Preweaned dairy calf nutrition: Veterinarian's role in a milk feeding program

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Abstract

The herd veterinarian has an important role on calf raising operations to promote the health and welfare of calves through having a role in the milk phase nutrition program. Optimal nutrition will benefit the calves and the herd veterinarian can help provide input and critique of a milk program using their expertise in animal health, husbandry, nutrition and behavior. Milk feeding of calves, traditionally around 60 days, has been shown to have long term production benefits for adult dairy cows, and yet often the milk feeding plan is delegated to a private or feed company nutritionist. This paper describes tools and best practices for herd veterinarians to ensure young calves are fed appropriately to meet their genetic potential and the dairy producer's goals. Even if the herd veterinarian does not have overall authority of a milk program, they can use the best practices to align producer expectations with what is being offered to the calves and give their impartial input of how to best apply the producer's resources in a feeding program for the benefit of the calves.

Key words: dairy calf, milk feeding

Introduction

Nutrition during the milk phase of a dairy calf's life will have short term and long-term benefits of health and production.[1,9,13,16,21,23,25] The dairy veterinarian often does not have a role in the nutrition of young dairy calves because nutrition decisions are delegated to a herd nutritionist or to an outside feed company consultant. As producers focus more on quality of the calf they raise as opposed to the quantity of calves raised, the veterinarian needs to take an active role in the young calf program which includes the nutrition. Proper nutrition can reduce disease incidence and ensure calves have energy to respond to vaccines and environmental challenges.[17,19] The milk diet of a young calf should be reviewed by the veterinarian from the plan on paper and how calves are performing, even if the veterinarian does have extensive training in young animal or adult cow nutrition. Proper implementation of a milk ration will improve calf health, decrease mortality, reduce challenges during weaning transition, and increase milk production in the herd long term.[13,22,23] This paper outlines research, tools, and best practices for a veterinarian to evaluate a calf milk feeding program.

Benefits of improved milk feeding

Dairy calves are born as functional monogastric animals designed to consume milk from their dam. When a calf is on a milk diet, she is the most feed efficient during her lifetime and calf raisers can take advantage of this feed efficiency by feeding more milk to have greater return in the form of average daily gain.[8,9,11] This is accomplished by feeding more milk each day either by increasing total volume of milk fed or increasing total solids of the milk solution fed; the efficiency of gain will also increase. When feeding more milk each day, also the ratio of protein to fat in the milk is important to maximize lean growth of skeletal muscle, structural growth of bone, and to promote starter grain intakes.[4,10]

Calves fed a higher plane of nutrition have a more rapid increase in WBC response and had a more rapid increase in leukocyte responses including the secretion of TNF-α when whole blood was stimulated with LPS as well as neutrophil oxidative burst.[19] Calves fed a higher plane of nutrition better handle a challenge with cryptosporidium seen by a faster resolution of diarrhea, maintenance of hydration through clinical diarrhea, and have better gains with greater feed efficiency compared to calves fed a lower plane of nutrition.[20] Calves fed more milk are also better able to handle salmonella challenge after weaning compared to calves fed a lower plane of milk nutrition.[2]

What is milk?

When evaluating a milk feeding program, remember the milk feeding routine of beef calves and the nutritional components of whole milk and compare to how dairy calves are fed milk because the two types of calves may have different goals, but share basic biology. A dairy calf's dam is producing high-value sellable milk, and therefore it makes sense that this whole milk is not available for the calves. A substitute for whole milk of reconstituted milk replacer is fed to dairy calves because they are born as functional monogastric animals and need to develop the rumen before calves can digest and utilize a grain or forage diet. One of the main goals of a dairy calf milk program is to drive starter grain intakes to promote rumen development and wean calves off of an expensive milk diet. For dairy calves, this is usually done over a 2-month period, as opposed to a beef calf that will nurse from the dam until 6 months of age. A good milk program for dairy calves will strike the right balance of supporting growth and health through the liquid diet while also encouraging starter grain intakes for rumen development.

Whole milk is composed of water, fat, protein, lactose, vitamins, trace minerals and ash. When mixing milk replacer, water quality is very important because it is the main ingredient and access to fresh water for the calves between milk feeding is important for calves to stay hydrated because milk replacer is often mixed to a higher total solids compared to whole milk. Laboratory analysis of water used to mix milk replacer and fed to calves should be routinely performed for analysis of, at a minimum, total solids, pH, sodium, nitrates and heavy metals. Dairyland Laboratories' "Calf Suitability Package" for water analysis uses specific standards for calves and reports the results in a user-friendly manner to understand where action needs to be taken. When sampling water, be sure to call the laboratory ahead of time for submission instructions, sample all the wells on a farm that provide water to the calves, and sample the water at the source point to the calves. It is important the water sample is representative of what the calves are drinking,

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went through all pipes and filtration or water softening systems. Water processed through a water softening system should not be fed to calves or used to mix milk replacer because of its high sodium content which will increase osmolality of mixed milk solution leading to scours and dehydration.

An average of total solids for whole milk is 12%, which means 88% of whole milk is water. If this 12% total solids line milk is 3.3% protein, 3.8% fat and 4.7% lactose, then on a dry matter basis the nutritional components are 28% protein, 32% fat and 39% lactose, with 1% vitamins, trace minerals and ash. To calculate components of milk on a dry matter basis, divide percentage of the component by total solids. For example, 3.3 divided by 12 gives the percentage of protein on a dry matter basis for the example of whole milk above. Also, it helps to think about nutritional components of milk (whole milk or milk replacer) as a pie chart that always has to add up to 100%. Know the percentage of protein and fat from the processor or a milk replacer tag, then simple subtraction is used to determine what other components are in the milk which will mostly be lactose and a small amount of vitamins, trace minerals and ash.

Dairy calves are fed many different combinations of feeds in their liquid diet including, but not limited to line milk, hospital milk, milk replacer, individual components such as whey, skim milk powder, dried fat, liquid tallow, vitamin and trace mineral packs, and other nutraceutical additives.[5] Milk replacer is most commonly sold as a complete feed in the form of a dried powder in 50-pound bags with the nutritional breakdown reported on a dry matter basis. For example, a 26/20 milk replacer is 26% protein and 20% fat on a dry matter basis. Protein is always the first percentage reported in a milk replacer tag or label followed by the fat percentage. The other main nutritional component of milk will be lactose, just like in whole milk, but the vitamin, trace mineral and ash component of milk replacer is higher than whole milk with an average of 10%, leaving lactose at 44% in this example of a 26:20 milk replacer. The higher ash content in milk replacer is due to the ingredients used to make milk replacer, which are the by-products of dairy processing, concentrating the ash content of whole milk through the processing steps to make dried whey or dried skim milk powder.

Sources of fat in milk replacer include lard, tallow, choice white grease, vegetable oil and coconut oil.[5] It is very important to note that butterfat, the fat in whole milk, is not included in this list as a common source of fat in commercial milk replacers. This is because butterfat is used for human dairy products, such as cheese and butter, making the ingredient too valuable to use as a fat source for commercial milk replacers. Butterfat is designed for young calf digestion and the fat sources in milk replacer are not an exact substitute for butterfat from a fatty acid profile and digestibility. Fat levels in milk replacer are always lower than fat levels in whole milk because feeding high levels of these fat substitutes in milk replacer suppresses starter grain intake, decrease in feed efficiency, and decrease lean muscle growth.[3,4,8,14,15,24] If milk replacer was formulated to match the percentage of fat in whole milk on a dry matter basis, for example 32%, with a blend of lard, tallow and vegetable oil, this milk replacer would cause scours and death because the calves cannot digest high levels of the alternative fat sources. Using alternative fat sources, like coconut oil, in milk replacer formulas to try and match the fatty acid profile of butterfat , has been shown to have benefits[7] Another reason why the fat levels in milk replacer are lower than fat in whole milk is because of the need to drive calves to eat starter grain for rumen development.[10,14,24] A beef calf will nurse from its mother for 6 months and have that time to begin eating solid feed for rumen development before the beef calf is weaned. Our modern dairy calf raising systems have expedited this process of milk feeding and rumen development to an average of only 2 months on milk. Dairy calves are often weaned at 8 weeks old and are then expected to continue to grow and develop a solid feed diet as a ruminant. This is not to declare a dairy calf has completed their rumen development at 2 months old, but promoting rumen development is one of the major goals of a calf milk feeding program.

Driving grain intake is how rumen development occurs by feeding the rumen with nutrients that will promote butyrate and propionate production in the rumen for papillary growth. Research has shown feeding a milk replacer with a higher percentage of protein than fat will drive starter grain intake.[4,9,10,15,24] A good milk program will support young calf growth while also encouraging grain intake to ensure there is rumen development. Fat is satiating and has twice the caloric density compared to protein and lactose. Feeding high levels of fat in the form of butterfat in whole milk or byproducts fat in milk replacer has been shown to decrease starter intake.[13,15] This can lead to calves not transitioning well at weaning because calves are not consuming enough grain at the beginning of weaning to maintain health and growth when milk is removed. Holstein calves should be eating 2 pounds of starter grain a day for a minimum of 3 consecutive days at the start of weaning to demonstrate they are ready to make the transition off of a milk diet.

Milk replacer protein sources are byproducts from milk processing. The main protein in whole milk is casein and the main protein in milk replacer is whey because it is readily available as a byproduct of cheese production. Whey protein is a milk protein, unlike fat sources, but through the processing and drying processes of making dried whey can be damaged through exposure to high temperature. Dried whey and dried skim milk powder are readily used as ingredients in human food production as well and often it is these ingredients that do not meet the standards for human consumption that are used for milk replacer production.

Milk math

A basic understanding of how much a calf is consuming, in the form of pounds of milk solids, is one of the first steps for evaluating a milk feeding program because it will give an estimation of the growth potential for the calves and the producer goals. There are some baseline benchmarks that can easily be evaluated on farm to determine if a milk feeding program is under or over feeding milk to young calves. In addition, using the NRC18 with the amounts of milk fed to the calves will give a modeled average daily gain expectation, and if the milk diet is protein-limiting or energy (fat)-limiting as formulated.

To perform milk math, use the total volume a calf is offered to drink each day in gallons, multiply by the conversion factor of 8.6, and then multiply by the total solids as a percentage. For example, if the calf is offered a 2-quart bottle of 12% total solids milk twice a day (total 4 quarts or 1 gallon per day) then the equation to determine pounds of milk solids is $(1 \times 8.6) \times 0.12 = 1.03$ pounds of milk solids per day. Due to the labor intensity of feeding calves, calves are often only fed 2 or 3 times a day via a bottle or a bucket. Calf-raising operations have to deliver milk solids to calves within the constraints of available labor and facilities and constraints of a calf that can only tolerate a certain

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upper limit of total solids, volume of milk in one feeding, and interval of time between feedings to allow the calves to become hungry for another milk feeding.

Delivering more milk solids to calves, even increasing by 0.5 pounds per day, will have large impacts on health as calves consumed 10-20% of their body weight daily. This can be accomplished by increasing total solids of the milk, increasing the volume of milk at a feeding, or increasing the number of feedings in a day. From a management perspective, increasing total solids or volume fed are easier changes than adding additional feedings. Using milk math calculations along with the NRC18 desktop application will help a calf raiser determine how to best deliver more nutrition to the calves. For example, if the size of bottles is increased from 2 quarts to 3 quarts fed twice a day, while total solids remain unchanged, then total dry matter delivered is (1.5 × 8.6) × 0.12 = 1.55 pounds milk solids. Comparing these two examples in the NRC of a 24/20 milk replacer under thermoneutral conditions, 1.03 pounds per day gives an expected average daily gain of 0.45 pounds per day. While feeding 1.55 pounds per day of this same milk replacer formulation gives an expected average daily gain of 1.19 pounds per day.

Whole milk total solids is an of average 12% and calves can tolerate a higher concentration of milk solids compared to whole milk, so milk replacer powder can be added to whole milk or milk replacer can be mixed at a concentration higher than 12% as a strategy to deliver more dry matter within the same amount of volume. In the example above, if instead of increasing volume, the total solids is increased to 14%, then total dry matter delivered in a day is (1 × 8.6) x 0.14 = 1.20 pounds of milk solids. Or if volume and total solids are increased, then total dry matter delivered in a day is (1.5 × 8.6) x 0.14 = 1.81 pounds milk solids. NRC modeled average daily gain for feeding 1.81 pounds of the 24/20 milk replacer under thermoneutral conditions is 1.44 pounds per day. This expected average daily gain is close to the benchmark of doubling birthweight in the first 2 months of life for an 85-pound Holstein heifer calf.

Pounds of milk solids fed to a calf each day do have a limit and recommended limits are 2.25 pounds per day for Holstein calves and 1.8 pounds per day for Jersey calves. In a mixed herd of Holsteins, Jerseys and crosses, feeding 1.8 pounds of milk solids per day will keep Jerseys healthy and have good growth in the Holsteins and crosses.

Total solids or concentration of the milk has an upper limit as well, and 14% is the highest total solids recommended for a milk formula. Naturally, a calf's digestive system is designed to digest a 12% total solids diet, and when fed a higher total solids milk, then there is an increased risk of osmotic diarrhea. The osmolality of whole milk is around 300 mOsm, which is isotonic to extracellular fluid and intracellular fluid compartments of the calf. Adding milk replacer powder to whole milk, as a way to increase total solids, will increase osmolality of the milk solution and should be limited to 14% based on milk math of total pounds of solids dissolved in a volume of water. Milk replacer mixed according to label instructions will lead to osmolality of 400-500 mOsm depending on the quality of the water used to mix the milk replacer. Calves can tolerate this higher osmolality of their milk, but only if they have free choice access to fresh water at all times because a high concentrated liquid diet will stimulate thirst. Osmolality of a mixed milk solution can be measured in the laboratory setting if there are questions of a milk diet causing osmotic diarrhea.

Feeding hospital milk

Feeding hospital milk is a common strategy on calf raising operations because hospital milk cannot be sold for human consumption, and since it is cow's milk, it has the natural nutritional components of butterfat and casein. Due to inconsistent volumes of hospital milk produced day to day and in general lower total solids in hospital milk, hospital milk is often used as an ingredient along with water and milk replacer powder to make a consistent milk ration for the calves. When feeding hospital milk, ensure that it is clean and easy for employees to use in the milk recipe ration to provide a consistent milk diet. Use milk math to formulate a milk ration recipe by using hospital milk total solids and volume available to provide simple instructions of volume of hospital milk, water and pounds of milk replacer needed to achieve desired total solids consistently with each batch of milk mixed.

First best practice for using hospital milk is to ensure it is clean when fed to the calves. As the herd veterinarian, this means following the hospital milk from harvest to storage to pasteurization and then to mixing. Hospital milk needs to be chilled after harvest and then stored in a refrigerated tank to reduce growth of bacteria. A high-temp/low-time pasteurizer will reduce bacterial load in the hospital milk when exposed to 161° for 15 seconds.[6] Hospital milk can be under- and over-pasteurized, and it is important that pasteurization process is checked through culturing samples and monitoring equipment functions. Calf kitchens traditionally use a large quantity of hot water for pasteurization, mixing milk and cleaning, and the supply of hot water to a calf kitchen can be a limiting factor based on hot water storage. The temperature on hot water heaters can often to be set to a temperature greater than 161°, for example 180°, as a way of extending hot water for the calf kitchen, but care must be taken to ensure hospital milk is not pasteurized at 180° because milk proteins will be damaged. Feeding calves milk that has been over pasteurized will lead to scours and poorer than expected growth rates relative to the amount of milk solids being fed. High-temperature water should also not be used to mix milk replacer powder into solution prior to feeding. Each milk replacer manufacturer will have different mixing instructions, include the proper temperature for mixing that specific brand and blend of milk replacer. High-temperature water can damage the protein and the fat in milk replacer powder causing damage to the proteins and can cause the fat in the milk replacer to come out of solution, leading to inconsistencies of the milk ration consumed by the calves. Remember, the fat in milk replacer is a spray-dried fat that can contain a mix of lard, tallow, choice white grease, vegetable, and coconut oil. Mixing instructions for the milk replacer are specific for that formula of replacer based on the ingredients used and need to be followed for milk replacer to work successfully. For example, not all milk replacers can be fed through an autofeeder because the fats have not been processed to be instantized, like human baby formula, and go into solution at a temperature of 110°.

Calves thrive when their milk ration is consistent in total solids, components, temperature, volume and timing of feeding. To achieve a consistent milk ration, a best practice is for the mixing tank to be on load cells and ingredients are added according to weight. Milk math is used to calculate how much water, milk replacer powder and hospital milk will be added to meet the total solids goal. Measuring sticks for a mixing tank or calibrated lines on the side of a mixing tank are not very useful when mixing milk replacer due to the foam that is created when

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using a high-speed agitator to mix the powder into solution. Water weighs 8.34 pounds per gallon, which is the other constant needed for milk math when using hospital milk. For example, if a mixing tank holds 300 gallons, the calf raiser has 100 gallons of hospital milk that is 11% total solids, and the goal is 300 gallons of a 14% total solids mixture, milk math is used to determine the amount of water and milk replacer powder to add. First, 100 gallons of hospital milk weighs (8.6 x 100) 860 pounds. Second, the total pounds of solids in 100 gallons of this 11% hospital milk is (860 × 0.11) 94.6 pounds, leaving pounds of water at (860-94.6) 765.4 pounds. The third calculation is total solids needed for the end milk solution goal of 300 gallons at 14% total solids which is (300 × 8.6) x 0.14, or 361.2 pounds. This 361.2 pounds is the total pounds of solids in the final milk mixture and from math above, 94.6 of those pounds are coming from the hospital milk. The amount of milk replacer powder needed is 361.2 – 94.6, or 266.6 pounds. A best practice is to add this powder according to weight because ideally the mixing tank is on a load cell. After doing this math, an alternative could also be to add 5 50-pound bags of milk replacer to the 100 gallons of 11% hospital milk, then fill water to 300 gallons for a milk mixing recipe that is easy for employees to implement. Steps for an employee to follow would be to bring over the hospital milk based on weight, ensure milk is at appropriate temperature for mixing powder, turn on the high speed agitator, add milk powder, mix, then fill with water at appropriate temperature to fill line of the 300-gallon mixing tank.

Evaluating a milk program

A veterinarian's role in evaluating a milk program is to ensure the plan on paper will meet the producer's goals and matches the plan executed on farm. Even if a private or feed company nutritionist is formulating the milk ration, a herd veterinarian can provide excellent feedback for implementation of the milk ration and objective evaluation of calf performance. Many of health challenges in young dairy calves are primarily nutritional issues such as feeding dirty milk, feeding inconsistently mixed milk, and not feeding enough milk to support growth and immune function. When nutrition challenges in young calves are well controlled, then a reduction in health events and mortality will follow.

The same basic rule applies for a veterinarian evaluating a milk ration in calves as when evaluating a total mixed ration in milk cows – the ration on paper, ration mixed, ration delivered and the ration the cows eat. These are the 4 places for the veterinarian to observe, ask questions, and take samples when reviewing a milk feeding program.

The first step is to evaluate the milk feeding plan on paper and perform milk math to determine if the plan is providing enough nutrition to the calf. The National Research Council Calculator app for calf milk formulations is a great tool to use during this first evaluation to outline expectations of what the milk formula on paper should be providing to the calves and then follow up with calf weight and health records. The app has an interface for predicted average daily gain feeding whole milk and another interface for feeding milk replacer. The size of the calf and environmental conditions are added, and starter grain information is added and an estimated average daily gain is generated based on NRC data.

The next step for evaluating a milk ration is to determine if the ration being mixed matches the plan on paper. This will be a visit to the calf kitchen early in the morning to check temperatures, watch mixing procedures and take samples for evaluation of total solids and bacterial counts. Ideally, a morning milk mixing is observed and an afternoon mixing is observed, representing all employees mixing milk. These calf kitchen visits are a time to observe and take notes on the steps an employee follows when mixing milk, note how much of each ingredient is added, temperatures for each step, look at status of equipment and check for cleanliness. Tools needs for these observations are a notebook, camera, high-temperature thermometer, containers to collect milk samples, sharpie and luminometer. Observing milk mixing is a good opportunity to swab stainless steel, bottles and nipples with a luminometer for a measurement of ATP levels as an indicator of cleaning procedures being followed. Milk samples to collect for bacterial counts are a post-pasteurization sample of hospital milk and a mixed-milk sample from the filled bottle. Milk samples to collect for total solids measurement are the first bottle filled and the last bottle filled for each batch of milk mixed. To determine total solids in a milk ration which includes milk replacer, a milk sample must be sent to the laboratory for a measurement of dry matter. This will give a true total solids to know if the milk ration is mixed according the plan on paper and also the samples from the beginning and end of filling bottles will show if the milk ration is mixed well for feeding a consistent milk diet. Do not use a Brix refractometer to estimate total solids of mixed milk replacer or a mixed whole milk that contains milk replacer powder. The Brix refractometer is not accurate with solutions containing milk powder and will give a reading that changes with the brand of milk replacer used.[12] Use milk math, scales, load cells and double checking with dry matter of mixed milk from the laboratory to determine and manage total solids.

The third location to observe is at the calves as milk is delivered. Questions to answer when watching milk being delivered are what time is milk delivered, which calves are fed first, what is the temperature of the milk when fed, are all calves fed, is the correct volume given to calves if bucket-fed, quality of the nipples, are nipples folded, are there employees following the milk feeding to observe calves, and is the angle of feeding and height of the bottle holder appropriate for the calves on that operation?

The final set of observations are determining what the calves actually consume and this is accomplished by walking calves while they are drinking, observing the different age groups drinking milk, and performing these observations during a morning and afternoon feeding because the feeding behaviors differ. Questions to answer while walking the calves drinking their milk are do calves drink all of the milk offered, what is the protocol for calves that do not get up and drink, how are new babies trained to drink milk, are calves tubed, what is the interval between feedings, when are bottles picked up, how is it communicated when a calf doesn't drink, and are other supplements offered during the milk feeding? Finally, follow the milk trailer back to the calf kitchen and measure milk refusals as bottles are dumped.

Conclusion

The herd veterinarian has a vital role on calf raising operations that extends beyond development of vaccine and treatment protocols. Nutrition impacts the health and performance of calves and proper nutrition in the milk phase of a calf's life will increase her lifetime production as a milk cow. With a basic understanding of how to analyze a milk ration, using the NRC guide, NRC Calculator app, and evaluating how a milk feeding

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program is implemented, the veterinarian will demonstrate their value to the producer and ensure the health and welfare of the calves.

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