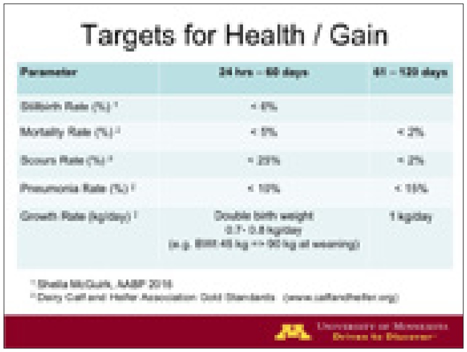
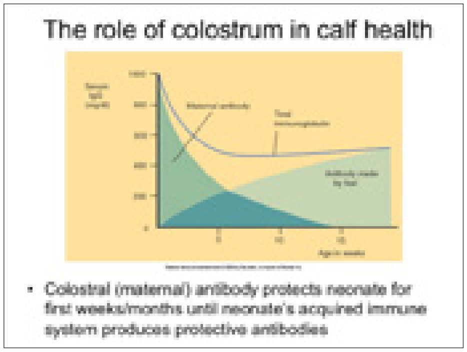
ADVANCES IN COLOSTRUM MANAGEMENT

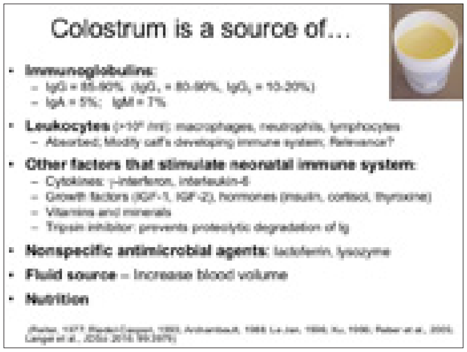
Dr. Sandra Godden, *University of Minnesota*

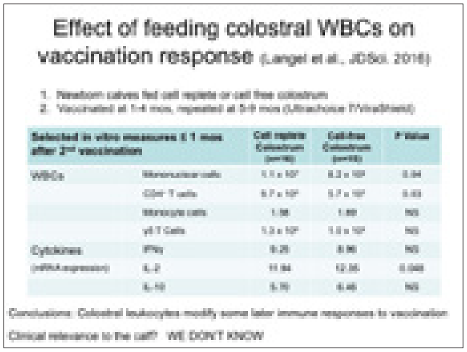


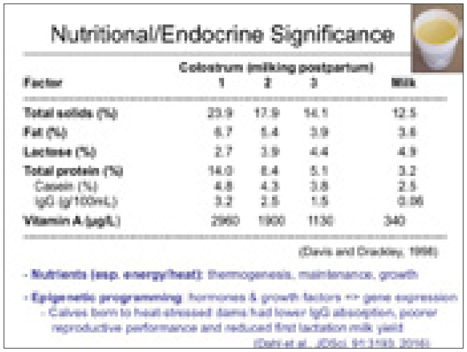
Parameter	24 hrs – 60 days	61 – 120 days
Stillbirth Rate (%) [1]	< 6%	
Mortality Rate (%) [2]	< 5%	< 2%
Scours Rate (%) [2]	< 25%	< 2%
Pneumonia Rate (%) [2]	< 10%	< 15%
Growth Rate (kg/day) [2]	Double birth weight 0.7- 0.8 kg/day (e.g. BW 45 kg => 90 kg at weaning)	1 kg/day

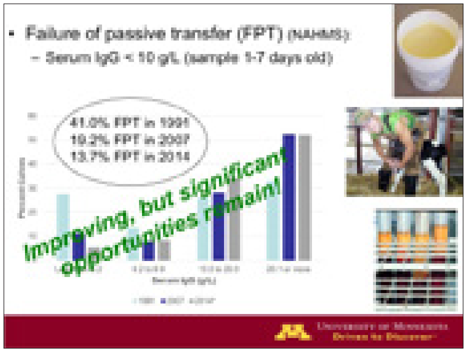
[1] Sheila McGuirk, AABP 2016
[2] Dairy Calf and Heifer Association Gold Standards (www.calfandheifer.org)


The role of colostrum in calf health
Colostral (maternal) antibody protects neonate for first weeks/months until neonate's acquired immune system produces protective antibodies


Colostrum is a source of…
Immunoglobulins:
IgA = 5%; IgM = 7%
Leukocytes
macrophages, neutrophils, lymphocytes
Absorbed; Modify calf's developing immune system; Relevance?
Other factors that stimulate neonatal immune system:
Cytokines: γ-interferon, interleukin-6
Growth factors (IGF-1, IGF-2), hormones (insulin, cortisol, thyroxine)
Vitamins and minerals
Trypsin inhibitor: prevents proteolytic degradation of Ig
Nonspecific antimicrobial agents: lactoferrin, lysozyme
Fluid source – Increase blood volume
Nutrition

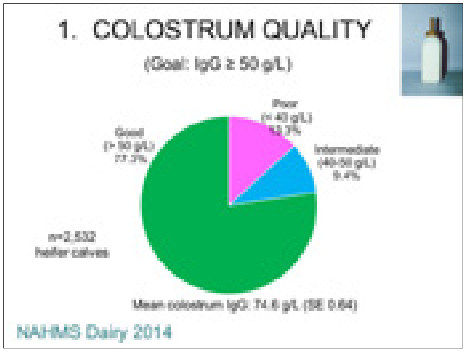

Effect of feeding colostral WBCs on vaccination response (Langel et al., JDSci. 2016)
1. Newborn calves fed cell replete or cell free colostrum
2. Vaccinated at 1-4 mos, repeated at 5-9 mos
Selected in vitro measures ≤ 1 mos after 2nd vaccination
Cell replete Colostrum
Cell-free Colostrum
P Value
WBCs
Mononuclear cells
CD4+ T cells
Monocyte cells
γδ T Cells
Cytokines
(mRNA expression)
IFNγ
IL-2
IL-10
Conclusions: Colostral leukocytes modify some later immune responses to vaccination
Clinical relevance to the calf? WE DON'T KNOW

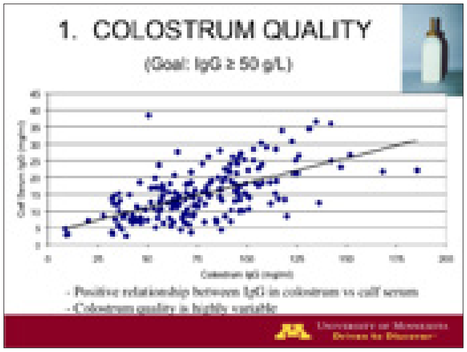

Nutritional/Endocrine Significance
Colostrum (milking postpartum)
Factor 1 2 3 Milk
Total solids (%) 23.9 17.9 14.1 12.5
Fat (%) 6.7 5.4 3.9 3.6
Lactose (%) 2.7 3.9 4.4 4.9
Total protein (%) 14.0 8.4 5.1 3.2
Casein (%) 4.8 4.3 3.8 2.5
IgG (g/100mL) 3.2 2.5 1.5 0.06
Vitamin A (µg/L) 2950 1900 1130 340
(Davis and Drackley, 1998)
- Nutrients (esp. energy/heat): thermogenesis, maintenance, growth
- Epigenetic programming: hormones & growth factors => gene expression
- Calves born to heat-stressed dams had lower IgG absorption, poorer reproductive performance and reduced first lactation milk yield

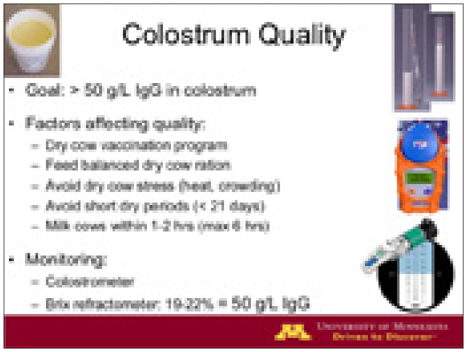

Failure of passive transfer (FPT) (NAHMS):
– Serum IgG < 10 g/L (sample 1-7 days old)
41.0% FPT in 1991
19.2% FPT in 2007
13.7% FPT in 2014
Improving, but significant opportunities remain!
Serum IgG (g/L)

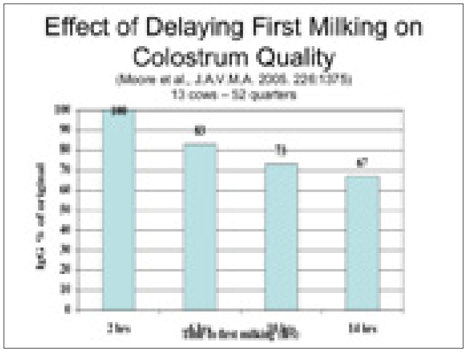

Benefits of Successful Passive Transfer
Reduced treatment and mortality rates
Improved growth rates and feed efficiency
Decreased age at first calving
Increase 1st & 2nd lactation milk production
Days of Age


The 5 Q's of Colostrum Management
Quality
Quantity
Quickness
SQueeky clean (bacterial contamination)
Quantifying passive transfer (monitoring)


1. COLOSTRUM QUALITY
(Goal: IgG ≥ 50 g/L)
Poor
(< 40 g/L)
Good
(> 50 g/L)
77.2%
Intermediate
(40-50 g/L)
9.4%
n=2,532
heifer calves
Mean colostrum IgG: 74.6 g/L (SE 0.64)
NAHMS Dairy 2014


1. COLOSTRUM QUALITY
(Goal: IgG ≥ 50 g/L)
- Positive relationship between IgG in colostrum vs calf serum
- Colostrum quality is highly variable


Colostrum Quality
Goal: > 50 g/L IgG in colostrum
Factors affecting quality:
– Dry cow vaccination program
– Feed balanced dry cow ration
– Avoid dry cow stress (heat, crowding)
– Avoid short dry periods (< 21 days)
– Milk cows within 1-2 hrs (max 6 hrs)
Monitoring:
– Colostrometer
– Brix refractometer: 19-22% = 50 g/L IgG


Effect of Delaying First Milking on Colostrum Quality
(Moore et al., J.A.V.M.A. 2005. 226:1375)
13 cows – 52 quarters
100
83
73
67
2 hrs
14 hrs


2. Colostrum Quantity
What volume should we provide at first feeding?
Goal: Feed 150 - 200 g of IgG
Reco: Feed 10% BW at first feeding (3-4 L)
Bottle or esophageal tube:
– both work equally well if feeding a sufficient volume
– Training and equipment cleaning/condition important
– Don't tube calves multiple times


3. Quickness
(time to first feeding)
Ig in intestinal epithelial cell
• Gut Closure:
– Progressive loss of ability to absorb Ig
– Complete by 24 hrs
• Goal:
Feed within 1-2 hrs
(6 hrs max)
Age (hrs)
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Options for 'Quick Colostrum Feeding'
• It's 11:00 PM and the calf was just born
Goal: Feed within 1-2 hrs (6 hrs max)
• Options:
– Milk cow and feed calf within 1-2 hrs
– Feed calf refrigerated stored colostrum
– Feed calf frozen stored colostrum
• Don't heat > 140 °F when thawing
• Keep water bath dish water hot (120-125 °F)
– Feed a colostrum replacer product
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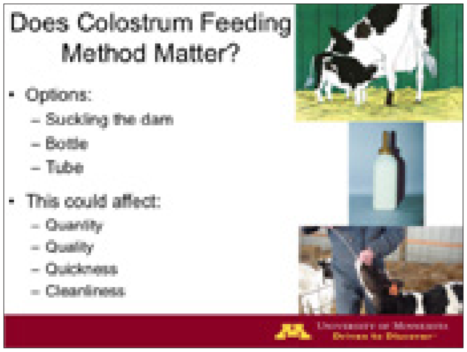
Does Colostrum Feeding Method Matter?
• Options:
– Suckling the dam
– Bottle
– Tube
• This could affect:
– Quantity
– Quality
– Quickness
– Cleanliness
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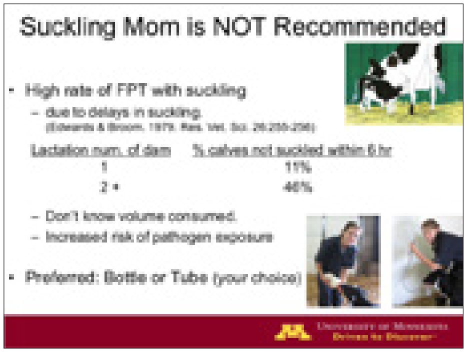
Suckling Mom is NOT Recommended
• High rate of FPT with suckling
– due to delays in suckling
(Edwards & Broom, 1979. Res. Vet. Sci. 26:255-256)
Lactation num. of dam   % calves not suckled within 6 hr
1   11%
2 +   46%
– Don't know volume consumed.
– Increased risk of pathogen exposure
• Preferred: Bottle or Tube (your choice)
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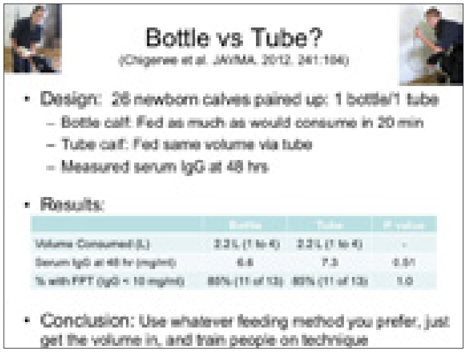
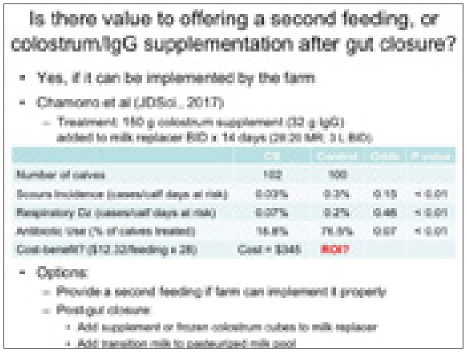
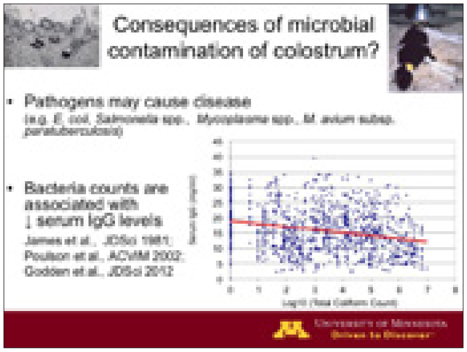
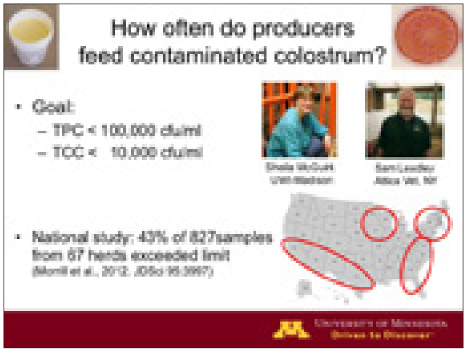
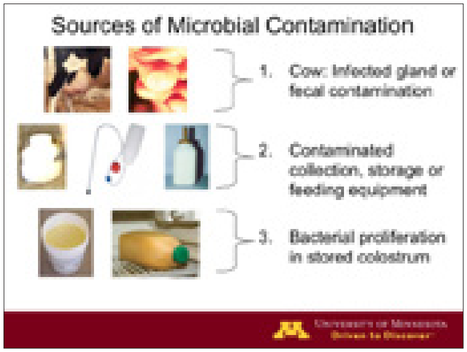

Bottle vs Tube?
(Chigerwe et al. JAVMA. 2012. 241:104)
• Design: 26 newborn calves paired up: 1 bottle/1 tube
– Bottle calf: Fed as much as would consume in 20 min
– Tube calf: Fed same volume via tube
– Measured serum IgG at 48 hrs
• Results:
Bottle | Tube | P value
Volume Consumed (L) | 2.2 L (1 to 4) | 2.2 L (1 to 4) | -
Serum IgG at 48 hr (mg/ml) | 6.6 | 7.3 | 0.51
% with FPT (IgG < 10 mg/ml) | 85% (11 of 13) | 85% (11 of 13) | 1.0
• Conclusion: Use whatever feeding method you prefer, just get the volume in, and train people on technique

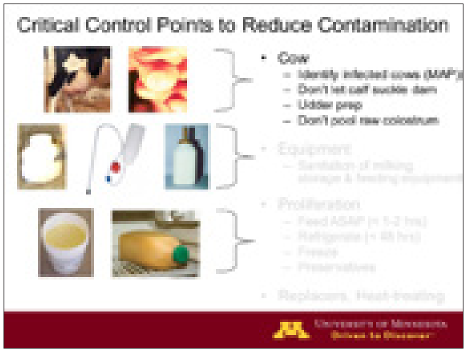

Is there value to offering a second feeding, or colostrum/IgG supplementation after gut closure?
• Yes, if it can be implemented by the farm
• Chamorro et al (JDSci., 2017)
– Treatment: 150 g colostrum supplement (32 g IgG) added to milk replacer BID x 14 days (28:20 MR, 3 L BID)
CS | Control | Odds | P value
Number of calves | 102 | 100
Scours Incidence (cases/calf days at risk) | 0.03% | 0.3% | 0.15 | < 0.01
Respiratory Dz (cases/calf days at risk) | 0.07% | 0.2% | 0.48 | < 0.01
Antibiotic Use (% of calves treated) | 16.8% | 76.5% | 0.07 | < 0.01
Cost-benefit? ($12.32/feeding x 28) | Cost = $345 | ROI?
• Options:
– Provide a second feeding if farm can implement it properly
– Post-gut closure
• Add supplement or frozen colostrum cubes to milk replacer
• Add transition milk to pasteurized milk pool


4. SQueeky Clean (Bacterial Contamination)


Consequences of microbial contamination of colostrum?
• Pathogens may cause disease
(e.g. E. coli, Salmonella spp., Mycoplasma spp., M. avium subsp. paratuberculosis)
• Bacteria counts are associated with ↓ serum IgG levels
James et al., JDSci 1981;
Poulson et al., ACVIM 2002;
Godden et al., JDSci 2012


How often do producers feed contaminated colostrum?
• Goal:
– TPC < 100,000 cfu/ml
– TCC < 10,000 cfu/ml
• National study: 43% of 827samples from 67 herds exceeded limit


Sources of Microbial Contamination
1. Cow: Infected gland or fecal contamination
2. Contaminated collection, storage or feeding equipment
3. Bacterial proliferation in stored colostrum


Critical Control Points to Reduce Contamination
• Cow
– Identify infected cows (MAP)
– Don't let calf suckle dam
– Udder prep
– Don't pool raw colostrum
• Equipment
– Sanitation of milking, storage & feeding equipment
• Proliferation
– Feed ASAP (< 1-2 hrs)
– Refrigerate (< 48 hrs)
– Freeze
– Preservatives
• Replacers, Heat-treating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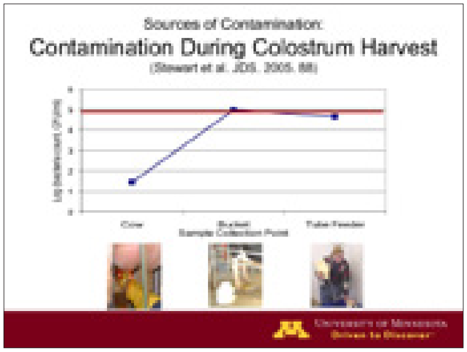
Sources of Contamination:
Contamination During Colostrum Harvest
(Stewart et al. JDS. 2005. 88)
Cow
Bucket
Tube Feeder
Sample Collection Point
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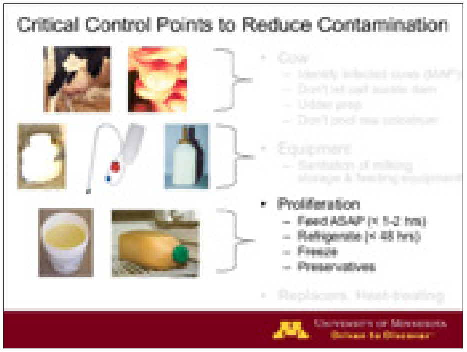
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Udder prep
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Equipment
Sanitation of milking storage & feeding equipment
Proliferation
Feed ASAP (< 1-2 hrs)
Refrigerate (< 48 hrs)
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Preservatives
Replacers, Heat-treating
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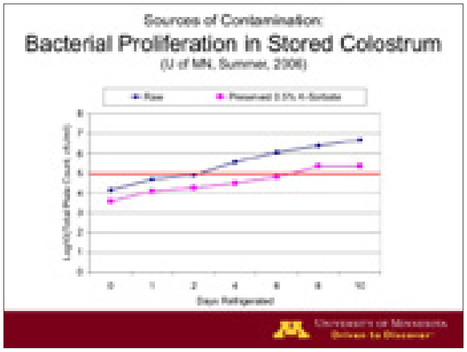
Sources of Contamination:
Bacterial Proliferation in Stored Colostrum
(U of MN, Summer, 2006)
Raw
Preserved 0.5% K-Sorbate
0 1 2 3 4 5 6 7 8
0 1 2 4 6 8 10
Days Refrigerated
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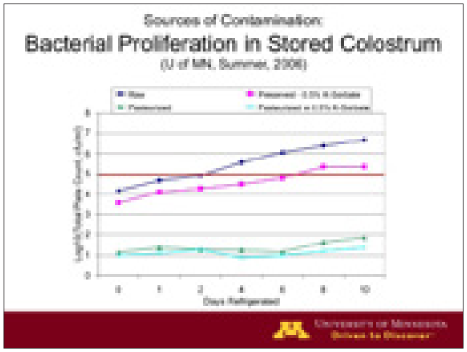
Sources of Contamination:
Bacterial Proliferation in Stored Colostrum
(U of MN, Summer, 2006)
Raw
Pasteurized
Preserved - 0.5% K-Sorbate
Pasteurized + 0.5% K-Sorbate
0 1 2 3 4 5 6 7 8
0 1 2 4 6 8 10
Days Refrigerated
University of Minnesota
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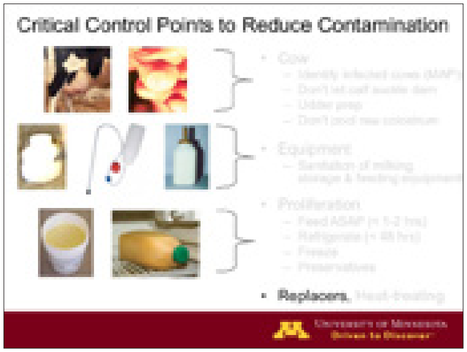
Critical Control Points to Reduce Contamination
Cow
Identify infected cows (MAP)
Don't let calf suckle dam
Udder prep
Don't pool raw colostrum
Equipment
Sanitation of milking storage & feeding equipment
Proliferation
Feed ASAP (< 1-2 hrs)
Refrigerate (< 48 hrs)
Freeze
Preservatives
Replacers, Heat-treating
University of Minnesota
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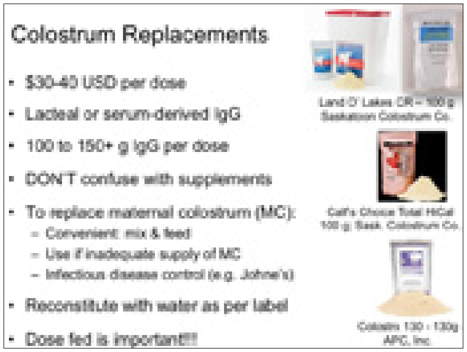
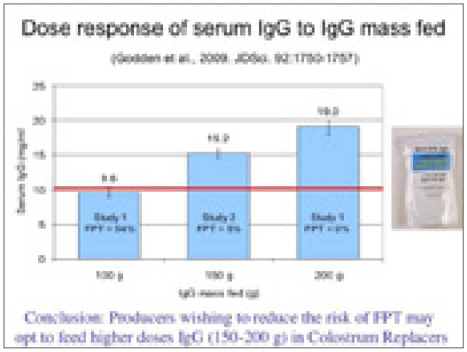
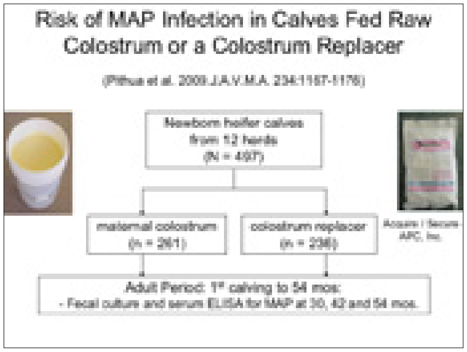
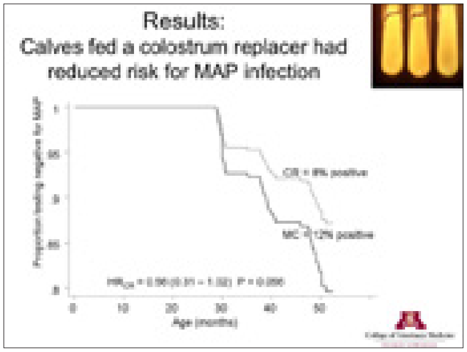
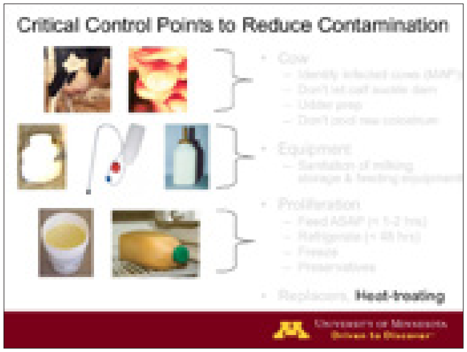

Colostrum Replacements
$30-40 USD per dose
Lacteal or serum-derived IgG
100 to 150+ g IgG per dose
DON'T confuse with supplements
To replace maternal colostrum (MC):
Convenient: mix & feed
Use if inadequate supply of MC
Infectious disease control (e.g. Johne's)
Reconstitute with water as per label
Dose fed is important!!!
Land O' Lakes CR – 100 g
Saskatoon Colostrum Co.
Calf's Choice Total HiCal
100 g: Sask. Colostrum Co.
Colostrx 130 - 130g
APC, Inc.

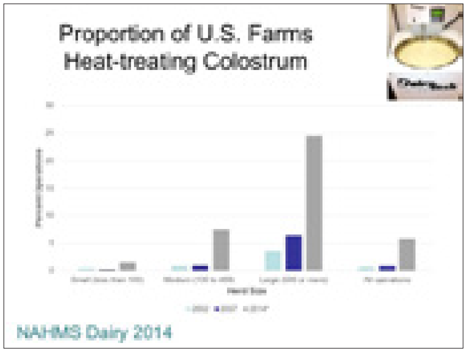

Dose response of serum IgG to IgG mass fed
(Godden et al., 2009. JDSci. 92:1750-1757)
9.8
15.2
19.2
Study 1
Study 2
Study 1
100 g
150 g
200 g
Conclusion: Producers wishing to reduce the risk of FPT may opt to feed higher doses IgG (150-200 g) in Colostrum Replacers

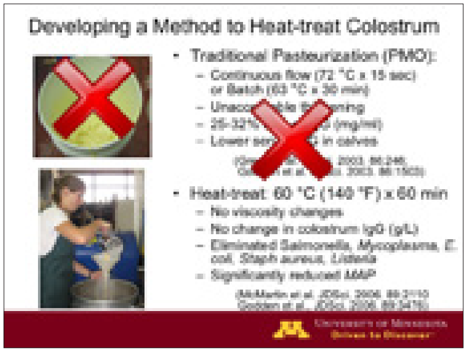

Risk of MAP Infection in Calves Fed Raw Colostrum or a Colostrum Replacer
(Pithua et al. 2009 J.A.V.M.A. 234:1167-1176)
Newborn heifer calves from 12 herds (N = 497)
maternal colostrum (n = 261)
colostrum replacer (n = 236)
Acquire / Secure APC, Inc.
Adult Period: 1st calving to 54 mos:
- Fecal culture and serum ELISA for MAP at 30, 42 and 54 mos.


Results:
Calves fed a colostrum replacer had reduced risk for MAP infection
CR = 8% positive
MC = 12% positive
0
10
20
30
40
50
Age (months)

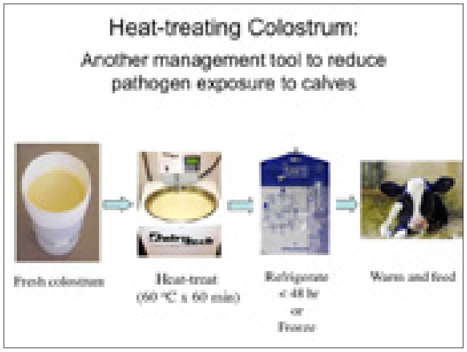

Critical Control Points to Reduce Contamination
Heat-treating


Effects of Heat-treating Colostrum on Colostrum Characteristics and Calf Health

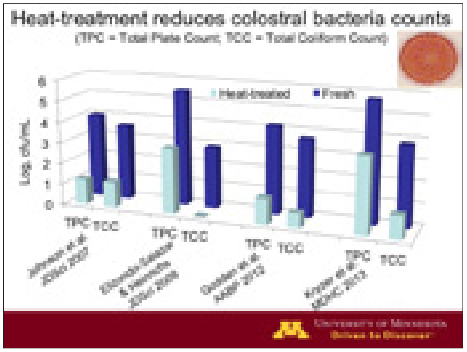

Proportion of U.S. Farms Heat-treating Colostrum
NAHMS Dairy 2014



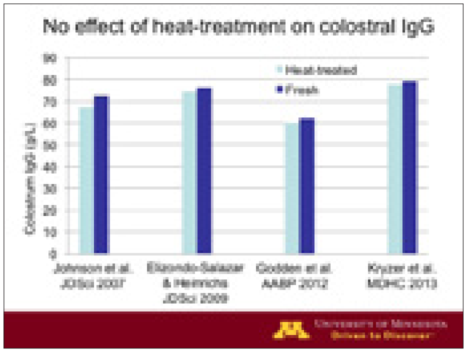
Developing a Method to Heat-treat Colostrum
Traditional Pasteurization (PMO):
Continuous flow (72 °C x 15 sec) or Batch (63 °C x 30 min)
Heat-treat: 60 °C (140 °F) x 60 min
No viscosity changes
No change in colostrum IgG (g/L)
Eliminated Salmonella, Mycoplasma, E. coli, Staph aureus, Listeria
Significantly reduced MAP



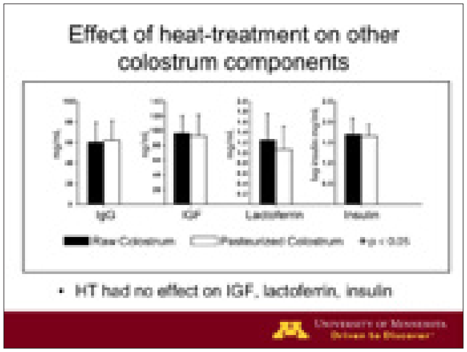
Heat-treating Colostrum:
Another management tool to reduce pathogen exposure to calves
Fresh colostrum
Heat-treat (60 °C x 60 min)
Refrigerate < 48 hr or Freeze
Warm and feed



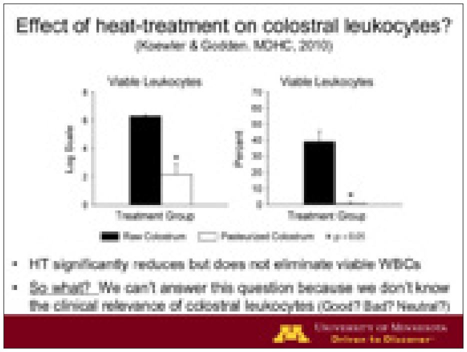
Heat-treatment reduces colostral bacteria counts
(TPC = Total Plate Count; TCC = Total Coliform Count)
Heat-treated
Fresh
Log, cfu/mL
TPC TCC
Johnson et al. JDSci 2007
Elizondo-Salazar & Heinrichs JDSci 2009
Godden et al. AABP 2012
Kryzer et al. MDHC 2013



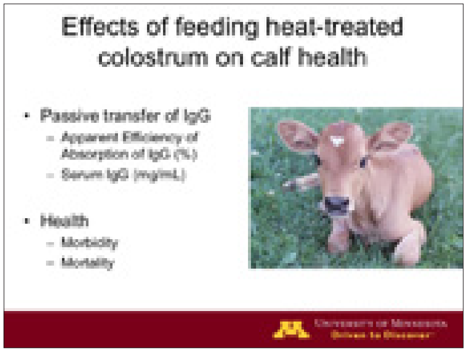
No effect of heat-treatment on colostral IgG
Heat-treated
Fresh
Colostrum IgG (g/L)
Johnson et al. JDSci 2007
Elizondo-Salazar & Heinrichs JDSci 2009
Godden et al. AABP 2012
Kryzer et al. MDHC 2013



Effect of heat-treatment on other colostrum components
IgG
IGF
Lactoferrin
Insulin
Raw Colostrum
Pasteurized Colostrum
HT had no effect on IGF, lactoferrin, insulin



Effect of heat-treatment on colostral leukocytes?
(Koewler & Godden, MDHC, 2010)
Viable Leukocytes
Viable Leukocytes
Treatment Group
Treatment Group
Raw Colostrum
Pasteurized Colostrum
HT significantly reduces but does not eliminate viable WBCs
So what? We can't answer this question because we don't know the clinical relevance of colostral leukocytes (Good? Bad? Neutral?)


Effects of feeding heat-treated colostrum on calf health
• Passive transfer of IgG
– Apparent Efficiency of Absorption of IgG (%)
– Serum IgG (mg/mL)
• Health
– Morbidity
– Mortality
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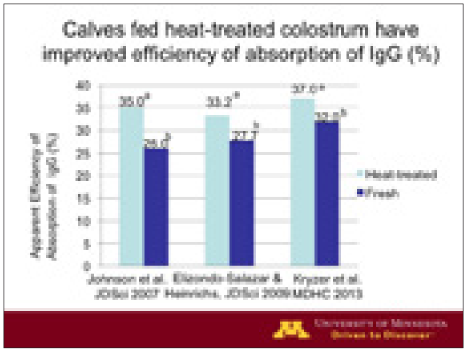
Calves fed heat-treated colostrum have improved efficiency of absorption of IgG (%)
Apparent Efficiency of Absorption of IgG (%)
40
35
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35.0ª
26.0ᵇ
33.2ª
27.7ᵇ
37.0ª
32.0ᵇ
Heat-treated
Fresh
Johnson et al. JDSci 2007
Elizondo-Salazar & Heinrichs, JDSci 2009
Kryzer et al. MDHC 2013
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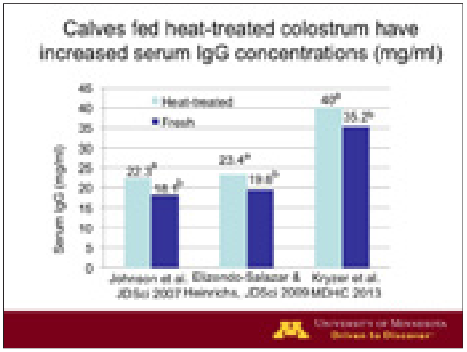
Calves fed heat-treated colostrum have increased serum IgG concentrations (mg/ml)
Serum IgG (mg/ml)
45
40
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Heat-treated
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22.7ª
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19.6ᵇ
40ª
35.2ᵇ
Johnson et al. JDSci 2007
Elizondo-Salazar & Heinrichs, JDSci 2009
Kryzer et al. MDHC 2013
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So What?!
…Will we have healthier calves?
…Will it control Johne's Disease?
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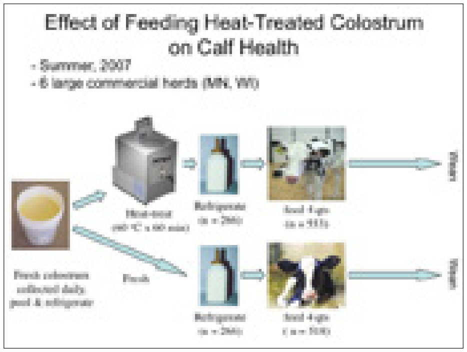
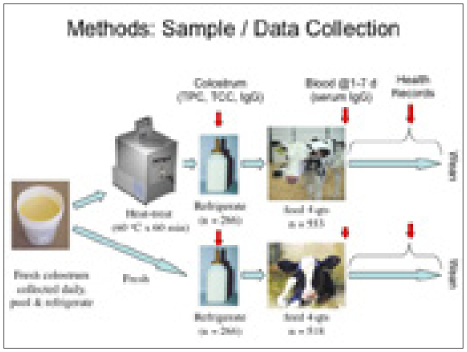
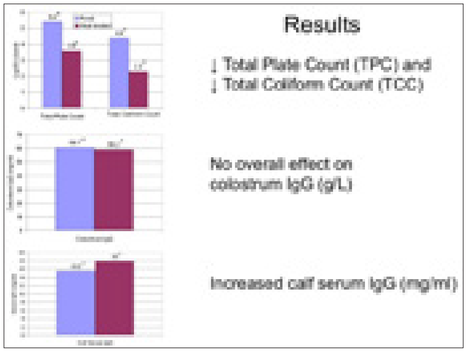
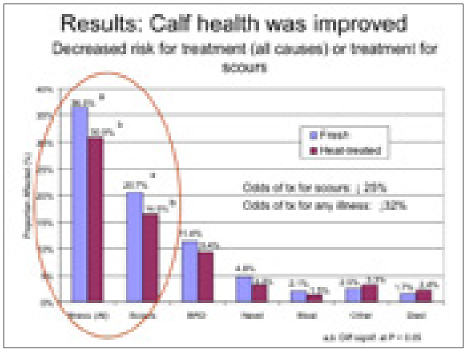
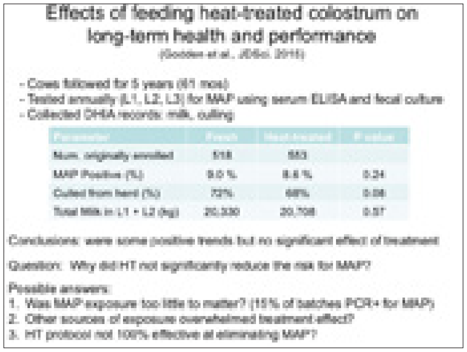

Effect of Feeding Heat-Treated Colostrum on Calf Health
- Summer, 2007
- 6 large commercial herds (MN, WI)
Fresh colostrum collected daily, pool & refrigerate
Heat-treat (60 °C x 60 min)
Fresh
Refrigerate
Wean
Wean

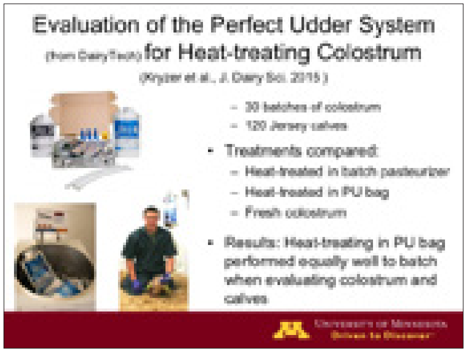

Methods: Sample / Data Collection
Colostrum (TPC, TCC, IgG)
Blood @1-7 d (serum IgG)
Health Records
Fresh colostrum collected daily, pool & refrigerate
Heat-treat (60 °C x 60 min)
Fresh
Refrigerate
Wean
Wean

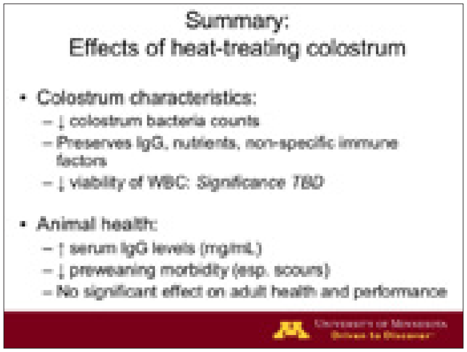


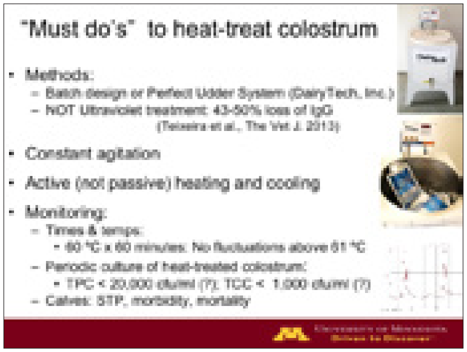




Parameter	Fresh	Heat-treated	P value
Num. originally enrolled	518	553	
MAP Positive (%)	9.0 %	8.6 %	0.24
Culled from herd (%)	72%	68%	0.08
Total Milk in L1 + L2 (kg)	20,330	20,708	0.37







GETTING THE MOST OUT OF YOUR FEEDING OPERATION INVESTMENT

David Greene, *Barton, Kiefer, and Associates Consulting Group*

The largest expense on your dairy operation centers around feeding the animals. Therefore, your bottom line benefits from every effort to manage all areas of the feeding operation. It can be a complex task to manage because of its many moving parts. You need to keep in mind your goal for the feeding program and track it daily to make sure every action helps achieve the goal. Measurable results indicate the state of the feeding operation and your progress toward the goal. Once you are obtaining the desired results, then you can evaluate the efficiency of getting the job done.

Based on current top industry performance, your feeding operation should target:

- Body weight (BW) at breeding should be 55% of mature BW
- Post-calving BW should be 85% of mature BW

By hitting these marks, we can achieve maximum potential performance from the replacement investment. If we delay growth until post-calving, then the dairy loses a considerable amount of production, not only in 1st lactation but in subsequent lactations as well. When replacements are not grown well enough prior to calving, nutrients are partitioned to growth instead of going to production. This can cost a significant amount of milk production in 1st lactation. Dr. Gavin Staley (2018) notes that the 1st lactation production sets the ceiling for the production of the herd. The peak milk of 1st lactation at weeks 10--15 in milk will be within 1--2 pounds of the herd average.

With all this in mind, every action, every day that is done feeding the animals has to be done consistently without having any lapse. If a dairy animal is going to meet her targeted growth and size, then there can't be any off days.

Keep in mind, there are two growth monitor points: One is body weight; the second is body condition score. We don't want fat, heavy animals.

Table 1. Shows the average daily gain (ADG) required for two different size mature body weight (BW) animals in regard to the age at first calving (Fresh).

1650 lb. Mature BW		1500 lb. Mature BW	
Age at Fresh (months)	Required ADG (lbs.)	Age at Fresh (months)	Required ADG (lbs.)
21	2.3	21	2.1
22	2.2	22	2.0
23	2.1	23	1.9
24	2.0	24	1.85
25	1.9	25	1.75

To achieve these numbers of growth, animals have to be given the opportunity to do their best every day. That means managing every aspect of the feeding operation, so that a consistent total mixed ration (TMR) is delivered to all the animals, every day with every bite. This means managing three distinct rations: (1) the ration that the nutritionist formulated; (2) the ration the feeder mixed and delivered; and (3) the ration the animals actually eat. The goal is for all three rations to be the same, but many times they can be different.

ARE ALL THREE RATIONS THE SAME?

When these three rations are not the same, it limits the opportunity to meet the targeted goals for growth and size. Daily lapses are going to prevent the animals from growing to their genetic potential or meeting the targeted goals. To achieve the goals, there must be check points in place to make sure these three rations are the same.

Formulated ration

The nutritionist formulates the ration for the animal to meet the desired goals. Ration balancing programs measure ingredients down to the milligram. This means accuracy is critical during the mixing process to keep the ration consistent with what the nutritionist has proposed. When formulating rations, the nutritionist must keep in my what is realistically capable of being done on the operation. If the small inclusion ingredients are being weighed and added by hand on the farm, then there is a higher likelihood they will not be mixed properly. So, is there an opportunity to have most or all of those ingredients mixed off the farm and delivered as one ingredient, for example, as a premix? However, this manufactured or off-farm premix would limit formulation flexibility, then can a premix be made on site at the farm to provide for better proportioning and mixing of those small ingredients?

Ration the feeder mixes and delivers

This ration represents a major opportunity for errors. The feeder can be loading wrong ingredients or wrong amounts of ingredients. Or, the loading order can be wrong. Or the mixing time may not be long enough. Or the feed delivery is off-schedule, resulting in "slug feeding." The error can also be in the mixer itself by having worn or broken parts. The main thing to remember in this area is to understand the mixer and how to maintain it. All mixers can mix well, but all mixers don't use the same protocol to mix well. Once you understand the mixer, then you can build your loading, mixing, and delivering protocols to do those tasks properly so a consistent ration can be delivered to the animal.

Ration the animal consumes

If the first two rations are done properly, then the chances are high that the animal will consume the proposed ration. The main watch-out in this area is to prevent sorting. Animals like to sort the TMR to pick out what they desire most. That is not the best scenario for the animal or for allowing us to meet the goals we need for the animal. Sorting can cause a lot of inconsistency in groups in terms of animal size, body condition, and health. There are many ways to reduce sorting, including: Reduce particle size in the TMR; lower the dry matter of the TMR; increase molasses or other ingredients that can help hold the feed particles together.

There has to be a monitoring system in place to make sure all three rations are the same. Otherwise, weak links in ration formulation and small ingredient inclusion, mixing and delivery, or consumption can cause a breakdown in animal performance that will not allow us to accurately assess the formulated ration. The ration the feeder makes and delivers can be monitored by sampling and sending to the lab for nutrient accuracy and also by calculating the co-efficient of variation (CV%) of particle size within the load. Dr. Tom Oelberg (2014) of Diamond V developed the TMR Audit® to help evaluate the accuracy of the feeder and the mixing equipment. This is a very good tool to help keep the TMR consistent going to the animal. Once the feed is delivered to the animal, samples can be taken at different intervals after delivery and of the refusals and calculate the CV% to see if sorting is taking place.

EFFICIENCY AND PROFITABILITY OF THE OPERATION

Once we have set our protocols in place to get the feeding operation consistent for the animals, then the management of the process has to be addressed to allow the system to operate as efficiently and profitable as possible. For efficiency and profitability, the main areas that need to be monitored are managing the shrink around the forage and feed storage areas and managing the efficiency of the actions around the feeding operation. Having check points in each of these areas allows you to better manage this large expense line item of your business.

Shrink

Shrink can be one of the largest expenses on an operation. Dr. Greg Bethard (2014) says that shrink is the fourth or fifth most significant expense on operations today. This expense often goes unnoticed because operations do not have systems and protocols in place to measure or monitor shrink. Operations today need to closely monitor every aspect of their operation in order to maintain a profitable business. Shrink occurs not only in feed ingredients but also in wasted or lost time, fuel and energy, use of other unnecessary inputs, etc.

Some shrink losses are typically considered as a cost of doing business. However, what frequently starts out as being an abnormal occurrence becomes commonplace and is easily overlooked. This seems to be a common occurrence on farms without shrink management. However, this cost of doing business can result in the extreme losses for the farm. For example, for an operation with a herd size of 1,000 head, where feed cost is $2.50 per cow per day and shrink is 8%, the total yearly cost of shrink for the herd is $73,000. This degree of loss can greatly impact profitability.

Dairy producers often go to great lengths to purchase ingredients at the best price possible in order to save money. However, when the ingredients arrive on the farm and go unmanaged, the losses due to shrink often are far greater than the initial savings when inputs are purchased. Table 2 illustrates the cost of shrink on different ingredients and increasing shrink levels. In order to truly be profitable, both a lower purchase price of ingredients and a decrease in shrink loss can help the operation maximize profitability.

Table 2. Common observed shrink values on dairy operations (Greene, 2017).[1,2]

Ingredient	Range, %		
Corn Silage	7	-	16
Haylage	9	-	18
Flat Storage Dry Ingredients	1.5	-	7
Bulky Dry Ingredients (whole cottonseed)	3.5	-	18
Upright/Overhead Storage	1.5	-	7
Wet Byproducts	12	-	20
Average Observed (all Ingredients)	5	-	7

[1] Shrink loss for each ingredient was observed on 21 dairy farms.
[2] Values were collected over the course of a year on farms by D. Greene.

There are many areas on an operation where shrink can occur. The four main areas are: (1) in the forage area (before, during and after harvest); (2) in the feed center; (3) during loading and mixing of the TMR; and (4) in the barn or feeding areas during and after feed delivery. Determining where shrink is occurring on your operation is key in order to be able to manage it. A total shrink management program should be implemented so that the resources spent can express optimum return. Goals and written protocols need to be in place to minimize shrink. Everyone from the management team to the feeders need to follow the set protocols and be committed to reach the set goals. A checklist system is a good tool to help monitor and manage the four major areas of shrink.

Managing the efficiency and actions around the feed center

Activities associated with the feed center are often very costly and inefficient. Every movement needs to be thought out and implemented into a process approach to feeding the animals. Wasted time and movement is money lost, so feed center activities need to be monitored and managed. Jason Karszes (2016) developed a model to calculate the cost of making, mixing, and delivering TMR on an operation. It allows the producer to breakdown the costs of different areas of the feeding operation. Table 3. illustrates the cost variation to make, mix, and deliver a ton of as-fed TMR on 41 herds across the U.S..

Table 3. Results of 41 herd study on feed center costs (Greene, 2017)

Expense per as-fed ton	Low	High	Average
Labor	$0.92	$3.51	$2.58
Loading	$0.99	$3.77	$2.11
Mixing & Delivery	$1.37	$3.74	$1.87
Total Cost of Making, Mixing, & Delivering	$3.42	$10.15	$6.48

It is important to understand the costs associated with the feeding operation. There is a lot of opportunity to have a leak in the "profitability bucket" if you are not measuring and managing these costs. Minutes cost money. For example, if you have a 200-horsepower tractor pulling a 1,100 cubic foot mixer, the typical cost to operate those two pieces of equipment is about $72.50 per hour. If you make 10 loads of TMR per day and you can change your process and save 10 minutes per load per day, that is an annual savings of $44,092.00. Similar savings can be obtained during the loading process. The bucket size needs to be correctly matched to the loads you are making. A maximum of two maybe three buckets of the largest ingredient is more efficient.

Feed center layout and design also can save you more or cost you more, depending on your operation. There are many different ways to build a feed center that will work. You have to decide what type best fits your management style. A fully automated system may be what is best suited to your management capabilities. Alternatively, you may want to have a feed center that has little to no mechanization other than a loader and a mixer. Another way may be to have a combination of these two systems in order to optimize your particular resources and management system.

The feed center is a critical part of your feeding operation. In looking to improve, you should research layout and designs, go visit as many of them as possible, and then watch them operate to see what system is best for you. When designing or remodeling a feed center always design it based on the Feed Zone Model Concept.

The Feed Zone Model Concept

This model helps manage the movements and actions around the feed center area to help increase efficiency, safety, organization, and biosecurity. In the Feed Zone Model Concept, there are five traffic zones that have to be managed:

- Zone 1 – the TMR loading zone in the feed center area. No other traffic should be in this area except for the loader making TMR loads. This zone is critical to keeping animals fed on a timely fashion.

- Zone 2 – the unloading zone for off-farm deliveries in the feed center area. Trucks should be able to come and go without interfering with making loads of TMR. The loader may be in this area during specific times making premixes or pre-batches but not on every load.
- Zone 3 – the on-farm delivery traffic area of TMR loads outside the feed center. There should be minimal to no traffic crossing this pattern between the feed center and the feeding area.
- Zone 4 – the off-farm delivery traffic area. This pattern should be from off the public highway, across the platform scales to the feed center, and return to the scales and public highway.
- Zone 5 – the on-farm traffic staging forages at the feed center. This pattern should not interfere with making TMR loads

The design of your feed center has a major impact on the efficiency of the feeding operation. It must fit the the management style of your operation and requires a lot of research and thought. Utilizing the Feed Zone Model Concept helps you design a more efficient feed center, where improvements in performance can be measured through a Feed Center Cost Analysis.

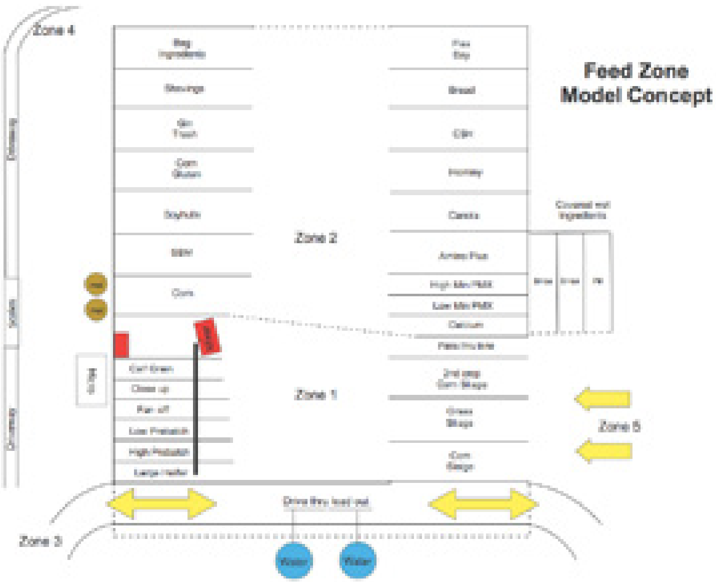


Figure 1. A typical feed center layout illustrating the Feed Zone Model Concept

Feeding operation Key Performance Indicators

Every area in a dairy operation benefits from tracking Key Performance Indicators (KPIs) to make sure it is on track and running efficiently. KPIs also indicate the success or failure of the protocols in place and whether there is compliance to those protocols. Here is a list of KPIs that should be tracked to monitor you feeding operation:

- Cost of loading variation -- \$0.009 -- \$0.011/head/day
- Shrink (all ingredients) -- <7%
- Calculated (ration on paper) vs. actual dry matter intake (DMI) – 3%
- Fed vs. actual forage DM% -s- 1%+/-
- Refusals percentage -- 1%-- 3% (heifers and cows are different)
- Cost of making, mixing, and delivering an as-fed ton of TMR -- < \$4.00/ton
- Coefficient of variation (CV%) of TMR delivered – < 2 -- 2.5%
- Actual push-up frequency – 1 – 1.5 hours

SUMMARY

The feeding operation is a complete system that can improve the performance of dairy animals and profitability. The system consists of everything related to feeding -- from balancing the diets, making and delivering the TMR, feed ingredient storage, the feed center, and through every stage to the feeding area. To objectively measure changes in the operation, it must have a monitoring system in place to track the KPIs along with all other areas. If your feeding system is designed, monitored, and managed well, you can realize greater profit from your feeding operation investment.

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CALF BARNS DESIGNED TO ENHANCE HEALTH

Dr. Ken Nordlund, *Emeritus Clinical Professor University of Wisconsin – Madison*

For some more than twenty years, the clinical group at the University of Wisconsin School of Veterinary Medicine has investigated calf health problems in dairy herds across the United States. In 2004, we conducted a research field trial to study air quality and risk factors associated with calf respiratory disease in naturally ventilated calf barns1. Since 2018, our clinical service has designed hundreds of positive pressure tube ventilation systems for a wide variety of calf barns. From our perspectives acquired from a vast number and variety of calf barns, we have developed preferences for certain design features that are associated with improved calf health. We view the well-managed individual calf hutch as being the optimal housing for a calf, but it can be a brutal environment for the calf caretakers. With careful design and management, we believe that calf barns can equal hutches as excellent environments for nursing calves.

Key features for all calf barns, both group and individual pens:

1. Spatial allowances of approximately 30 square feet (2.8 m2) or more of bedded space per calf, not including service alleys
2. Deeply bedded surfaces in cool weather less than 50°F (10°C)
3. Drainage below the bedding
4. Multiple smaller barns that allow for "all-in, all-out" groupings, which allow for complete cleaning and down-time between occupancy
5. Natural ventilation supplemented with positive pressure tube ventilation
6. Minimal solid sidewalls limited to approximately 2 feet (61 cm) high

Key features of calf barns with individual pens:

1. East-West orientation of the barn to avoid extreme afternoon sun exposure in the pen
2. Optimal barns are narrow barns with one or two rows of pens, and limited to a width of 36 feet (11 m) or less
3. Pens separated from the outer wall by at least 3 feet (0.9 m) of space to avoid cold air from dropping from over the curtain directly into the calf pen
4. Pens with solid panels between every other calf, an open mesh front, and a rear panel that is solid to about 2 feet high (61 cm) with mesh above

FEATURES PREFERRED IN BOTH GROUP AND INDIVIDUAL PEN BARNS

1. Space per calf or calf pen

Provision of sufficient space per calf is the single most important determinant of air quality in a calf barn. Based upon airborne bacterial density studies1, we have recommended that calf pens should provide a minimum of ~30 square feet (2.8 m2) of bedded area per calf. We have clinical experience with repeated failures to successfully ventilate calf pens that provide 15 square feet (1.4 m2) per calf.

2. Bedding in cool weather

Deeply bedded resting surfaces are critical for very young calves in cold weather. The thermoneutral zone of newborn calves is 50 to 78°F (10 to 26°C), and drops to 32 to 73°F (0 to 23°C) by one month of age2. A newborn calf lying on top of a bare floor at 45°F (7°C) will be unable to maintain core body temperature without some thermal support. Deep bedding allows the calf to build up a layer of heat within the bed and minimize heat loss. The University of Wisconsin-Madison, School of Veterinary Medicine developed a scoring system to evaluate the sufficiency of bedding called "Nesting Score"1. It is a simple visual evaluation of the visibility of the rear leg of a calf lying down in the bedding. If the entire leg is visible, it is scored as Nesting Score 1. If the leg is partially obscured by loose bedding, it is Nesting Score 2. If the rear leg is completely obscured by bedding, it is Nesting Score 3. Provision of deep bedding, or moderate bedding plus calf blankets are important factors in preventing respiratory disease in calves during cold weather.

It is our opinion that calf blankets are equivalent to approximately one unit of Nesting Score. In other words, provision of Nesting Score 2 plus calf blankets is approximately equal to Nesting Score 3 without blankets. While Nesting Score 1 is satisfactory during warm weather, the addition of calf blankets to a Nesting Score 1 surface does not appear to achieve the desired level of thermal support in cold weather.

3. Drainage below the bedding

To maintain a deeply bedded surface, it is critical that the pen has good drainage so that urine, spilled milk, and water can move out of the pen rather than soak the bedding. Excellent drainage has been achieved using a tiled gravel bed approximately 1.5 feet (0.5 m) deep below the bedded area. The drainage tiles beneath the gravel should lead to a collection area outside of the calf barn. The tile is covered with gravel, and bedding is applied on top of the gravel. Sand is not an acceptable substitute for gravel, as straw bedding becomes churned into the sand as calves walk on it. With a gravel base base, operators typically report that the straw usage is half of that used to maintain equivalent beds over a concrete surface.

Some producers use deep straw bedding over traditional slatted flooring, allowing urine and water to drain quickly from the bed. While we have little experience with the technique, it would appear to accomplish a similar end.

If the surface below the bedding must be solid concrete, three issues must be addressed through sloping of the floor. First, the floor needs to be sloped to move liquids out of the pen as efficiently as possible with a minimum of a 2% slope, equivalent to 2.4 inches (6 cm) per 10 feet (3 m). Second, liquids moved from the pen should not move into an area exposed to the foot traffic of the calf caregiver. Third, the service alleys should be sloped to prevent water from draining into the pen and bedding. This can be accomplished with a crowned central work alley and a gutter at the immediate front of the calf pen. The pen itself can be sloped toward the same gutter at the front of the pen, or preferably, sloped to the back of the pen with a second drainage gutter at the rear. Drainage gutters would be designed to carry liquids to collection points outside of the building.

4. Multiple smaller barns that allow for "all-in, all-out" groupings, which allow for complete cleaning and down-time between uses

We have developed a strong preference for multiple, smaller barns as compared to large capacity single barns. The optimal system appears to be four or more individual calf nurseries that allow for "all-in, all-out" management systems. With four separate barns, each single barn is filled with newborn calves over period of two to three weeks. At the appropriate time, the entire group of calves in the barn are weaned, given a period of a few days to acclimate to weaning, and moved to another space. The entire barn can be dismantled, cleaned, and allowed to dry for about a week before being re-assembled and used again for the next group of calves.

There are at least two significant benefits associated with the practice. First, young and vulnerable calves are not directly exposed to older calves that may be shedding infectious pathogens. Second, the ability to clean and let a barn dry out for a week between uses appears to be a powerful tool in breaking infectious disease cycles.

5. Natural ventilation with supplemental positive pressure tube ventilation

Natural ventilation has obvious advantages in that natural forces are used to ventilate buildings, reducing costs for both fans and electrical power. Natural forces include wind moving through, against and over buildings, and thermal buoyancy of warmed air rising inside a building. However, natural ventilation has a number of shortcomings, especially in calf housing when winds are still. Wind roses that summarize wind conditions are available for most parts of the United States, and can be accessed through the USDA at the following website:

http://www.wcc.nrcs.usda.gov/ftpref/downloads/climate/windrose/

When the wind is still, naturally ventilated barns are dependent upon thermal buoyancy for ventilation. Unlike adult cows, calves do not generate sufficient heat to effectively warm the air that surrounds them to allow for thermal buoyancy to occur, thus natural ventilation becomes insufficient.

Further limitations of natural ventilation occur when outside air is warmer than the air inside of the barn, a situation that occurs for a period of several hours almost every day as the sun warms the air outside of the barn more quickly than inside. During these periods of time, air entering the cooler interior of the barn through eaves will rise and leave the barn without ever falling toward the floor and mixing with the air around the calves.

Because of these occasional limitations with natural ventilation, we have advocated the use of positive pressure tube ventilation systems to supplement natural ventilation in calf barns.

General comments on supplemental positive pressure tube systems

The supplemental positive pressure tubes systems are usually sized to provide the minimum of four changes of interior air per hour year-round. This ventilation rate assumes a "normal" stocking density and was recommended as the minimal winter ventilation rate by Bates and Anderson3. The tube fan never stops, running 24 hours a day and 365 days per year. If designed properly, the tube system(s) will deliver fresh air without a draft into the microenvironment surrounding the calf. The air introduced through the tube(s) is distributed around the barn and then exits passively through the typical ridge and eave openings. If the barn does not have ridge and eave openings, additional passive openings may need to be constructed or exhaust fans equivalent in capacity to the tube fans may need to be installed to avoid pressurizing the barn.

During the coldest period of the year, the sidewalls of the barn can be closed except for the eaves and ridge opening. As the weather warms, the sidewalls are opened more and more to allow winds to enter the barn. In warm weather, the sidewalls are completely opened. With opened sidewalls in windy conditions, the fresh air exiting the tubes gets carried away by the winds entering the barn. While the tubes are not effective in these conditions, it is generally believed that it is preferable to simply let the tube fan run continuously rather than stopping and starting the tube fans depending on outside wind conditions.

Concerns are frequently raised about whether the tube fans should be shut down in very cold weather. We had an opportunity to compare winter temperatures between two identical naturally ventilated calf barns on the same dairy, one with a supplemental tube system and the other without. Over a two-week period, the average inside temperatures of the barns were identical at 23°F (-5°C). However, the barn with the tube would usually get 2°F (1°C) colder during the middle of the night and 2°F (1°C) warmer during the middle of the day. This is because the tube system results in a modestly higher ventilation rate that causes the interior temperature of the barn to track with the outdoor ambient temperature more closely, both up and down.

Heat can be added and distributed through the supplemental tube systems. Successful approaches include installation of natural gas heating units onto air intake ducts that lead to the tube fans, and the use of buried underground geothermal heat exchange pipes that temper cold air prior to being used in the positive pressure tube systems.

Typical systems are relatively inexpensive and require modest electricity for operation. For example, a tube system in a 100-foot by 35-foot (30.5 m by 10.7 m) calf nursery might require a single 20-inch (51 cm) fan. Depending on what materials chosen, the fan and tube might cost $1,000 USD plus the design of the system, installation, and wiring bringing the total to approximately $2,000 USD. The 20-inch (51 cm) fan may consume 500 watts or 0.5 kWh of electricity, which would yield 12 kWh per day or 4,380 kWh per year. If electrical costs are $0.10 USD per kWh, the annual electrical costs would total ~$438 USD per year.

The reported benefits of supplemental positive pressure tube ventilation systems have been remarkably consistent. We have designed literally hundreds of supplemental tube systems, and the expected comment from the owners is a substantial reduction in the number of calves with respiratory disease, usually reporting reductions of 50 to 75 percent. A recent study conducted by Jorgensen in Minnesota reported that calves raised in barns without supplemental positive pressure tubes were 80% more likely to show signs of disease4. In addition, calf barn workers report that floors dry out more quickly and that odor is reduced inside the barn.

Technical aspects of "New Generation" tube design

Many times, people say that "yeah, we had tubes like that in the seventies." Yes, they may have had a fan and polyethylene tube, but those tube systems were not designed for use above nursing calves. In the traditional tube system, the fan and tube were recirculation devices designed to mix air and equalize temperature within a barn. Typically, the tube fan would be located inside the barn and about 3 feet (1 m) away from an intake louver in a wall. In this location, the fans draw predominantly used interior air and therefore recirculate pathogens within the barn. Further, the discharge holes were usually located to discharge air straight out to the sides at the 3:00 and 9:00 hole positions. At this location, the air was not directed toward the animals and draftiness from high speed air was not a concern. This historical approach is not what we are recommending!

The "New Generation" tube systems distribute small quantities of 100% fresh air from outside of the building into the microenvironment of the calf without creating a draft. Said again, *small quantities of fresh air to the calf without a draft!*

The fans are mounted on an exterior wall and are chosen to change the interior air within the barn approximately four times per hour. There will be one fan and tube for approximately every 30 feet (9.1 m) of building width with the tubes running parallel to the length of the barn. While there are general recommendations to limit the length of individual tubes to 100 feet (30.5 m), we have monitored excellent performance of tubes of more than double that length.

The tubes can be made of a variety of materials that range from very inexpensive clear polyethylene, moderate cost woven polyethylene or vinyl, and relatively expensive PVC or drainage pipe. Each material has advantages and disadvantages related to cost, durability, and flexibility in options for discharge hole sizing and location. We find the best overall value in the moderately priced woven polyethylene tubes that are supported with double-cable supports on each side of the tube. These tubes cost between $5 to $12 USD per linear foot ($16 to $40

USD per linear m), depending largely on the diameter of the tube.

The diameter of the tube relative to the capacity of the fan is critical. The tube should be sized so that the calculated velocity of air in the inlet portion of the tube is less than 1,200 feet per minute (6.1 m/s)5. This helps to deliver a uniform quantity of air from each discharge hole along the length of the tube. When the proximal air speed is greater than this, air discharge becomes less uniform, there will be greater noise, and in more severe cases, the tube will flutter and flap near the fan and wear out quickly. In most cases, the diameter of the tube will be wider than the fan on which it is mounted.

The diameter and spacing of the holes are custom designed for each installation. The fundamental requirement is that the tube delivers fresh air to the calves without creating a chilling draft. The technical terms are "throw distance" to "still air." Still air is defined as air moving at a speed of less than 60 feet per minute (0.3 m/s) or less than a foot per second 2. The throw distance of air from a tube is determined by the static pressure inside the tube and by the diameter of the holes or perforations in the tube4. At a given static pressure, air exiting a larger diameter hole will travel further than air exiting from a smaller diameter hole.

The desired throw distance will be determined by how high the tube is located above the floor and how far to the side the air needs to travel. Our guidelines are to achieve "still" air at a point approximately 4 feet (1.2 meters) above the floor. The location of the discharge holes is specified by clock positions such as 5:00 and 7:00, or 4:30, 6:00, and 7:30, which are dependent on the height to the bottom of the tube from the floor, and the desired width of the throw pattern. The throw distances to desired points of still air are calculated using trigonometry, and the diameters of the discharge holes are sized based upon these distances and the estimated static pressure within the tube.

These calculations require the use of principles of fluid mechanics that are beyond the scope of this paper. Training sessions on how to design positive pressure tube systems using the Positive Pressure Tube Calculator© spreadsheet are offered periodically through The Dairyland Initiative Workshops. A list of trainees can be found at https://thedairylandinitiative.vetmed.wisc.edu/professionals/industry-contacts/.

6. Minimal solid sidewalls limited to approximately 2 feet (61 cm) in height

To optimize natural ventilation in warm weather, sidewalls should be sufficiently open to allow winds to easily enter the barn. Minimal height to the roof is related to barn width. In general, 12 feet (3.7 m) should be viewed as the minimal sidewall height for buildings less than 40 feet (12.2 m) in width, but reaching 14 feet (4.3 m) in buildings of 60 feet (18.3) in width or greater. The sidewall should be fitted with retractable curtains, preferably split so that all air does not have to enter above the top of the curtain.

We prefer a minimal solid sidewall for naturally ventilated calf barns, limited to approximately 2 feet (61 cm) above the floor. During warm weather when the sidewall curtains are fully open, the low sidewall allows wind to move directly into the calf pens and maximize ventilation. These low solid sidewalls contrast with traditional sidewalls of about 4 feet (0.9 to 1.2 m) height which may prevent winds from reaching the calf pens, particularly if the air temperature of the wind is higher than the interior temperature of the barn. When exterior winds are warmer than interior temperatures, they pass over the high solid wall and fail to drop into the calf pen. Instead, those winds rise as they travel across the calf barn and also carry away fresh air emerging from a positive pressure ventilation tube. In this situation, the traditional high solid wall prevents both natural and positive pressure tube ventilation from reaching the calves.

If an existing barn has a traditional high solid sidewall, ventilation of the calf pens can be improved by mounting a "baffle board" on the sidewalls to deflect winds downward into the pens. The baffle board can be as simple as a wide plank of 8 to 10 inches (20 to 25 cm) hinged to support posts and positioned just above the concrete sidewalls. The angles of the deflector boards can be controlled using cables that run from the boards upward and then to cranks.

FEATURES SPECIFIC TO CALF BARNS WITH INDIVIDUAL PENS

Calf barns with individual calf pens have some special characteristics for optimal calf health and comfort. These features include an East-West orientation, barns with one or two rows of pens, solid panels between every other calf, and a walkway between the pens and the outside wall.

1. East-West orientation

In larger group pens, the calves can move to shaded areas during mid- to late afternoon. In contrast, a calf confined to an individual pen along the West side may be unable to find shade when the sun is relatively low in the afternoon sky. Therefore, it is important to orient barns with individual calf pens in an East-West orientation.

2. Narrow barns with 1 to 2 rows of pens

The overall rule is the narrower the barn, the better. Narrow barns are easier to ventilate by wind forces in warm weather. Our experience with supplemental tube systems is that when barns get wider than 40 feet (12.2 m), the owners frequently want to install additional mechanical ventilation for the summer.

In addition, it is easier to limit the spread of disease from calf to calf in a longer narrow barn. In single-row calf barns, new calves are placed in freshly cleaned pens, and there is usually a space between them and the oldest calves in the barn. In barns with two rows of pens, both rows can be filled simultaneously from one end, similar to a single-row calf barn, leaving the new arrivals in freshly cleaned pens with a few empties between them and the oldest calves about to be weaned. In barns with three or more rows, the situation is almost always present where vulnerable young calves are directly across a service alley from older calves that are potentially shedding pathogens.

The optimal situation is a series of four or more narrow barns that allow for “all-in, all-out” management systems, as discussed in the general barn section above.

3. Individual calf pens separated 3 feet (0.9 m) from the outside wall

When the temperature inside the barn is warmer than the outside temperature, air entering through the eaves will fall at relatively high “draft” speeds into calf pens adjacent to the outside walls. Because of this phenomenon, it has been a common practice in cold climates to place a cover over individual calf pens during the winter. However, our field study showed that a pen cover was associated with tremendous increases in total airborne bacteria counts, which was a risk factor for respiratory disease1. While a cover can eliminate the draft, it also ensures that the air quality in the pen will become very poor. Neither the draft nor the cover is desirable.

The optimal solution is to separate the pen from the outside wall with a walkway about 3 feet (0.9 m) wide. There should be a solid vertical rear panel about 20 to 24 inches (51 to 61 cm) high between the calf and the outside walkway. Cold air can fall over the curtain and into the walkway without chilling the calf. If the outside walkway is impossible to install, an acceptable solution is to close the curtain and eave on the windward side of the barn and install a well-designed positive pressure tube system that delivers at least four air changes per hour on a non-stop basis. The pens will be ventilated sufficiently by the tube system, and the curtain sidewall can be opened slightly for natural ventilation when the extreme conditions have passed.

4. Solid side panels with mesh panels on front and rear of pen

In the field trial reported in Lago et al., the prevalence of respiratory disease was reduced with lower airborne bacterial counts and the presence of a solid panel between each calf. However, the solid panels between each calf tended to increase the airborne bacterial counts, a confounding finding1. Because of this finding, we have recommended solid panels between each calf, or every other calf, and the use of positive pressure tube systems to deliver fresh air between the solid panels.

The optimal individual calf pen has solid side panels with relatively open mesh to the front and rear. The rear panel can have an open mesh on the upper portion with a solid base panel to a height of 2 feet (61 cm) as it provides a solid barrier that the calf may nest against during cold weather.

With the open front and rear panel, there is greater opportunity for breezes to move through the pens in warm weather when the sidewall curtains are open. Solid panels on all sides of a calf pen create extreme impediments to natural ventilation. We have done investigative work in open-sided calf barns during the summer where solid panels on all sides of the calf pen prevented prevailing winds from ventilating the pen, and the wind would pass over the top of the pen and carry away the air discharge from the positive pressure tube before it reached the pen.

CONCLUSION

Our experiences in the past decade have shown us that calf barns designed and constructed using the techniques described in this paper can produce calves as healthy as those raised in hutches, and also improve the working conditions of the calf caregivers.

More information about youngstock housing can be found on The Dairyland Initiative website at https://thedairylandinitiative.vetmed.wisc.edu/.

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