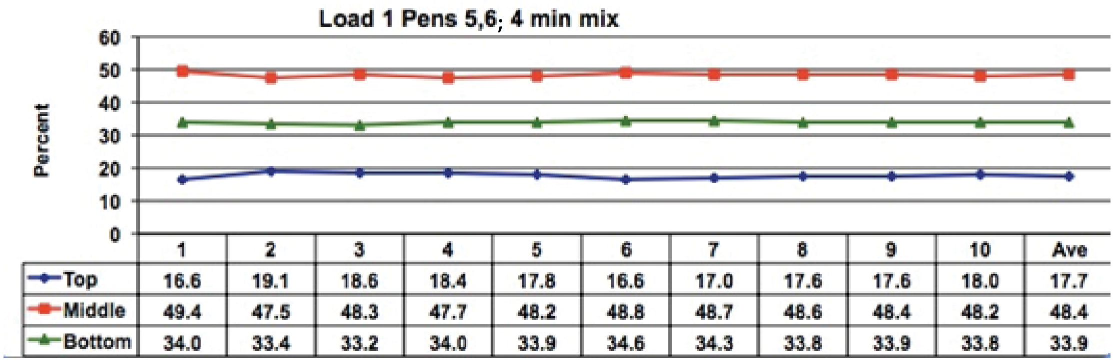
One of the objective measurements in a TMR audit is an evaluation of the TMR particle size distribution along the length of the feedbunk. Ten TMR samples, approximately 1.4l in volume and lightly packed, are collected along the feedbunk in a proportional distance to the unloaded TMR. TMR samples are then run through the Penn State Particle Separator (PSPS; 2 screens and pan) as recommended.[2,3] The particle size distributions are graphed and the coefficient of variation for each screen and the pan determined. Our goals are to have the coefficient of variation (CV) to be less than approximately 2.5% for the middle screen and pan. The top screen often has much less material on it, and hence can be more difficult to have a small CV. However, the top screen CV can be kept to less than 10% even with relatively small amounts of TMR retained on it. TMRs can be highly consistent (Figures 1a and 1b), and highly variable (Figures 2a and 2b). Although entirely anecdotal, we have observed improvements in production, milk components, and reduced digestive disturbances as CV have been reduced from above 5% to less than ~ 2.5% on the middle screen and pan of the PSPS.

The mixer wagon should also be observed when mixing a full load of feed. Are all regions of the TMR being aggressively mixed? Look carefully for areas or regions that are stagnant or moving very little. This can be an indication of a mixer problem, such as worn parts, overloaded wagon, or improper loading sequence.

The 10 primary factors contributing to TMR variability within and between loads include the following: equipment wear (augers, kicker plates, knives, etc.); mix time after the last ingredient; load size; levelness of mixer during mixing; loading position on the mixer box; hay/straw quality and processing; loading sequence; liquid distribution; vertical mixer auger speeds; and hay restrictor plate setting in vertical mixers.

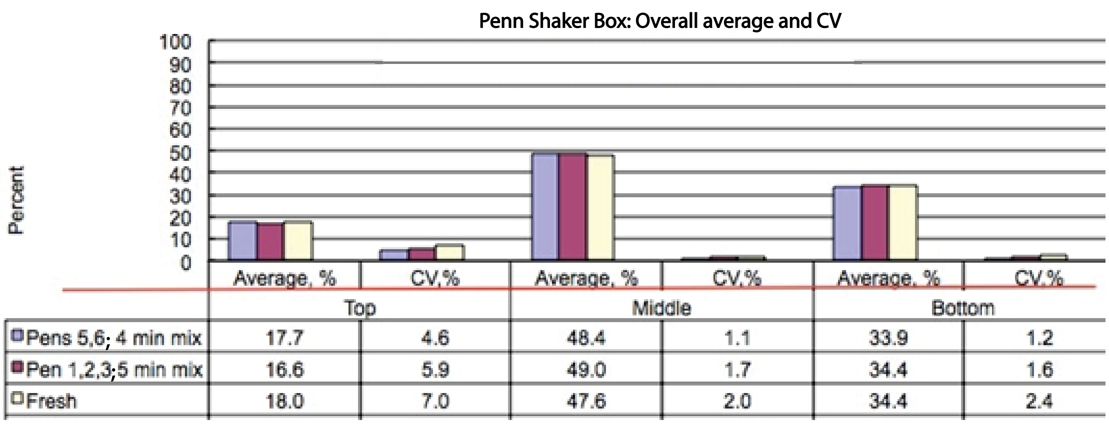
Equipment wear

Feed mixing equipment is not routinely evaluated. If the mixer is delivering a TMR, it is generally assumed to be working properly. Unfortunately, this is often not the case. Worn parts and equipment can result in poor mixing action. The kicker plate is mounted on the lateral aspect of the leading edge of the auger in vertical mixers. Most, but not all, vertical mixers utilize some type of a kicker plate to remove feed from along the bottom wall of the mixer. This allows feed from the upper aspect of the mixer to move down the wall. The mixing process occurs as feed is "falling" along the wall, and then "rising" more in the center regions of the mixer because of the auger movement. A worn kicker plate does not remove sufficient feed from the wall of the mixer, resulting in improper feed flow and inadequate mixing. Worn augers won't mix properly, while dull or missing knives won't adequately process long forage. Dairies should have regular maintenance programs, measuring the clearance between the kicker plate and the mixer wall, and evaluating augers, knives, and other parts on the mixer. Although the frequency will vary with ingredients, this should be done approximately every 500 loads.



	1	2	3	4	5	6	7	8	9	10	Ave
Top	16.6	19.1	18.6	18.4	17.8	16.6	17.0	17.6	17.6	18.0	17.7
Middle	49.4	47.5	48.3	47.7	48.2	48.8	48.7	48.6	48.4	48.2	48.4
Bottom	34.0	33.4	33.2	34.0	33.9	34.6	34.3	33.8	33.9	33.8	33.9

Figure 1a. The particle size distribution determined with the Penn State Particle Separator from 10 TMR samples collected along the feedbunk as the TMR was unloaded. This TMR was prepared with a twin-screw vertical mixer wagon (the same type as in 2a below) and is extremely consistent; the particle size distribution changes very little within a screen along the length of the feedbunk.



	Top		Middle		Bottom	
	Average, %	CV,%	Average, %	CV,%	Average, %	CV,%
Pens 5,6; 4 min mix	17.7	4.6	48.4	1.1	33.9	1.2
Pen 1,2,3;5 min mix	16.6	5.9	49.0	1.7	34.4	1.6
Fresh	18.0	7.0	47.6	2.0	34.4	2.4

Figure 1b. The mean particle size and coefficient of variation from 10 TMR samples collected from 3 different loads from the dairy in Figure 1a. This is an example of 3 TMR loads that are very consistent within a load. The goal is to have the CV be less than 2.5% for the middle screen and pan, which this dairy meets for all loads tested.

Mix time after the last ingredient

Many feeders do not use a timer to monitor mix time after the last ingredient has been added to a load. The best procedure is to utilize the timer function available on most feed management software programs, but external timers, such as phones and clocks on radios, can also be used. Most mixers need about 4 +/- 1 minutes to properly mix when run at nearly full power (1700 to 2000 RPM engine speed). This can be assessed with the TMR sampling procedure discussed above.

Load size

Feed particles mix best when they are falling, or at least dropping, together at the same time. Additionally, shrink increases if load sizes are too large and feed is spilling out of the mixer. Reel auger mixers are notoriously over-loaded. One simple technique we have learned is to simply observe the mixing action of the mixer when a full load of feed is being mixed. Feed should be actively moving in all visible areas of the load of feed.

Levelness of the mixer during mixing

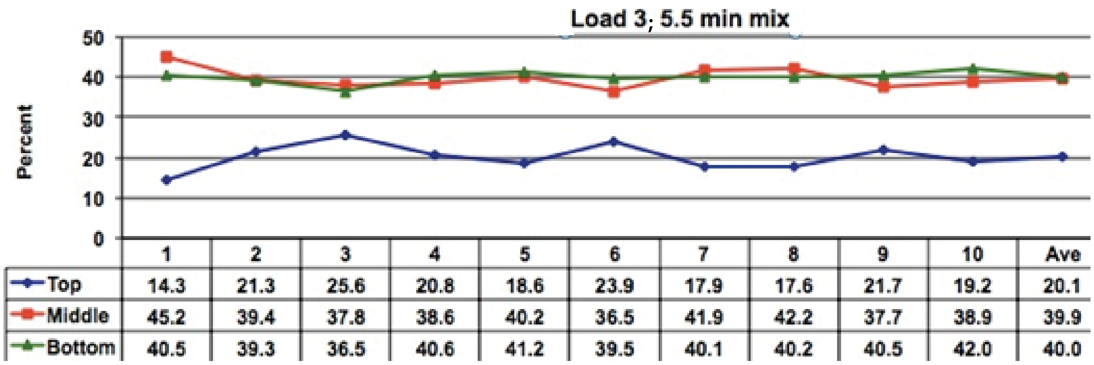
A mixer that is not level when mixing can lead to feedstuffs migrating to a region of the mixer, and to spilling out of the mixer box. Loads should be level at least during mixing, and preferably at all times. In addition to parking on level ground, sometimes the hitch can be moved up or down to level out the mixer wagon.

Loading position on the mixer box

Why make it any harder on the mixer than necessary? Targeting the loader bucket for the center of the feed mixer assists in uniform feed distribution throughout the mixer more quickly.

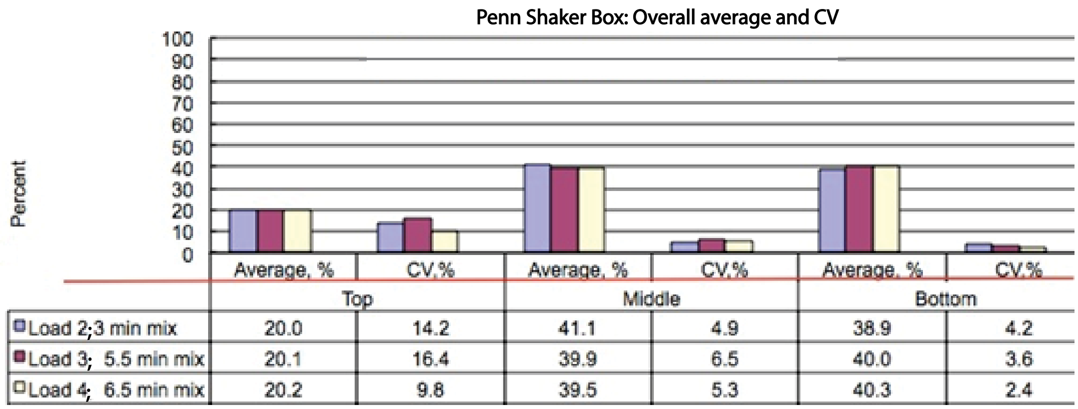
Hay/straw quality and processing

Alfalfa hay and straw should be processed to less than 2” to minimize sorting. A reasonable guideline is to have the particle size distribution of straw be approximately 1/3, 1/3, and 1/3 on the top screen, middle screen, and pan of the PSPS.[a] Most dairies process hay and straw prior to loading



	1	2	3	4	5	6	7	8	9	10	Ave
Top	14.3	21.3	25.6	20.8	18.6	23.9	17.9	17.6	21.7	19.2	20.1
Middle	45.2	39.4	37.8	38.6	40.2	36.5	41.9	42.2	37.7	38.9	39.9
Bottom	40.5	39.3	36.5	40.6	41.2	39.5	40.1	40.2	40.5	42.0	40.0

Figure 2a. The particle size distribution determined with the Penn State Particle Separator from 10 TMR samples collected along the feedbunk as the TMR was unloaded. This TMR was prepared with a twin-screw vertical mixer wagon (the same type as in Figure 1a) and is not as consistent as it should be.



	Top		Middle		Bottom	
	Average, %	CV,%	Average, %	CV,%	Average, %	CV,%
Load 2;3 min mix	20.0	14.2	41.1	4.9	38.9	4.2
Load 3; 5.5 min mix	20.1	16.4	39.9	6.5	40.0	3.6
Load 4; 6.5 min mix	20.2	9.8	39.5	5.3	40.3	2.4

Figure 2b. The mean particle size and coefficient of variation from 10 TMR samples collected from 3 different loads from the dairy in Figure 2a. There is more variation in each load of feed than optimal; the goal is to have the CV be less than 2.5% for the middle screen and pan. A defacer was purchased, mix times were made more uniform and of adequate length through use of a timer, and the ingredient order was changed during load preparation. The result was a much more consistent TMR.

to ensure proper particle size and reduce equipment wear on the mixer. Knives must be properly maintained in mixers if the mixer is going to be used to process long forage.

Loading sequence

Equipment maintenance, load size, and mix time all trump loading sequence, but it too can affect mix uniformity. Loading sequence will depend on mixer type, ingredient type (density, particle size, moisture level, and flowability), inclusion level, and convenience of the feeder relative to ingredient location. Generally, lower density and large particle feeds (straw, hay) are loaded first, followed by dry grains, wet by-products, haylage, corn silage, and liquids. Haylage can go in earlier if clumps are present and a longer mix time is desired to try to break down clumps. However, the best way to break down haylage clumps is with a defacer. Again, sometimes experimentation needs to be done to determine the best loading sequence for a given mixer and set of feedstuffs.

Liquid distribution

Liquids should be added so that they are dispersed over the central half to two-thirds of the mixer. They are often added as the last ingredient. However, we have often seen excellent mixing results if they are added after all grains have been added to the mixer, followed by forages in increasing order of density.

Vertical mixer auger speeds

Remember that feed particles mix the best when they are falling or actively moving. If the vertical augers are moving too slowly, the feed movement may not be sufficient for feed particles to mix properly. Different companies have designed their equipment to mix at different speeds, but in general TMR consistency will be enhanced when auger speed is increased.

Hay restrictor plate settings in vertical mixers

Restrictor plates force the TMR closer to the auger, enhancing the cutting action of knives. However, they also decrease the mixing action within the mixer. If the mixer is not being used to process forage, then the restrictor plates can be set all the way out on most mixer wagons.

Feed Bunk Management

The 2 primary initiators of a meal are the delivery of fresh feed and the cow's return to the pen from the parlor. Thus, if cows are fed once per day, the largest meal will occur the first time they are fed fresh feed in the morning, especially if this coincides with milking time.[1] This can result in a "slug" of ingested carbohydrate, a relatively large drop in rumen pH, and a decrease in ruminal efficiency. Feeding 2 to 3 times per day results in more and smaller meals, and a more stable, efficient rumen. Although pushing up feed is critical to allowing access to feed along the bunk, it does not bring animals up to the bunk nearly as much as offering fresh feed.[1]

Conclusion

A rigorous evaluation of the feeding program on a dairy can often improve herd performance and the efficiency of the feeding system. A TMR Audit can help to identify problems with the current program and potential solutions. The good news is that often the solutions involve slight changes in procedures, protocols, or equipment as opposed to large capital investments. Consider conducting TMR Audits at your clients' dairies, and see where improvements can be made.

Endnote

[a]Dann HM. Personal communication, 2012.

Acknowledgements

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Current concepts in dairy cattle vaccinology

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Abstract

Vaccination is an important component for the prevention and control of disease in the dairy herd. Modified-live vaccines (MLV) have been used because of the good antibody response, longer duration of immunity, fewer doses needed per animal, and lower cost. Non-adjuvanted MLV vaccines fail to booster well-vaccinated animals, as active vaccine-induced immunity neutralizes vaccine virus preventing the MLV from replicating and preventing a booster immune response. Improved adjuvants have increased the scope and duration of inactivated virus immunity. Prepartum vaccination aimed at colostrum development is critical. Inactivated viral vaccines aimed at reproductive disease have greatly improved and should be considered to be given in the dry period to provide maximum conception rate during the fresh period. The periparturient period (the last 3 weeks prior to calving and the first 3 weeks following calving) are poor times to initiate an immune response–hormonal, dietary and metabolic factors limit immune responsiveness. Post-partum is also a difficult time to vaccinate, as lactation energy demand supersedes immunity. Each vaccine program needs to be designed based on animal flow, actual "disease" threats, and labor on the farm.

Key words: dairy, vaccine, health

Résumé

La vaccination est une composante importante de la prévention et du contrôle des maladies dans les troupeaux laitiers. Les vaccins vivants modifiés (VVM) sont utilisés en raison de leur bonne production d'anticorps, de la longue durée de l'immunité, du faible nombre de doses requises et du moindre coût. Les VVM sans adjuvant ne causent pas d'amplification chez les animaux bien vaccinés parce que l'immunité active induite par le vaccin neutralise les virus du vaccin ce qui nuit à la réplication du VVM et empêche l'amplification de la réponse immunitaire. De meilleurs adjuvants augmentent la portée et la durée de l'immunité induite par des virus inactivés. La vaccination en prépartum ciblant le développement du colostrum est primordiale. Les vaccins viraux inactivés visant les maladies reproductives se sont très améliorés et devraient être considérés durant la période de tarissement pour maximiser le taux de conception durant la période fertile. La période autour du vêlage (les trois dernières semaines avant le vêlage et les trois premières semaines suivants le vêlage) n'est pas bien indiquée pour initier une réponse immunitaire car des facteurs hormonaux, alimentaires et métaboliques limitent l'immunocompétence. Il est aussi difficile de vacciner après le vêlage car la demande énergétique de la lactation supplante l'immunité. Chaque programme de vaccination doit s'ajuster aux mouvements des animaux, aux réelles menaces de santé et à la main d'œuvre de la ferme.

Immune Response

The immune system consists of 3 lines of defense systems: barriers, innate immunity, and adaptive or acquired immunity (Figure 1) that work together to give cattle protection from disease. The barrier system is probably the most overlooked, but it eliminates 99.9% of all infections. This system is very susceptible to dehydration and changes in microbial populations. The innate system is the first to be activated and responds almost immediately (Figure 2). The adaptive response follows up 10 to 14 days later in naïve animals. The immune system is regulated by anti-inflammatory response to prevent over-response. The cumulative effect of this anti-inflammatory response is to suppress the immune system and to direct the immune response away from the memory response to the short-term antibody immune response. At the same time, over-expression of pro-inflammatory cytokines from infectious agents, feed intake issues (acidosis, ketosis), and stress can result in immune dysfunction and an over-reactive immune system that can result in immunopathology and disease.[37]

Active Immune Interference—Maternal Interference that Never Goes Away

Modified-live vaccines (MLV) have been used because of the good antibody response, longer duration of immunity, fewer doses needed per animal, and lower cost. These vaccines are administered intramuscularly, intranasally or subcutaneously. As the basis for establishing a good immune response, they are the best. Although the return to virulence in MLV viruses has been minimal, mutations will occur and there is some risk of new strains arising. Non-adjuvanted MLV vaccines also fail to booster well-vaccinated animals. Active vaccine immunity neutralizes vaccine virus, preventing the MLV from replicating and preventing a booster immune response.[9,32] The animal's immune system can't differentiate between a natural infection or vaccine virus.

Inactivated vaccines contain chemically or physically treated bacteria, toxins, and/or viruses so there is no danger of replication in the vaccinated animal of the pathogen or adventitious agents that may be present in a MLV. Improved adjuvants have increased the scope and duration of inactivated virus immunity. They have several disadvantages including cost, and more doses are required per animal. Inactivated vaccines generate cell-mediated responses.[34,38] Interestingly, there is ample evidence that inactivated vaccines can effectively boost MLV vaccines.[11,19,32]

Stress, Immunosuppression, Nutrition, and Immunity

There is ample evidence that both physical and psychological distress can cause immune dysfunction in animals, leading to an increased incidence of infectious disease (Figure 3).[28,33] Excess heat or cold, crowding, mixing, dehydration, weaning, calving, limit-feeding, shipping, noise, and restraint are stressors that are often associated with intensive animal production and have been shown to influence immune function in cattle.[13] Also social status, genetics, age, and the duration of stress (chronic vs acute) have been shown to be important in the animal's response to stress (Figure 4).[33] There is clear evidence that waiting at least 2 days, and preferably as long as 2 weeks, before vaccination will result in better immunity and less sickness in that adjustment period after the stress.[29,30]

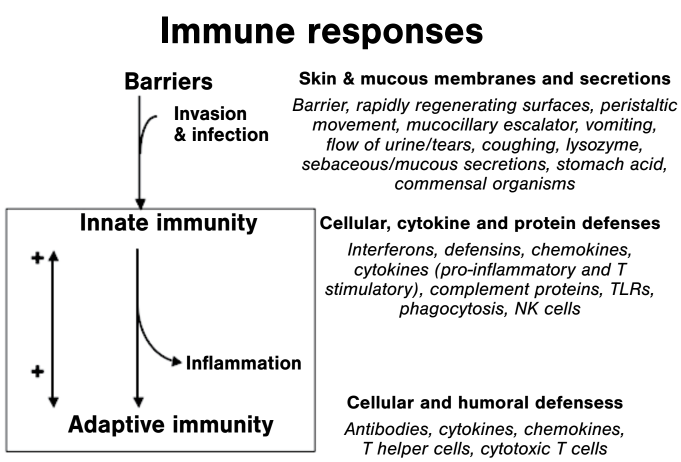

Figure 1.

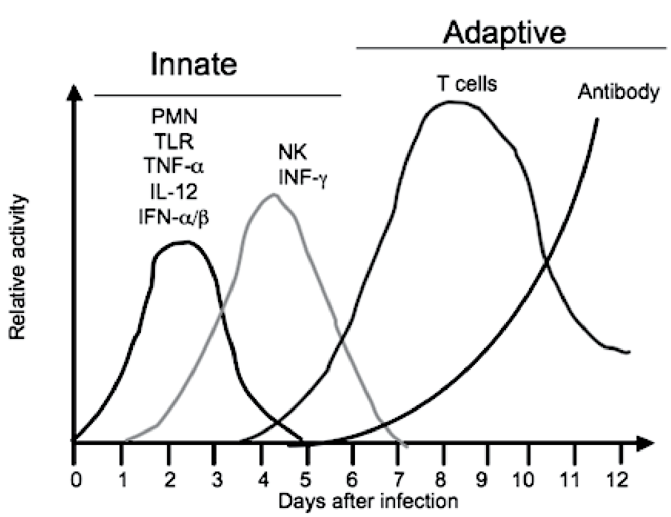

Figure 2.

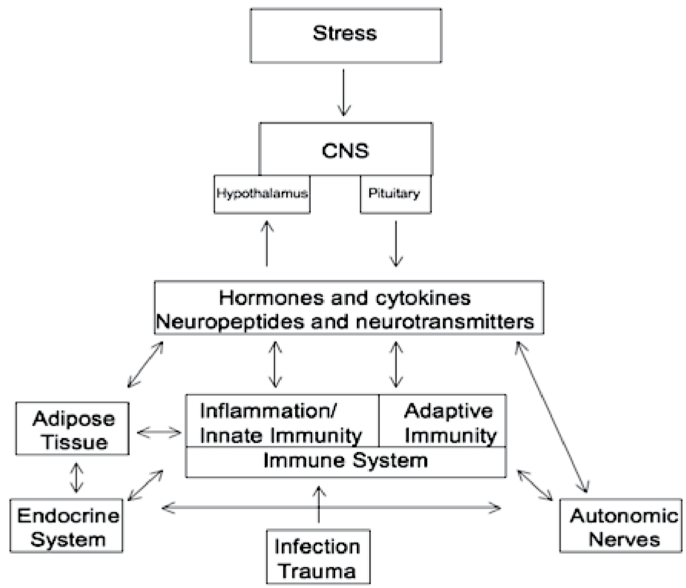

Figure 3.
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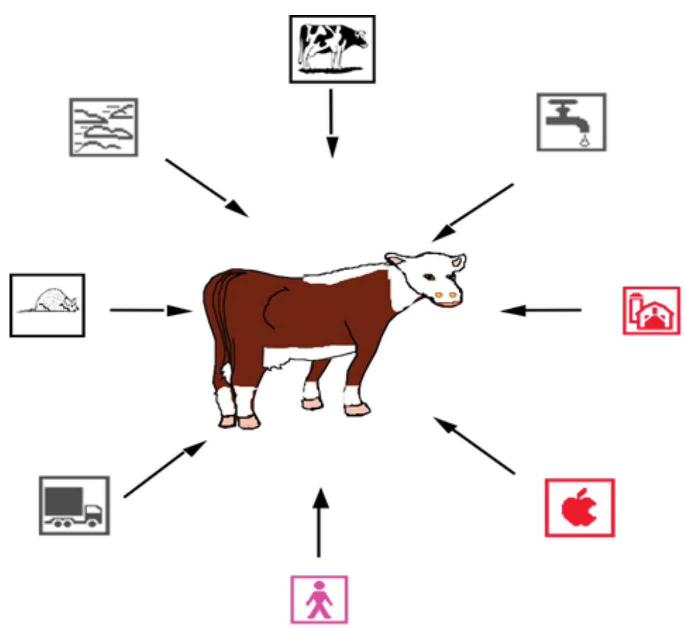

Figure 4.

Nutritional Influences on Immunity

The immune system does not get a free ride when it comes to nutrition.[37] The immune system requires energy, protein, vitamins, and trace minerals. Both malnutrition and overfeeding may result in impairment of immune function and increased susceptibility to disease due to a deficiency or excess of proteins or calories, or a relative imbalance in vitamin or trace mineral content. Animals under intensive production conditions typically have a completely controlled diet. Therefore, it is very important that the diet, especially the vitamin and trace mineral content, be optimally formulated. Key vitamins and minerals for optimal immune function include vitamins A, C, E, and the B complex vitamins, copper (Cu), zinc (Zn), magnesium (Mg), manganese (Mn), iron (Fe), and selenium (Se). Of these zinc, copper, and selenium are the "immune microminerals". The balance of these constituents is especially important since excess or deficiency in one component may influence the availability or requirement for another. Zinc is involved in protein synthesis and antibody formation, cell differentiation, and enzyme formation and function. Zinc also plays a major role in skin and mucosa integrity, the first line of defense of the immune system. It is also essential for innate immune responses.[3] Copper and manganese are directly involved with cell-mediated immunity and protein matrix formation during the healing process. Copper has been linked with the ability of isolated neutrophils to kill yeast and bacterial infections. Selenium is an essential anti-oxidant.[36] Manganese plays a role in facilitating the "germ-killing" function of macrophages.[37]

Immunity, negative energy balance, microflora, and cytokine storm

The immune system is a major consumer of energy, and in times of negative energy like seen in the newly weaned calf and the fresh dairy cow it can be difficult for the immune system to respond.[37] In addition, the mobilization of energy from adipose tissue (fat) results in infiltration of macrophages as activity of adipocytes (fat cells) results in inflammation. These macrophages are particularly sensitive to signals from gut bacteria, including endotoxin from gram-negative bacteria.[42] With diet changes that occur at weaning or at parturition for the dairy cow, the microflora populations are changing considerably. This combination of adipose remodeling, macrophage activation, and microflora can result in a cytokine storm (Figure 5).[4,40] A cytokine storm (hypercytokinemia) is the systemic expression of a healthy and vigorous immune system resulting in the release of more than 150 known inflammatory mediators (cytokines, oxygen free radicals, and coagulation factors).[40] It is an overreaction of the immune system. Both pro-inflammatory cytokines (such as tumor necrosis factor-alpha (TNF-alpha), Interleukin-1, and Interleukin-6) and anti-inflammatory cytokines (such as Interleukin 10 and Interleukin 1 receptor antagonist) are elevated in the serum of people or animals experiencing a cytokine storm. It is believed that cytokine storms were responsible for many of the human deaths during the 1918 influenza pandemic, which killed a disproportionate number of young adults. In this case, a healthy immune system may have been a liability rather than an asset. Preliminary research results also indicated this as the probable reason for many deaths during the severe acute respiratory syndrome (SARS) epidemic in 2003.[40] Human deaths from the bird flu H5N1 usually involve cytokine storms as well. Recent reports of high mortality among healthy young adults in the 2009 swine flu outbreak has led to speculation that cytokine storms could be responsible for these deaths, since the swine flu results from the same influenza strain as the Spanish flu of 1918.

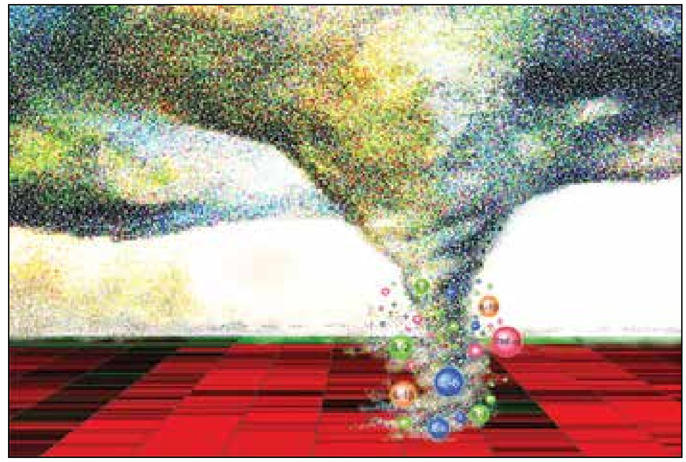

Figure 5.

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What is the Best Time to Vaccinate Cows and Calves?

Immunity during the prepartum period

Dairy cows are continuously managed to increase milk production. Some alterations in the host defense mechanisms that occur during the preparturient period are associated with changes in hormone profiles and the metabolic and physiological stress of parturition. The alteration of the immune system and the innate host resistance mechanism in dairy cows usually begins 3 weeks before parturition, and it is maximized 3 weeks after calving, when milk yield peaks and the energy balance begins to improve These changes can contribute to the high incidence of disease and the low immune response to vaccination experienced by the periparturient cow. Evidences of the changes in the immune system and the non-specific host defense mechanism occur in the periparturient dairy cow.[17,18]

Hormonal changes in the endocrine system of cows later in pregnancy are well known and are characterized by higher circulating levels of estrogen and progesterone. These hormones can depress the immune system function. High estrogen concentrations, for example, can reduce neutrophil function, and high levels of progesterone can suppress lymphocyte function. Cortisol produced in the fetal adrenal glands can affect the cellular mediated response in the cow, such as the production of interleukin-2 and interferon gamma.[5] Among these changes at calving time are high cortisol levels, which produce immunosuppression and an increment in estrogen that can also suppress lymphocyte function.

Prepartum Vaccination: Colostrum Formation—a Key Component of Dairy Vaccine Strategy

The lack of antibody transfer in the developing fetal calf makes the importance of colostrum ingestion paramount. Colostrum with high immunological activity is a product of proper vaccination and nutrition in the dam.

Colostrogenesis

Colostrum synthesis in the mammary gland of the pregnant female is dependent on 2 factors, the presence of serum antibodies and a transport mechanism to move the antibody, primarily immunoglobulin G1 (IgG1), into the mammary gland.[2] Although the pregnant cow must be immunosuppressed to maintain the allogenic fetus (otherwise the bovine fetus would be rejected), this immunosuppression appears to occur most strongly in the uterus and the placenta. This fetal protective immunosuppression does not appear to cause a high level of generalized systemic immunosuppression that affects the cow's antibody response to vaccines or environmental antigens. However, some effect on the cell-mediated adaptive responses is observed in the pregnant animal. The movement of antibody from the circulation to the mammary gland is hormonally regulated and begins 3 to 4 weeks prior to calving, and has its highest transport in the last 1 to 2 weeks of pregnancy. This coincides with increases in estrogen, decreases in progesterone, and increase in the neonatal receptor (FcRn) in the mammary gland.[2] This small window of colostrogenesis makes timing of vaccine administration to the dry cow important. Non-adjuvanted vaccines would need to be given within 4 weeks of calving to get maximum circulating levels during colostrogenesis. Adjuvanted vaccines could be given earlier in the dry cow period, as they sustain higher antibody levels for longer periods of times. This ability to concentrate antibody ends rapidly after parturition. Colostrum from cows with premature calves will have lower levels of antibodies, so premature calves should be fed colostrum from cows that deliver a full-term calf.

Colostrum components

Colostrum's immunological component is composed primarily of antibodies, cytokines, and cells. Antibody is an extremely critical component of colostrum and provides an immediate source of antibody for the agammaglobulinemic calf. Colostrum contains 32 to 212 mg/ml of total IgG (20 to 200 mg/ml IgG1 and 3 to 12 mg/mL IgG2) and 1 to 6 mg/ml IgA.[14,23] Calves that ingest colostrum shortly after birth have significant concentrations of immunoglobulin in serum, while colostrum-deprived calves have only trace amounts of immunoglobulin during the first 3 days of life. Production of IgM in colostrum-deprived calves does not begin to appear in the circulation until 4 days after birth, and doesn't reach functional levels (1 mg/mL) until 8 days of age. Levels of circulating IgA, IgG_1, and IgG_2 do not reach appreciable levels in these calves until 16 to 32 days after birth.[21] The levels of these antibodies do not approach adult levels until about 4 months after birth, at which time IgG_2 is only half of adult levels, indicating a strong TH2 bias.

It has been well demonstrated that preparturient vaccination of the cow for enteric diseases such as colibacillosis, *Clostridium perfringens*, coronavirus, and rotaviruses results in production of pathogen-specific antibodies that provide protection for the neonate against severe disease.[15] Similar protection is also seen against respiratory pathogens including infectious bovine rhinotracheitis (IBR-bovine herpesvirus 1), bovine respiratory syncytial virus (BRSV), and bovine viral diarrhea virus (BVDV).[35] The quantity and the overall quality (i.e., not contaminated with bacteria and/or spoiled, having a relatively high concentration of total protein and sufficient fat) are important. Keeping colostrum free of microbial contaminants makes good collection and storage imperative, particularly in operations that pool and feed "normalized" colostrum, a practice that has favor in dairy operations.

The second family of components of colostrum includes cytokines.[12] These immunological hormones help in the development of the fetal immune response. It is not clear if these cytokines are secreted in the mammary gland or produced by the leukocytes found in colostrum, or both. Interleukin 1-beta (IL-1beta), IL-6, tumor necrosis factor beta (TNF-beta), transforming growth factor beta (TGF-beta), and interferon-gamma (INF-gamma) are present in bovine colostrum and are associated with a pro-inflammatory response, and may help in the recruitment of neonatal lymphocytes into the gut to aid in normal immune development. Colostrum rapidly improves the ability of neutrophils to phagocytize bacteria, which is primarily accomplished by absorption of small molecules like cytokines.[31] Work in pigs has demonstrated that colostral cytokines are absorbed and can be detected in the blood. The level of these cytokines (IL-4>IL-6>INF-gamma>IL-10) peaked at 1 to 2 days post-partum.[25] The high levels of 2 anti-inflammatory cytokines, IL-4 and transforming growth factor beta-1 (TGF-beta1), would suppress local secretion of pro-inflammatory cytokines in the intestine, allowing gut microbial colonization.

The third family of components of colostrum are cells. Colostrum contains between $1x10^6$ and $3x10^6$ cells/ml; almost exclusively leukocytes.[21] These viable leukocytes are present in percentages similar to peripheral blood, but with a larger fraction of macrophages (40 to 50%) and a smaller fraction of lymphocytes (22 to 25%) and neutrophils (25 to 37%).[22,26] The vast majority of lymphocytes are T-lymphocytes, with less than 5% being B-lymphocytes. Some of these maternal cells enter the circulation and reach peak levels 24 hrs after birth.[27] Animals that receive colostrum-containing maternal leukocytes develop antigen presenting cells (APC) faster, which is important since APCs are the keystone cell for the development of an acquired immune response to pathogens or vaccines. Additionally, pathogen-specific maternal T lymphocytes from vaccinated cows have been isolated from the neonatal calf with maximum inducible proliferation at 1 day following birth.[7] The exact role of these cells in the long-term development of pathogen-specific acquired immunity is not clear, as they are no longer detectable in the circulation at 7 days of age.

Immunity in the post-partum period

The common practice of vaccinating during the fresh period (15 to 45 days-in-milk) is an immunological challenge for the cows due to the negative energy balance associated with the high energy demands and the low dry matter intakes typically observed post-partum. The requirement of the immune system for energy becomes a secondary requirement compared to lactation.

Depression in post-partum leukocyte function has been correlated to shifts in leukocyte trafficking patterns at this time.[18,19,20,24] The alteration in the proportions of the peripheral blood lymphocyte subset has been monitored in dairy cows during the pre-partum and post-partum periods. The variation of T cells was significant during the peri-partum period, particularly around parturition. B cell and MHC II + populations remained constant until after calving and then decreased, returning to the initial subset proportion by week 16. A decrease in the total number of T lymphocytes and changes in the T subpopulation have been reported in peripheral blood. In our research, we found that production, mastitis and reproductive health were improved in cows vaccinated in the prepartum period as compared to cows vaccinated in the post-partum period.[1]

Approximately 30% of dairy cows suffer subclinical ketosis during the fresh period as a result of the negative energy balance. The pathogenesis of this phenomenon is explained by the metabolic changes that occur when nutrient intake, particularly energy, does not meet production demands. In high-producing cows this metabolic disorder usually occurs from a few days up to 6 weeks post-calving, with the highest incidence occurring at about 3 weeks post-partum. Most high-producing cows undergo subclinical ketosis in early lactation when they are unable to consume enough energy to meet demands. Cows in negative energy balance are utilizing body fat and protein stores as a result of a drop in blood glucose concentration (glycemia). When fat molecules reach the liver, they are converted to ketones, and elevate ketone levels in the blood. High levels of blood ketone bodies interfere with the production of T cells and impair the chemotactic response of leukocytes.[39] There is a link between elevated ketone levels and the risk of mastitis.[10] In addition, subclinical ketosis results in increased pro-inflammatory cytokine production, enhancing the cytokine storm (Figure 5).[8] The presence of subclinical ketosis in nearly 30% of fresh dairy cows suggests vaccination during this period is probably not the best approach and that vaccinating during the dry period might be a better alternative.

Evidence also exists that cows selected for high milk production traits, have unfavorable correlated responses in the functional capacity of immune function traits. There is sufficient genetic variation in these immunological traits among sires of high genetic merit for milk production.[6]

Another consequence of peripartum cows' feed disorders is hepatic lipidosis, a consequence of the fat cow syndrome. Upon vaccination, over-conditioned cows have lower humoral and cellular response when compared with cows with a low liver triacylglycerol (TAG) at day 14 after vaccination.[41] Cows in the transition period often face a challenge associated with low trace mineral levels. This is due to low dry matter intakes and stress, which causes excretion of trace minerals. Of particular concern are deficiencies in zinc, copper, chromium, manganese, cobalt, and selenium. The influence of these minerals on immunity was discussed above.

Conclusions

Management of the dairy cow and calf's immune system is not a simple process. Stressors and nutrition often compromise immunity. It is important that vaccinations be given at optimal times and that vaccination is not overused. Vaccination can never overcome poor management.

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Current concepts in dairy cattle immunology

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Abstract

Protection from disease-causing organisms is critical to the survival of cattle in all production systems. The immune system is composed of organs, tissues, and cells tasked with providing protection from invading pathogens. The first line of protection of pathogens relies on physical, chemical, and mechanical barriers to invasion. Durable tissues, harsh environmental conditions, and targeted chemical defenses provide continuous protection. When these barriers are breeched, innate immune cells use molecular patterns common to large groups of pathogens to quickly recognize and respond to invaders. Innate immune cells also serve to alert and activate adaptive immune cells through the process of antigen presentation. As an infection progresses, adaptive immune cells (lymphocytes) produce molecules, including cytokines and antibodies, that direct innate immune cells to clear pathogens from the host. The purpose of these proceedings is to discuss each of these defenses to provide an understanding of immune protection in cattle.

Key words: bovine, dairy, immunology

Résumé

La protection contre les organismes qui causent des maladies est essentielle à la survie du bétail dans tous les systèmes de production. Le système immunitaire se compose d'organes, de tissus et de cellules dont la tâche est de protéger l'animal contre les agents pathogènes envahisseurs. Les barrières physiques, chimiques et mécaniques contre l'invasion sont la première ligne de défense contre les agents pathogènes. Les tissus résistants, les conditions environnementales difficiles et les défenses chimiques ciblées fournissent une protection de tout instant. Lorsque ces barrières sont assiégées, les cellules de l'immunité innée utilisent des structures moléculaires que se partagent de grands groupes de pathogènes pour reconnaître et réagir rapidement aux envahisseurs. Les cellules de l'immunité innée servent aussi à alerter et à activer les cellules du système immunitaire adaptatif via le processus de présentation des antigènes. Durant la progression de l'infection, les cellules du système immunitaire adaptatif (lymphocytes) produisent des molécules comme les cytokines et les anticorps qui dirigent les cellules de l'immunité innée afin d'éliminer les agents pathogènes de l'hôte. Le but de cette présentation est de discuter chaque type de défense pour approfondir les connaissances sur la protection immunitaire chez le bétail.

Introduction

Protection from disease-causing organisms is critical to the survival of cattle in all production systems. The immune system is composed of organs, tissues, and cells tasked with providing protection from invading pathogens. These proceedings will provide an overview of how the structure and function of the immune system work in concert to protect the host from disease.

Anatomy of the Immune System

Generally, the anatomical structures associated with immune defense can be separated into three broad systems. First, a barrier defense systems exists to create inhospitable conditions for invading pathogens. Second, a systemic immune system provides surveillance and defense against invasion into internal organs. Finally, a mucosal immune system provides surveillance and defense against invasion via mucosal surfaces.

The barrier defense system is a series of physical, mechanical, and chemical obstructions to invasion via several common routes of entry into the animal. Physical barriers to infection include tight junctions between epithelial cells that seal pathogens out of sensitive, sterile internal environments. Many layers of relatively dry squamous cells of the skin also provide an inhospitable environment for pathogens that would gain entry via a transdermal route. Mechanical barriers to infection include the flushing action of secretions across sensitive surfaces (e.g. tears, respiratory secretions) as well as the uni-directional flow of ingesta and urine through the GI and urogenital tracts, respectively. Fluid and air flow help displace potential pathogens from the host. Finally, low pH conditions in the stomach and antibacterial systems in the respiratory, mammary, and ocular systems kill pathogens in areas sensitive to infection.

The systemic immune system is composed of organs (thymus, spleen, lymph nodes, bone marrow), transport paths (lymph vessels, blood vessels), and cells (Dendritic cells, macrophages, phagocytes, etc) that survey for and respond to threats in the vasculature and internal tissues. The central area of activity in a mature immune system is the lymph node. Lymph nodes serve as a common area where both T and B lymphocytes and antigen presenting cells (APC) can interact. Tissue fluid containing antigen-bearing APCs flows from all points in the body to regional draining lymph nodes via afferent lymph vessels. T and B lymphocytes interact with the APC in the lymph nodes and circulate out of the lymph node via efferent lymph vessels. Lymph fluid ultimately returns to the vasculature via the thoracic duct. Lymphocytes then home back to lymph nodes either by specialized venules (naïve lymphocytes) or by extravasating in tissues and returning via the tissue fluid route.

The mucosal immune system is comprised of specialized tissues located on mucosal surfaces known as mucosa-associated lymphoid tissue (MALT). MALT tissue takes two basic forms. First, tonsils are immune organs designed to survey incoming materials, including air and ingesta, for the presence of pathogens. Tonsils have many of the same characteristics as lymph nodes with the notable exception that tonsils are located on mucosal surfaces and have exposure to air and ingesta to allow sampling and surveillance. The second type of MALT takes the form of discrete areas of lymphoid tissue in various locations across all mucosal surfaces. The most well-known form of this type of tissue is the Peyer's patch in the small intestine. Peyer's patches contain specialized cells designed to sample intestinal lumen contents as well as APCs and Lymphocytes. Lymphocytes of activated at one mucosal site travel to mucosal sites distant from the point of activation.

Immune System Function

An immune response is a tightly control sequence of events that is designed to control pathogens quickly while minimizing damage to the host. Successful immune responses proceed through a series of 4 stages. First, pathogens invade the host and are recognized as foreign and potentially dangerous. Second, innate immune functions act quickly to control spread and limit damage associated with the pathogen. Third, innate immune cells communicate with cells from the adaptive immune system to initiate a targeted adaptive immune response to eliminate the pathogen. Fourth and finally, the adaptive immune system eliminates the infection, resolves damage, and generates long-lived memory to prevent future infections by the same pathogen.

The first step, pathogen invasion and recognition, occurs locally in the area of the host where invasion occurs. Sentinel cells, including dendritic cells, macrophages, and mast cells are equipped with pattern recognition receptors (PRRs). PRRs recognize molecular patterns that are common to certain classes of pathogens. An important class of PRRs are the Toll-like receptors (TLRs). TLR binding indicates the presence of a pathogen invader and triggers inflammation in the host. For example, TLR4 recognizes lipopolysaccharide found on gram negative bacteria. TLRs are found either on the surface of sentinel cells to detect the presence of extracellular pathogens or in vesicles inside the cells to detect the presence of intracellular bacteria and viruses. Other systems can also play a role in pathogen recognition. Complement fixation produces molecules that draw phagocytes to the site of infection. Also, physical damage to cells and the resulting leakage of enzymes into the extracellular space can trigger inflammation.

The second step in an immune response is characterized by rapid activation of innate immune defenses to limit the spread of infection and the resulting damage. Once a PRR is activated, the innate immune systems uses localized measures to inactivate pathogens. Less-than-specific responses like phagocytosis, oxidative burst, etc. to capture and remove pathogens. Innate immune cells also produce many cytokines that elicit inflammatory effects. Vasoactive cytokines result in increased vascular permeability to ease delivery of cells and serum components to sites of inflammation. Other cytokines activate tissues to increase fibroblast and phagocyte production. Cytokines also serve as chemotactic agents that draw more immune cells to the site of inflammation.

An important step in the inflammatory process is the communication between innate immune cells and lymphocytes. Antigen presenting cells recruited the site of inflammation collect antigens and carry them back to the draining lymph node for presentation to helper T lymphocytes. APCs process antigens into small peptide chains and present them to the T cells on major histocompatibility complex II (MHCII). APCs and T cells in lymph nodes essentially perform a version of cellular speed dating in which various T cells assess the fit of T cell receptor for the antigen expressed on MHCII by the APC. Once a T cell binds to the antigen displayed by the APC, the T cell becomes activated and begins to replicate itself to form a large population of identical T Cells. During the process of activation, the APC also supplies additional information to the T cell in the form of cytokines that convey the circumstances of the activation. Based on the cytokines it detects, T cells will either differentiate into T helper 1 or T helper 2 lymphocytes (TH1 or TH2, respectively).

Antigen presentation can also occur via presentation on MHC I. MHC 1 molecules are found on nearly all cells in the body and are used to give surveying immune cells a snapshot of the protein profile being made inside a cell. During intracellular infections, pathogen proteins are degraded, loaded onto MHC I, and displayed in the same way that host proteins are in homeostatic conditions. Naïve cytotoxic T lymphocytes patrol the MHC I receptors and destroy any cell that harbors a protein sequence recognized by the cytotoxic T lymphocyte. Cells that are carrying non-self proteins are force to undergo apoptosis by cytotoxic T cells and professional antigen presenting cells collect the debris and display it to T helper cells on MHC II. In this way, T helper cells can provide cytokine stimulation to cytotoxic t cells as well.

B lymphocytes must also be activated to produce a complete immune response. First, a B cell must bind its cognate antigen before it can become activated. B cells typically reside in lymph nodes where they can sample antigens in lymph fluid draining from sites of inflammation. Once antigen is bound, B cells internalize the antigen and express it on MHCII. When displayed to a T cell recognizes the antigen bound on the B cell, the T cell can become activated itself and can also provide stimulation to the B cell to allow differentiation in to

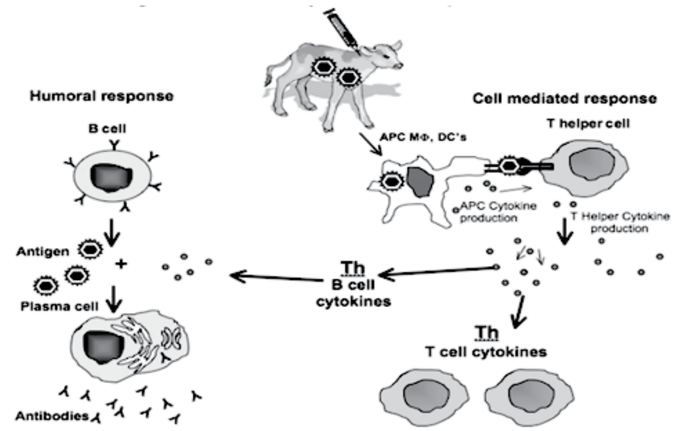

Figure 1. Summary of an immune response. Courtesy of Dr. Chris Chase, South Dakota State University. Used with permission.

an antibody secreting plasma cell. See Figure 1 for a schematic summarizing an immune response.

As the immune system gains the upper hand against the pathogens, the process of winding down the immune response begins. Specialized cells, including macrophages and regulatory T lymphocytes down-regulate inflammation and initiate tissue repair and healing. Simultaneously, memory T and B lymphocytes develop in order to provide long-lived immune memory so that if the pathogen in question is encountered again, it can be quickly removed before it can damage the host.

Conclusion

Immunity of pathogens is a carefully orchestrated balance between destroying invading organisms and protecting host tissues and homeostasis. The structure of immune tissues allows rapid identification and response to pathogens and well-regulated effector cells and molecules are produced to quickly remove the invader and protect the host from further damage.

Acknowledgements

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The Veterinary Feed Directive

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Abstract

We will be writing Veterinary Feed Directives (VFDs) and prescriptions in December of 2016 to authorize the use of medically important antibiotics in the feed and water of our client's animals starting on January 1, 2017. The major challenge for our profession is not to master the limited number of labels we will be dealing with, or to master the VFD process; it is that we are now not only responsible for authorizing the use of almost every antibiotic in food animals, we are also accountable.

The decision process for if we should provide a VFD or prescription is centered on applying our professional training and experience to establish a clinical justification for the use. This process centers on these considerations. Do I have a valid VCPR? Is there a reason for this use or is it just habit? Is it legal? Is it effective? Are there any issues with residues or antibiotic resistance to consider?

After these considerations, veterinarians are then responsible to lead in antibiotic stewardship. This involves assuring accurate case definitions, searching for antibiotic alternatives, selecting the appropriate antibiotic, monitoring use, and constant re-evaluation of the need for the antibiotic.

Key words: VFD, veterinary feed directive, antibiotics, food grade

Résumé

En décembre 2016, nous rédigerons des directives sur les aliments médicamenteux et des prescriptions afin d'autoriser l'utilisation d'antibiotiques médicalement importants pour les aliments et l'eau des animaux de nos clients à partir du premier Janvier 2017. Le plus grand défi pour notre profession n'est pas seulement de maîtriser le nombre limité d'antibiotiques permis ou de maitriser le processus de règlementation sur les aliments médicamenteux. Il est plutôt qu'en plus de la responsabilité d'autoriser l'utilisation de presque tous les antibiotiques pour les animaux de production, nous devons aussi rendre des comptes.

La prise de décision concernant une directive sur les aliments médicamenteux ou une prescription se base sur notre formation professionnelle et notre expérience afin d'en justifier l'utilisation clinique. Ce processus prend en compte les considérations suivantes : est-ce que ma relation vétérinaire-client-patient est valide?, est-ce qu'il y a une bonne raison pour cette utilisation ou est-ce seulement une habitude?, est-ce légal?, est-ce effectif?, est-ce qu'il y a des doutes concernant les résidus ou la résistance antimicrobienne?

Après avoir pris ces éléments en considération, les vétérinaires sont donc tenus de promouvoir l'utilisation judicieuse des antibiotiques. Cela implique de s'assurer d'une juste définition des cas, de rechercher des alternatives à l'utilisation des antibiotiques, de choisir l'antibiotique approprié, de surveiller son utilisation et de constamment réévaluer le besoin d'utiliser cet antibiotique.

Introduction

We will be writing Veterinary Feed Directives (VFDs) in December of 2016 to authorize the use of medically important antibiotics in the feed of our client's animals starting on January 1, 2017. We will also be authorizing the use of medically important antibiotics in the water of food animals through the prescription process starting at the same time. It is important to understand the ins and outs of writing a VFD, but this presentation is about the work that has to be done before the VFD is created.

The major challenge for our profession is not to master the limited number of labels we will be dealing with, or to master the VFD process; instead, it is that we are now not only responsible for authorizing the use of almost every antibiotic in food animals, we are also accountable. And, we will be accountable in an environment of ever-increasing transparency, a transparency which will focus attention on the relationship between our clinical decisions and our financial interests in the authorized products.

The success of our profession in this endeavor will depend on the navigation of key steps in an organized decision process. This process precedes the navigation of the VFD authorization protocol. In contrast to the regulatory details of creating a valid VFD, the decision process is centered on applying our professional training and experience to establish a clinical justification for the use.

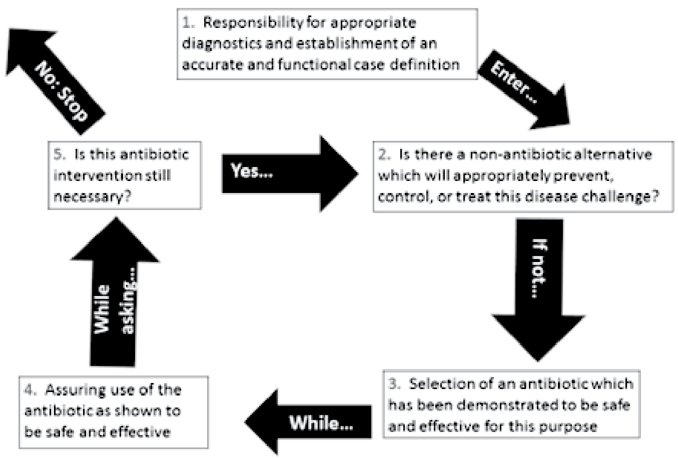
A VFD checklist (which applies to any antibiotic use authorized by a veterinarian) includes:

- Do I have a valid VCPR to authorize this use?
- Is there a reason to use the product, or is it just habit?
- Is it legal?
- Is it effective?
- Are there any residue issues to consider?
- Are there any issues with antibiotic resistance?

Only when the proposed use survives this list should it be authorized, But, before our profession starts the new responsibility of clicking down through this list for in-feed antibiotics on a routine basis, it is important to define the environment within which we will be functioning. We need to be clear on the difference between judicious use and stewardship.

Antimicrobial Stewardship

I propose that there are basic inclusions in antimicrobial stewardship regardless of branch of medicine or animal species. Judicious use involves the proper application of the antibiotic when used. Stewardship in food animals involves the following loop, with an emphasis on judicious use as well as seeking to reduce or eliminate the need to use the antibiotic.



1. The veterinarian is responsible for establishing the nature and presence of disease that requires prevention, control, or therapy. Once the presence is established, then the veterinarian is also responsible for establishing a case definition for the client to use to monitor the disease and to determine the need for antimicrobial use.
2. A constant requirement of antimicrobial stewardship is the search for non-antimicrobial alternatives for prevention, control, and treatment. These alternatives may include environmental management, vaccines, animal flow, genetic selection, and a systems approach to the evaluation of the relationship between level of production and disease pressure.
3. The veterinarian is responsible for working with their client to make a rational antimicrobial decision based on the disease(s) characterized in step 1. The principles of evidence-based medicine include evaluating the best evidence available combined with the practitioner's clinical experience and the needs of the client.
4. The responsibilities of the client/veterinarian relationship do not stop with step 3; this next step requires an ongoing commitment for interaction between the veterinarian and client. In fact, of all the steps, I feel that this step is the one most highly correlated with a true, functional veterinary-client-patient relationship. Step 4 requires evaluation of records as well as on-site evaluation of protocol application. Are the case definitions being used appropriately? Is protocol drift occurring? Are new employees properly trained to put the protocols into practice? Do the client and their employees have buy-in related to the protocol? Are there established goals? Do protocols need changed?
5. Have changes in management practices made the need for antibiotic prevention or control obsolete? If so, stop! If not, what can be done to reduce or remove the need for treatment.

The AABP has a guideline document entitled Prudent Antimicrobial Use Guidelines for Cattle, which is available on the AABP website.[1] The stewardship loop proposed is consistent with this statement in the AABP guideline. "The veterinarian's primary responsibility is to help design management, immunization, housing and nutritional programs that will aid in reducing the incidence of disease and, thereby, the need for antimicrobials".

A Valid Veterinary-Client-Patient Relationship?

The precise details of the VCPR can only be defined by establishing a local standard of practice. When evaluating the text of the VCPR as published in 21 CFR Part 530.3(i), it is possible to identify at least 5 areas which are arguably open to interpretation as a standard of practice (highlighted in boxes below).[2]

"(i) A *valid veterinarian-client-patient relationship* is one in which:

(1) A veterinarian has assumed the responsibility for making medical judgments regarding the health of (an) animal(s) and the need for medical treatment, and the client (the owner of the animal or animals or other caretaker) has agreed to follow the instructions of the veterinarian;

(2) There is **sufficient knowledge of the animal(s)** by the veterinarian to initiate at least a general or preliminary diagnosis of the medical condition of the animal(s); and

(3) The practicing veterinarian is **readily available for follow-up** in case of adverse reactions or failure of the regimen of therapy. Such a relationship can exist only when the veterinarian has **recently seen** and is personally acquainted with the keeping and care of the animal(s) by virtue of **examination of the animal(s)**, and/or by **medically appropriate and timely visits** to the premises where the animal(s) are kept."

The advent of the VFD provides for more veterinary-client interactions where unscrupulous members of our profession may seek to derive income by providing VFDs outside of a legitimate client relationship. It is clear that the VCPR definitions are to be determined within the individual states, as long as the definitions meet at least a minimum federal standard. I encourage veterinarians to actively engage with their state licensing boards and veterinary associations to work towards definitions.

The AABP has a guideline document entitled "Establishing and Maintaining the Veterinarian-Client-Patient relationship in Bovine Practice".[3] A lot of work went into this document by AABP members seeking to establish a baseline for the VCPR.

Another resource for forms to help with establishing a VCPR is the MN Dairy Quality Cares site.[4] On this page they provide a VCPR relationship agreement as well as forms which detail the information you should know when writing prescriptions for clinical disease, mastitis and udder health, reproductive programs, and youngstock health.

Reason or Habit?

Veterinarians will have to decide whether to authorize some standard in-feed antibiotic use practices which in the past have been determined by producers and, in some cases, nutritionists. The first step in antimicrobial stewardship requires that we must confirm that the real or perceived reason(s) for use are still valid, and that the antibiotic use cannot be replaced with another management practice.

A common concern that I have encountered is that if one veterinarian declines to write a VFD, then another may be willing to do so, and clients will be lost if requests for VFDs are refused. Looking at the big picture, I think this challenge is going to be addressed by transparency and benchmarking of antibiotic use within programs required for access to marketing channels. Granted, some of the pressures on the marketing channels from the consumer (or at least the perceived consumer on social media) may not be driven by science, and therefore some antibiotic use pressures related to the marketing channel may be nonsensical. However, the comparison of antibiotic use practices across multiple producers within the food animal industries should at least drive further research into the reasons for the diversity of use.

Is it Legal?

In contrast to the previous category, this one is relatively easy. For the VFD, if the dose or inclusion rate, duration of therapy, and indication do not exactly match the label, the application of the antibiotic in feed isn't legal. The veterinarian is responsible for this accuracy. Provision of a VFD for a label indication while knowing that the actual use will be different is both illegal and unethical.

This prohibition of extralabel use in feed will undoubtedly lead to a lot of tense situations where, for example, requests for use of a tetracycline in the feed for control of seminal vesiculitis in bull tests, pinkeye, or footrot will result in a conflict between adhering to the law and addressing the needs of the client and welfare of the animals. The answer lies in a combination of critical evaluation of the evidence for need (above) and the efficacy of the requested use (below) along with pursuing additional label claims. The challenge with pursuing additional label claims is the required capital investment on the part of a sponsor related to the studies required for a new claim, as well as the risk of opening up a label for a new claim, with the accompanying requirements to also update numerous other sections such as microbial and environmental safety.

We also have some problems where, due to the feed consumption of today's fed cattle, it is essentially impossible to match both the label feed inclusion rate and the mg/head/day dose. Discussions are ongoing, but no real solutions to my knowledge have been proposed as of the writing of these proceedings.

Is it Effective?

One of the biggest possible tragedies is to go through all of the work of establishing a legitimate VCPR, need, and legality of the application, only to make no real difference in disease outcome. Following the disease status of treated populations doesn't do us that much good without negative controls. We aren't likely to conduct a prospective, randomized, negative control clinical trial in practice situations; although more and more larger production systems are conducting these in-house. Therefore it is imperative that as a profession we insist on these types of data for older products with no recent studies to assure us that efficacy is reasonably likely. Levels of evidence for efficacy vary from fairly robust to incredibly thin or nonexistent.

Residue Considerations?

This is fairly straightforward. Follow the label withdrawal time, making sure that the client has sufficient feed management and animal identification capabilities to observe the withdrawal time. Where this can get complicated is when export markets with different tolerances (Maximum Residues Limits, or MRLs) are involved. If a client is just entering the export markets, then advice on altered withdrawal times should be sought from the marketing channel or by consulting others familiar with the requirements.

Another residue potential exists in cattle feeding environments where the mixing of feed for organic or natural never-ever cattle occurs in the same system (mill, trucks…) as cattle where feed antibiotics are used. This situation requires extreme attention to some well-crafted standard operating procedures for flushing of equipment and ration sequence. With today's chemical analytical capabilities applied in the zero-tolerance environment of organic and never-ever programs, in some operations it just may not be possible to share feed systems.

Any Issues with Antibiotic Resistance?

Consider this heading as a placeholder for increased understanding of this relationship in the future. We have much to learn about the relationship of dose and duration of antibiotic exposure to the selection pressure for resistant pathogens and/or the transfer of resistance genetic elements within bacterial populations. Currently, the research focuses on reasons that might cause us to curtail or eliminate current uses. If the precautionary principle becomes a major regulatory driver in the United States, the research focus would switch to attempting to prove safety in an effort to get products back.

Conclusions

The only things really new about the VFD process are the increase in the breadth of responsibility for antibiotic use in food animals and the altered procedure details as compared to the current prescription process. Our clinical decision processes are still based on the same principles as in the past; however, the evolving landscape of regulatory and legislative activity, food sales competition, and social media presence have served to hold up our antibiotic use practices for public scrutiny in a way we have never encountered before.

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Stakeholder views, including the public, on expectations for dairy cattle welfare

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Abstract

Animal welfare is emerging as one of the key social concerns regarding animal agriculture. Concern for the welfare of farms animals is not new, but the last few years have seen increased interest in farm practices. One of the dairy industry's core strengths is the very positive view that many people have about dairy farming. Many consumers believe that cows spend their days grazing green pastures. This strength can also be regarded as a threat if some industry practices no longer match evolving public expectations. Every year there are fewer farms, and the ever decreasing proportion of society that works within this industry will never be able to able to 'educate' the large majority, at least not on all issues, all of the time. Moreover, the farmers themselves are part of this rapidly evolving society, and practices that were accepted by past generations as necessary may not seem so to the next generation of producers. Change will happen. During my presentation I will highlight some of our most recent work on engaging dairy farmers and the public as a means to help identify practices that do and do not come into harmony with public expectations.

Key words: dairy, animal welfare, tail docking, disbudding

Résumé

Le bien-être animal est en train de devenir l'une des principales préoccupations sociales concernant l'agriculture animale. Préoccupation pour le bien-être des animaux des fermes n'est pas nouveau, mais les dernières années ont vu un intérêt accru dans les pratiques agricoles. L'un des principaux points forts de l'industrie laitière est le point de vue très positif que beaucoup de gens ont à propos de l'élevage laitier. De nombreux consommateurs croient que les vaches passent leurs journées à brouter les pâturages verts. Cette force peut aussi être considéré comme une menace si certaines pratiques de l'industrie ne correspondent plus à l'évolution des attentes du public. Chaque année, il y a moins de fermes, et de moins en moins la proportion de la société qui travaille au sein de cette industrie ne pourra jamais en mesure d 'éduquer' la grande majorité, du moins pas sur tout, tout le temps. En outre, les agriculteurs eux-mêmes font partie de ce monde qui évolue rapidement, et les pratiques qui ont été acceptés par les générations passées que nécessaire peut ne pas sembler si à la prochaine génération de producteurs. Des changements se produiront. Au cours de mon exposé, je vais présenter certains de nos travaux les plus récents sur l'engagement des producteurs laitiers et le public comme un moyen d'aider à déterminer les pratiques qui font et n'entrent pas en harmonie avec les attentes du public.

Introduction

Questions concerning the sustainability of food-animal producing industries have become the focus of intense public debate by social critics, animal advocates, and scientists. Specific concerns about the welfare of dairy cattle is nothing new; producers and veterinarians have always been concerned about the condition of animals in their care and have tried to ensure that they are healthy and well nourished.[27] In the tradition of good animal husbandry, good welfare can be seen largely as maintaining high levels of production and the absence illness or injury. However, recent interest in farm animal welfare stems more from concerns about pain or distress that the animals might experience, and concerns that animals are kept under "unnatural" conditions, with limited space and often a limited ability to engage in social interactions and other natural behaviors.

In addition to the tremendous increase in scientific research on the welfare of cattle, some new work has begun to investigate stakeholder views on dairy farming and practices common in the dairy industry.[31] An objective of the current paper is to summarize some of our recent work on stakeholder views. We focus on four common management practices (tail docking, pain mitigation for disbudding/dehorning, access to pasture and cow calf separation) and describe how research in the natural sciences and social sciences can be integrated to identify more sustainable practices.

Farm Animal Welfare

For the purposes of this paper we have adopted the three part definition of animal welfare proposed by Fraser et al[7] and adapted for dairy cattle by von Keyserlingk et al[27]: 1) animals should exhibit good physical health and biological functioning; 2) animals should have the ability to live reasonably natural lives including the ability to perform natural behaviours that are important to them; and 3) animals should experience minimal negative psychological states and the presence of at least some positive psychological states. These different types of concerns can and do overlap. For instance, a lactating dairy cow unable to seek shade on a hot day (natural living) will likely feel uncomfortably hot (affective state) and may show signs of hyperthermia, and ultimately reduced milk production (poor biological functioning).[27]

These three key concepts of animal welfare have been included in official definitions such as the World Organization for Animal Health which defines an animal as being in good welfare if it is *"healthy, comfortable, well nourished, safe, able to express innate behavior, and it is not suffering from unpleasant states such as pain, fear, and distress"*.[14]

Agriculture Sustainability

Definitions of sustainability frequently include three pillars, economic, environment and social, which should be weighted equally.[28] Traditionally academics working in agriculture, and farmers and others working in food animal production systems, have placed greater emphasis the economic pillar.[6,20] More recently sustainability discussions on animal agriculture have focused on the environmental concerns resulting in this aspect receiving much attention. For example, debates frequently discuss the role that food-animal production plays in competition for natural resources (i.e., water, land, and energy) and how to mitigate any negative effects of food animal agriculture on the environment.[22] The fact that the social pillar has received the least amount of attention may be a consequence of it having an aspect of human values,[21] and because it is difficult to quantify using traditional natural science based metrics. Furthermore, values are influenced by cultural norms within societies.[2] Despite these difficulties there is a growing recognition that the social pillar is an important component of sustainability.[28] This may be particularly true for production that takes place in intensive housing systems that are the subject of increased societal criticism.[22]

Animal welfare is an important social concern and, as such, needs to be integrated into the concept of sustainable agriculture, rather than made to 'compete' with environmental goals[8] and economic goals.[29] To achieve this we argue that those not directly involved in farming must be accepted as credible stakeholders in the discussions on the way farm animals are cared for.

Stakeholder engagement on contentious practices in dairy industry

Our perspective is that rather than focusing efforts on one-way efforts to 'educate' the public, we should instead develop methods of facilitating constructive, informed engagement among the stakeholders. We suggest that this approach will likely to be more effective in identifying shared concerns and potential solutions likely to find general appeal.

At The University of British Columbia (UBC) we have been using web-based platforms to provide opportunities for people within the dairy industry to discuss dairy management practices with each other and with members of the public interested in these issues. For example, UBC's Cow Views site provided the opportunity for people to state their views, and also vote on the views of others. The idea was to get people discussing uncomfortable issues in dairy farming. Our aim was to use these discussions to provide farmers and the industry a better basis for making informed decisions about management on farms and policy for the industry.

For each issue, participants were given a brief background of the perceived advantages and disadvantages associated with each practice (see tail docking for example). They were then asked to vote on whether or not the practice should continue or not. We recruited participants into multiple virtual 'town hall' meetings, such that participants could see each other's responses, but participants in one meeting could not see the reasons discussed in other meetings. In this way each meeting provides an independent test of how this type of discussion unfolds. Also, an especially persuasive reason can only influence the votes within a single town hall meeting.

Our intention was not to collect a random or representative sample of any specific population, but rather to include a diverse range of participants to increase our chances of achieving saturation in views. The forum was made available on the Internet so anyone with Internet access could participate. To encourage participation of people in the North American dairy industry, we published brief articles in producer magazines (*Progressive Dairyman* and *Ontario Farmer*) that invited readers to participate. For the broader public samples we recruited online via Mechanical Turk.[a] Several studies have assessed this tool and concluded that this approach results in high-quality and reliable data[3,17,18] that is more representative than many other samples.[9,18]

To provide context, for each of the specific issues we have summarized below we also state the current position in Canada's Code of Practice and the United States National Federation of Milk Producers based Farmers for the Assurance of Responsible Practice, and where relevant have described policy in other parts of the world.

Should we continue docking the tails of dairy cattle?

The responses to this question are fully described in Weary et al.[30]

Briefly, 178 participants were provided the following context:

> *"Tail docking dairy cattle first became common in New Zealand where workers thought this could reduce their risk of diseases like leptospirosis that can be carried by cows. Some milkers also preferred working with docked cows because the shortened tail was less likely to hit them in the parlor. Some people also felt that docking improved cow cleanliness, and cleaner cows should be exposed to fewer pathogens and have improved udder health.*
>
> *There may also be disadvantages associated with docking. For some, at least, there is a 'yuk' factor of seeing cows without their tails. Docking might also cause pain, and prevents cows from using their natural fly-swatter. For these reasons several European countries including Norway, Sweden, the Netherlands, the United Kingdom,*

and Switzerland have prohibited tail docking of dairy cattle.

More recently, Canada's new Code of Practice for the Care and Handling of Dairy Cattle states that dairy cattle "must not be tail docked".

In the United States, about 40% of dairy cows have docked tails."

Participants were then asked, "*Should we continue docking the tails of dairy cattle?*"

Approximately 79% of participants were opposed to docking (i.e., responded "No" to the question). Responses varied with participant demographics (e.g. females were more likely than males to oppose docking), but in every demographic sub-group (e.g., by gender, age, country of origin and dairy production experience) the majority of respondents were opposed to tail docking. Common reasons for opposition to docking included the lack of scientific evidence that docking improves cleanliness or udder health, that docking is painful for cows, that docking is unnatural and that tails are important for controlling flies. Some respondents in favour of docking cited cow cleanliness as an issue, despite the scientific evidence showing no positive effect of docking on cow cleanliness or udder health. Additional reasons included protecting producer safety.

These results illustrate the range of reasons that are cited for supporting and opposing tail docking. This approach can be used to better target outreach efforts (e.g. improving farmer education on the lack of positive effects of docking on cleanliness and udder health while addressing concerns about producer safety).

Given the extent of public opposition to this practice it is not surprising that in some countries tail docking has been banned, including Norway, Sweden, the Netherlands, the United Kingdom and Switzerland. This has also likely motivated corporations to take a stand on this issue as part of their corporate social responsibility practices. For example, Nestlé, the world's largest food company, has announced their objection to tail docking.

In Canada, dairy producers have taken a clear position on this issue. Our Code of Practice for the Care and Handling of Dairy Cattle has a *requirement* that cows "*must not be tail docked unless medically necessary*." This is also the position of the Canadian Veterinarian Association and the American Association of Bovine Practitioners. Most recently the National Federation of Milk Producers in the US announced that members of their assurance program will be prohibited from tail docking their cows effective January 1, 2017.

Should we provide pain relief for disbudding and dehorning dairy calves?

The responses to this question are fully described in Robbins et al.[16]

For this issue participants were provided the following context:

"The developing horns of dairy calves are typically removed to reduce the risk of injuries to farm workers or other cattle that can be caused by horned cattle. Horns of calves three months of age or older are normally removed surgically ("dehorning") by scooping, shearing or sawing. Horn buds of younger calves are typically removed ("disbudding") using a caustic paste or a hot iron.

There is considerable scientific evidence that all of these procedures cause pain. The immediate pain can be reduced using a local anesthetic to provide a nerve block – this procedure has been used safely for decades and costs just pennies a shot. Pain can persist 24 hours or more; this longer lasting pain can be reduced using non-steroidal anti-inflammatory drugs (like the ibuprofen you take for a headache). Providing calves a sedative before the procedure can reduce handling stress and make the procedure easier to carry out.

In many countries some pain relief is required. For example, Canada's new Code of Practice for the Care and Handling of Dairy Cattle requires that pain control be used. Approximately 18% of dairy farms in the United States report using pain relieving drugs for disbudding or dehorning dairy calves."

Participants then answered the question "*Should we provide pain relief for disbudding and dehorning dairy calves?*"

Participant composition was as follows: dairy producer or other farm worker (10%); veterinarian or other professional working with the dairy industry (7%); student, teacher or researcher (16%); animal advocate (9%) and no involvement with the dairy industry (57%).

Of 354 participants, 90% thought pain relief should be provided when disbudding and dehorning. This support was consistent across all demographic categories suggesting the industry practice of disbudding and dehorning without pain control is not consistent with normative beliefs. The most common themes in participants' comments were: pain intensity and duration, concerns about drug use, cost, ease and practicality and availability of alternatives.

These results show a clear disconnect between current practice (with many farmers failing to provide pain control) and the attitudes of participants (including dairy producers) in these virtual town hall meetings. Causing pain to animals under our care, especially when this pain can easily be prevented, no longer seems acceptable. Our challenge is to find ways of getting pain control techniques applied widely on dairy farms.

In Canada, dairy producers have also taken a clear position on this issue. The Code of Practice for the Care and Handling of Dairy Cattle requires that *"Pain control must be used when dehorning or disbudding."* In many countries (i.e., Sweden, Denmark, Netherlands, New Zealand, and Australia) pain control for disbudding and dehorning is a legal requirement.[1,11,15] The US based FARM program states the following: *"Pain mitigation is provided for disbudding or dehorning in accordance with the recommendations of your herd veterinarian."* Initially concerns were raised whether these industry led initiatives would be sufficient to maintain consensus amongst all stakeholders in the long run, given that they would require voluntary compliance by all farmers.[29] However, recent developments such as the Saputo Inc. (milk processing company) policy on Animal Welfare (June 2015) that states (among other things) that *"The use of pain control when dehorning or disbudding cattle must become a minimum industry standard"* suggests that compliance on certain animal welfare standards will be mandatory.

Should dairy cows be provided access to pasture?

The responses to this question are fully described in Schuppli et al.[19]

For this issue participants were provided the following context:

> *"On many dairy farms cows are always kept indoors. Some dairy farmers believe that well-designed indoor housing provides a more comfortable and more suitable environment for the cows. In addition, some farmers keep cows indoors to more easily provide and control diets formulated to sustain high milk production.*
>
> *Others consider pasture access to be important. For example, some believe that grazing is more environmentally sustainable, that pasture provides a healthier and more comfortable environment for cows, and that grazing is a natural behaviour important for cows."*

Participants then answered the question "*Should dairy cows be provided access to pasture?*"

A total of 414 people participated. Providing access to more natural living conditions, including pasture, was viewed as important for the large majority of participants, including those affiliated with the dairy industry. This finding is at odds with current practice on the majority of farms in the United States where less than 5% of lactating dairy cows have routine access to pasture.[23] To our knowledge there is no research indicating about how many lactating cows in Canada have routine access to pasture.

Participant comments showed that the perceived value of pasture access for dairy cattle went beyond the benefits of eating grass; participants cited as benefits exposure to fresh air, ability to move freely, ability to live in social groups, improved health, and healthier milk products. To accommodate the challenges of allowing pasture access on farms, some participants argued in favor of hybrid systems that provide a mixture of indoor confinement housing and grazing.

Despite the public indicating that access to pasture is important,[4] the Canadian Code of Practice and the US based FARM program are largely silent on this issue. For instance the Canadian Code of Practice recommending only "*for bedded-pack or composted-pack barns, provide access to pasture or an exercise*." In contrast, Sweden requires that cows be given pasture access during summer months.[10]

The National Federation of Milk Producers FARM program essentially stays silent on this issue of pasture access for dairy cattle. The fact that the majority of cows in Canada and the United States are not routinely provided pasture access[23] is an issue that is receiving increased public attention.[4] We speculate that external stakeholders, and in particular the public, will become increasingly unwilling to accept this practice.

Should dairy calves be separated from the cow within the first few hours after birth?

The responses to this question are fully described in Ventura et al.[26]

For this issue 195 participants were provided the following context:

> *"Dairy farmers often remove the calf from within the first few hours of birth. This is done in response to several concerns including the following: the calf may become infected from pathogens carried by the cow or her environment; the calf may become injured by the cow or the barn equipment; the calf will not be able to nurse from the cow and receive adequate colostrum (first milk produced by the cow after birth) and milk; the calf will drink too much milk which increases the farmer's cost of feeding and increases the risk of diarrhea; allowing the cow and calf to bond will result in greater separation distress when separation does occur; farms are often not well designed for cow-calf pairs, so keeping cows and calves together can be considered an extra chore. Others consider that some form of cow-calf contact is an important element of natural behavior, and believe that this contact is beneficial to the cow and calf. On these farms the cow and calf are kept together for days or even weeks after birth."*

Participants then answered the question "*Should dairy calves be separated from the cow within the first few hours after birth?"*

Opponents of early separation contended that it is emotionally stressful for the calf and cow, it compromises calf and cow health, it is unnatural, and the industry can and should accommodate cow-calf pairs. In contrast, supporters of early separation reasoned that emotional distress is minimized by separating before bonds develop, that it promotes calf and cow health, and that the industry is limited in its ability to accommodate cow-calf pairs. Opponents of separating calves from their cows in the first few hours after birth often based their based their views on the emotional experiences of cows and calves. They compared the bond of a cow and her calf to the bond between mother and offspring in other species.

A major theme raised by proponents was that separation was inevitable, and that early separation was easier on the cow and calf than separation at a later age. There is considerable scientific evidence in support of this claim. Separating calves at an older age results in a much stronger response (high rates of vocalization and other activities) in comparison with calves separated soon after birth.[5] Some respondents also believed that early separation minimized disease transmission from the cow. We are aware of little evidence to support this link.

The Canadian Dairy Code of Practice[12] states the following:

> *"Generally, dairy calves are separated from their mothers shortly after birth. There are benefits to both calf and dam by allowing the pair to bond. Allowing the calf to spend a longer period of time with the dam may result in lowered morbidity and mortality in the calf; however, separation stress to both the cow and calf will be higher the longer they are together. Cow health is generally improved by allowing the calf to suckle (related to oxytocin effects on the post partum uterus)."*

Based on this summary of information the Code provides the following recommended best practice – "*reduce separation distress by either removing the calf shortly after birth or by using a two-step weaning process."*

The National Federation of Milk Producers FARM program[13] has elected to remain silent on the issue of cow calf separation.

The fact that cows and calves are routinely separated at birth is an issue that the public is largely unaware of,[24] perhaps explaining why this issue has received little attention within non-dairy audiences. However, we speculate that external stakeholders will become increasingly unwilling to accept this practice.

Conclusions

The examples illustrated in this paper show how social science methodologies can document the shared and divergent values of different stakeholders, the associated beliefs regarding the available evidence, and the barriers in implementing changes. In some cases we documented shared values amongst the majority of stakeholders (e.g. that dehorning causes pain), but we also found important disconnects between current dairy production methods and widely held public values. Understanding the attitudes of people affiliated and unaffiliated with the dairy industry allows for the identification of contentious topics as well as areas of agreement; this is important in efforts to better harmonize industry practices with societal expectations.

We have also identified where the Code of Practice on the Care and Handling of Dairy Cattle and the National Federation of Milk Producers FARM program align with stakeholder expectations and where gaps exist. We encourage the dairy industry to work to overcome these gaps.

Endnotes

[a]Mechanical Turk, MTurk, www.mturk.com

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Why is change so hard? Communication as a tool for optimizing producer adherence to veterinary recommendations

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Abstract

Awareness of the importance of communication in veterinary medicine has been heightened in the last 2 decades. Formal communication instruction is now a core requirement for all AVMA-accredited Colleges of Veterinary Medicine. The profession as a whole is realizing the importance of communication as it relates to business success, professional satisfaction, and patient outcomes. Clinicians, clients, and patients benefit from the use of evidence-based clinical communication skills; assuring accurate, efficient, and effective transfer of information. While the initial efforts for communication in veterinary medicine seemed to focus on companion animal practice, few would dispute that communication is critical for production animal veterinarians. The complexity of the contexts in which production animal veterinarians work to effect change requires even greater understanding of how people make decisions and how to influence those decisions effectively. Veterinarians are encouraged to be curious: Take the time to understand your clients and stakeholders; what extrinsic and intrinsic motivators are present? How does their organization run and why is it run that way? To ensure accurate understanding, consider demonstrating an understanding of the client through summarizing and empathy. Once there is clear understanding that has been communicated, only then can the veterinarian begin to make recommendations.

Key words: client adherence, veterinary communication

Résumé

Depuis les deux dernières décennies, l'importance de la communication en médecine vétérinaire est de plus en plus reconnue. Une formation en communication officielle est maintenant une exigence fondamentale dans toutes les facultés de médecine vétérinaire accréditées par l'*AVMA*. La profession dans son ensemble réalise l'importance de la communication car cette dernière est reliée au succès d'affaires, à la satisfaction personnelle et aux résultats pour les patients. L'aptitude à bien communiquer les résultats cliniques de la médecine factuelle bénéficie les cliniciens, les clients et les patients. Ceci assure un transfert d'information juste, efficace et performant. Initialement, la communication en médecine vétérinaire semblait surtout viser les pratiques de petits animaux mais il y a peu de doute que la communication est aussi essentielle pour les vétérinaires en production animale. Les vétérinaires en production animale opèrent dans plusieurs contextes souvent complexes pour faire avancer les choses et cela nécessite une plus grande compréhension de la prise de décision par les individus et jusqu'à quel point il est possible d'influencer ces décisions efficacement. On encourage les vétérinaires à être curieux : Prenez le temps de comprendre vos clients et les intervenants, quels sont les incitatifs internes et externes en jeu? Comment l'organisation est-elle gérée et pourquoi est-elle gérée de cette façon? Pour s'assurer d'une juste compréhension, on peut essayer de démonter au client qu'on le comprend bien en résumant les choses et en montrant de l'empathie. Lorsqu'une bonne connaissance est établie, le vétérinaire devient maintenant en mesure de faire des recommandations.

Introduction

Biosecurity, food safety, extra-label drug use, adherence to standard operating procedures and treatment protocols, lameness identification, animal welfare considerations, limiting and managing antimicrobial resistance, employing optimal healthy calf rearing, and protecting the environment; the challenges facing producers and production animal veterinarians are complicated and numerous. There is ample information intended to guide practitioners, consultants, and producers on how to address these challenges. And yet, guidelines and recommendations go unheeded by producers and veterinarians alike.[2,3,5,7,12,14,16] With all the know-how and creativity going towards meeting these challenges, why do we seem to fall short of the goal of implementing change so often? What seems to be an obvious plan for an operation may be met with ambivalence or even hostility from a client or quiet sabotage from workers.

In the struggle to understand resistance to changes that are in a producer, animal, or society's best interest, we may fail to realize the choices we are asking a producer to make. The way they see their role, the heritage of an operation, or how they work with their employees may be impacted by a change in protocol. The loss or sacrifice that may result from this change may not be apparent to the veterinarian. The producer may not be consciously aware of the complexity of their decision-making process: where economics intersect with producer's sense of worth, values, personal and professional satisfaction, and sense of self-efficacy; where stakeholders hold competing interests and expectations from society; and where the desire to produce a wholesome product and consider the impact of their actions on future generations may work against ensuring short-term profitability.

Scholars in leadership and change have divided these challenges into 2 categories. They have contrasted the idea of a technical solution (1 where there is a clear answer and path forward) to adaptive challenges (where the complexity of the situation means there is no 1 clear path to follow).[11] Too often, we make the mistake of assuming we are dealing with a technical problem when we are really being confronted by an adaptive challenge. The challenges facing production animal medicine fall into both categories. Technical solutions might include writing a treatment protocol for a given condition, translating that protocol into Spanish, developing an educational handout, and changing the configuration of a foot bath. Each has a clear objective and can be directly measured for compliance and outcome. Adaptive challenges offer less clarity, requiring more conversation and understanding of another's point of view. For example, identifying as a self-reliant producer who is fiscally responsible may run counter to paying for appropriate DVM services that may enhance profit margins. Adaptive challenges have far greater implications for producers and veterinarians, are often more difficult to reach common ground on, and are ubiquitous.

Further complicating a veterinarian's agenda is the challenge of multiple people working on operations with diverse education levels, disease/health/agriculture literacy, ideas about animal welfare, agendas, and backgrounds. Everyone on an operation is an individual with their own motivations, goals, barriers, and ideas. How each of these people works together and within an organization also impacts adherence of veterinary recommendations. The flow of information and assignment of work tasks can directly impact the bottom line for a producer. It is fair to say that in most production animal contexts; there are high levels of uncertainty, a considerable level of interdependence, and resource constraints. Jody Hoffer Gittell offers important explanations and guidance for these types of high-stakes environments.[9] Relational Coordination came out of studies of aviation, but quickly expanded to human healthcare.[8,10] In a hallmark study, post-operative pain, length of hospital stay, and return to function in joint replacement patients are impacted by the quality of relational coordination exhibited by a healthcare team.[8,10]

Relational coordination relates to the quality of relationships and the type of communication that occurs between work groups and offers some useful insights to production operations.[4,8-10] The following 7 elements have strong influence on the effectiveness of an organization or work group:

1. Shared goals
2. Shared knowledge
3. Mutual respect
4. Frequent communication
5. Timely communication
6. Accurate communication
7. Problem-solving communication

Work groups that share these attributes within the groups and between groups function at a higher level than work groups that do not share these attributes.[4,8-10] At Washington State University, we have begun to use this construct with our students as a way to look at the working relationships within a producer's operation. Consultants and practitioners alike may find that determining the flow of information and methods of communication on an operation may reveal as much as a good post-mortem examination on a sentinel animal. Practitioners and consultants may want to consider how their own approaches would be interpreted by their clients in relation to these 7 elements. A tool along these lines has been developed to assess organizational communication on dairy farms.[18] To learn as much as possible about an operation, veterinarians need to hear from a number of stakeholders within the operation. To have that type of access and to get accurate information from stakeholders, trust between the producer, stakeholders, and veterinarian is imperative.

To build that kind of trust it is useful to understand the workings of the human brain. In recent years, findings in neuroscience have supported many of the ideas put forth by educators, psychologists, and leadership scholars. Behavior changes when people have the following: 1) a trusted relationship with someone who understands and is attuned to their wishes, ideas, etc.; 2) an appropriate level of arousal; 3) activation of both thinking and feeling; 4) method of self-reflection; and 5) a sense that what is being asked of the person is possible.[6,11]

Skills that allow us to develop a trusted relationship with clients and stakeholders include active listening skills; eliciting and clarifying individual's ideas, expectations, concerns, and potential impacts of any action; demonstrating empathy; and using appropriate non-verbal behavior.[16,17] Active listening involves hearing what the client is and is not saying, hearing them out completely before interjecting, and confirming understanding of what you heard prior to moving on. Listening is as much an art as a science and is perhaps 1 of the most under-used skills available to veterinarians and producers alike. Veterinarians and physicians alike are notorious for interrupting clients within seconds of beginning to speak.

Not only is it important to get all of the facts as accurately as possible from the client, but is also important to understand their perspective. Articulating what we understand of the problem parameters, including what the client's experience is with the situation and the impact it is having on them as well as any limitations helps clarify our own assumption. These skills ensure we acknowledge the client's unique perspective on the situation. Understanding their ideas, concerns, expectations, and the impact the problem is or may have on their life is an important contributing factor to how we will need to approach clinical reasoning.

Determining the client's perspective, concerns, and any potential impacts is another area that does not necessarily come naturally to people. A person's knowledge and belief is a powerful force. To effect change, the veterinarian must understand the starting point of the person whom you wish to influence. Because disease literacy, agendas, etc., can vary, it is crucial to start with stakeholder's understanding, barriers, etc. Know where to start based on what the client knows and thinks they understand is important for buy-in and for effective education. Understanding that clients are often more concerned about avoiding losses than achieving gains,[11] it is vital to understand the clients point of view to determine how to frame recommendations in a way that is most likely to achieve adherence. Clarifying questions and summarizing are great ways to ensure the client knows they have been heard while allowing them to correct any misunderstandings. Focusing on listening to hear and understand, rather than to make early assumptions and quickly reach a diagnosis, may be a challenge for many of us in our busy lives.

Empathy is a word that can evoke discomfort for many veterinarians. What is important to understand is that there are many types of empathy: reflection, legitimization, support, partnership, respect, and acknowledgement.[17] The fear with empathy may be that we would need to "fix" any problems we find. That is really not the point. Again, turning to neuroscience, we know that people who feel connected and understood are more able to make changes.[6] As veterinarians work to truly understand where a client is coming from and expressing that understanding, neurochemicals are released leading to greater trust.

To keep the appropriate level of arousal (manage the temperature) there must be an on-going honest dialogue between producer and veterinarian. The veterinarian needs to ensure they understand the producer's motivations and priorities as well as losses that might be incurred. For many producers, the ideals we strive for may not match their own. While it has been reported that practitioners believe one-on-one communication is the most effective for effecting producer change,[5] there is mounting evidence that the social dimension of learning may be crucial for the challenges to be met. Benchmarks, workshops, and think tanks allow producers to compare their thoughts and approaches to those of their peers with the structure of the clear goal or objective. Learning is a social process of constructing and internalizing an interpretation of one's experience to guide future action. Done well, this type of learning can cause radical changes in paradigm. It uncovers distorted assumptions or errors in learning. Stages of transformative learning: 1) initial learning development, 2) learner critical self-reflection, 3) transformative learning, and 4) increased empowerment.

Conclusion

Veterinary medicine is in a time of change. The challenges facing our production animal clients are considerably different than they were only a few decades ago. While information is available to anyone with a web browser, producers stand to benefit from a collaborative relationship with their veterinary team. The challenges and opportunities are shifting the role of a veterinarian to one who must have an excellent grasp of human behavior and communication. One of the biggest challenges for the profession is that communication skills are not easily developed without coaching.[1,13,19] There is often a misconception of what we intend to do compared to what we actually do and the impact our efforts have on other people. The most effective communication training programs are experiential using simulated clients and expert communication coaches to raise awareness and impact skill development.

> "We are what we repeatedly do. Excellence then, is not an act, but a habit." Aristotle

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