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Colostrum Management

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Outline

- Introduction
- Principals of colostrum management:
 - Quality
 - Quantity
 - Quickness
 - Cleanliness
- Augmenting the IgG mass presented to the calf
- Evaluating the colostrum management program

What is Colostrum?

- Produced during the five weeks preceding parturition
- Concentrate immunoglobulins and other important factors in mammary gland
- Colostrum = first milking only



Nutritional Significance

Factor	Colostrum (milking postpartum)			Milk
	1	2	3	
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)	2960	1900	1130	340

(Davis and Drackley, 1998)

Energy from fat and lactose critical for thermogenesis and maintenance of body temperature (calf born with little reserve energy).

Immune Components

- Immunoglobulins:
 - IgG = 85-90% (IgG₁ = 80-90%, IgG₂ = 10-20%)
 - IgA = 5%
 - IgM = 7%
 - Leukocytes (>10⁶/ml): T and B lymphocytes, neutrophils, macrophages:
 - Some absorbed, some provide local protection
 - Direct cellular immunity
 - May provide antigenic stimulation to develop newborn immune responses
 - Factors that stimulate immune system:
 - Cytokines: γ -interferon, interleukin-6
 - Growth factors (IGF-1, IGF-2), hormones (insulin, cortisol, thyroxine)
 - Vitamins and minerals
 - Tripsin inhibitor
 - Nonspecific antimicrobial agents:
 - lactoferrin, lysozyme
- (Reiter, 1977; Riedel-Caspari, 1993; Archambault, 1988; Le Jan, 1996; Xu, 1996)

Why is Colostrum so Important?

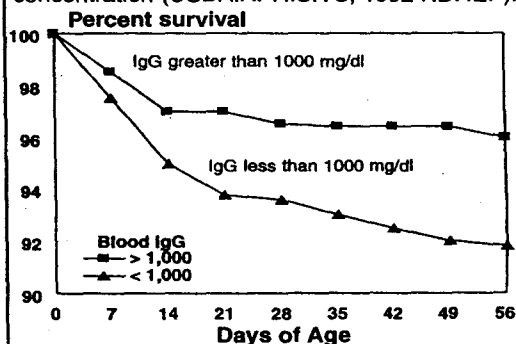
- Calf is born agammaglobulinemic
- Colostrum provides immediate passive (maternal) immunity through:
 - Absorption of immunoglobulins (Ig)
 - Local protection by Ig, other immune factors in the GIT
- Requires time (weeks – to – months) to develop acquired humoral immunity:
 - > 2 wks if colostrum deprived
 - > 4 wks if colostrum present



Passive Transfer of Immunity

- Calf serum IgG concentration is associated with:
 - Calf survival and health (Robison et al., 1988; Selim et al., 1995; Wells et al., 1996)
 - Growth (Nocek et al., 1984; Robison et al., 1988)
 - Subsequent milk production (DeNise et al., 1989)
- Failure of Passive Transfer (FPT):
 - Blood IgG < 10 mg/ml at 48 hrs of age (Bovine Alliance on Management and Nutrition, 1995)

Figure 2. Calf survival by serum IgG concentration (USDA:APHIS:VS, 1992 NDHEP).



Low (0-9.9 mg/ml) vs High IgG (> 10 mg/ml)
(Fowler, 1999)

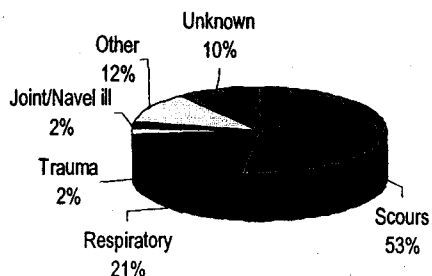
- 2016 calves
- Benefit of High IgG:
 - 2.2 lbs more weight gain.....(+ \$1.53)
 - 12 lbs less feed/calf(+ \$5.70)
 - 12.1% less mortality(+ \$12.10)
 - Lower health treatment costs ...(+ \$3.74)
 - Potential benefit+ \$23.07*

So, how are we doing as an industry?

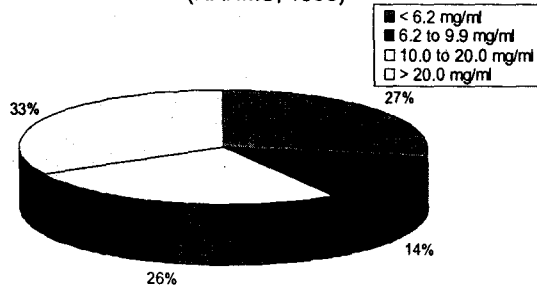


Prewearing Mortality Rates in Heifers

8.4 – 10.8 % mortality rate (NAHMS, 1993, 1996)
8.7 % mortality rate (NAHMS, 2002)



Distribution of Serum IgG (mg/ml) Concentrations in Newborn Calves (NAHMS, 1993)



FPT in 41% of calves of 2177 calves sampled 24-48 hrs. old

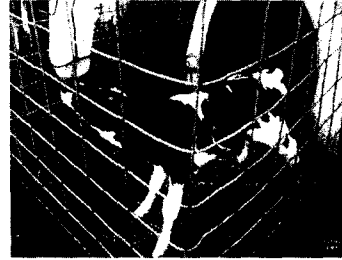
Colostrum Management and Calf Mortality on 1811 U.S. Dairy Farms

- Colostrum deprivation resulted in a 74-fold greater risk for mortality during the first 21 days of life in heifer calves.
- Estimated that 31% of all dairy heifer mortality during the first 21 days could be prevented by improved colostrum management.



Wells et al., 1996. Prev Vet Med 29:9-19.

So, how are we doing as an industry?



So, how are we doing as an industry?

Not so great!

Colostrum Management

- The cornerstone of a good calf-rearing program
- Goal: Maximize calf's immune status by optimizing passive immunity as soon as possible after birth.
- Adequate passive immunity requires that:
 - Calf consumes a sufficient quantity of Ig
 - Function of concentration of Ig in colostrum
 - Function of quantity (volume) of colostrum fed
 - Calf able to absorb colostral Ig
 - Function of time fed after birth

3 Q's of Colostrum Management

(Drackley, 2000)

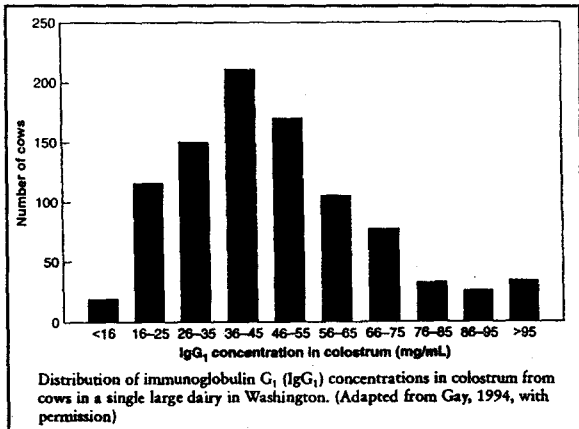
- Quality
- Quantity
- Quickness
- Cleanliness



1. QUALITY

- **Goal:** Total colostrum Ig concentration > 50-60 mg/ml
- Quality of colostrum highly variable (Quigley, 1996), ranging from:
 - 20 to 100 mg/ml IgG in Holsteins (avg 48.2 mg/ml)
 - 28 to 115 mg/ml IgG in Jerseys (avg 66 mg/ml)





Factors Affecting Quality


- Parity:
 - IgG levels lower in heifers than cows due to shorter duration of exposure to antigens. (Kruse, 1970; Devery-Pocius and Larson, 1983)
- Volume produced at first milking:
 - Volume dilutes IgG accumulated in the gland
 - Better quality if first milking volume < 8.5 kg (18 lb) for Holstein cows (Pritchett et al., 1991)
 - Important implications for milking cow ASAP after calving
- Excessively long or short dry period:
 - < 3 weeks dry => insufficient time for Ig to accumulate in mammary gland (Dixon et al., 1961)

Factors Affecting Quality (con't)

- Dry cow management:
 - Nutrition:
 - Energy status (Subclinical ketosis) (Klimes et al., 1989)
 - Vaccination:
 - Increase transfer of specific IgG to colostrum
 - E. coli, rotavirus, coronavirus, clostridial enterotoxemia
 - Heat Stress:
 - Lower DMI => lower colostrum IgG
 - Leaking prior to calving

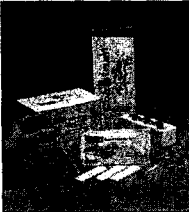
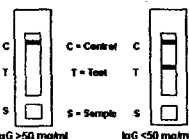
Options for Measuring Colostrum Quality on Farm

- Colostrometer
- Midland Quick Test Kit
- Other commercial test kits?



Commercial Test Kits

- E.g. Midland Bioproducts Bovine Colostrum Test Kit:
 - Measure colostrum into dilution liquid
 - Place drop in well of test cassette
 - Wait 20 mins.
 - If no line, A = acceptable
 - If line, NA = < 50 mg/ml
- Cost: Approx. \$4.50/test U.S.

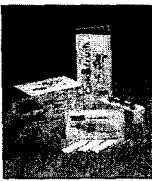
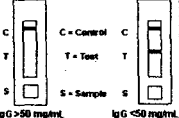



Commercial Test Kits

- Preliminary results of MN evaluation of the Midland Bioproducts Bovine Colostrum Test Kit:
 - 105 samples collected at freshening
 - Test kit vs true colostrum IgG
 - Positive test: colostrum IgG > 50 mg/ml

Sensitivity for = 78.8%
 Specificity = 35.0%
 PV+ = 83.8%
 PV- = 28.0%

If "A", test was correct 84% of time
 If "NA" (FPT), test was only correct 28% of time

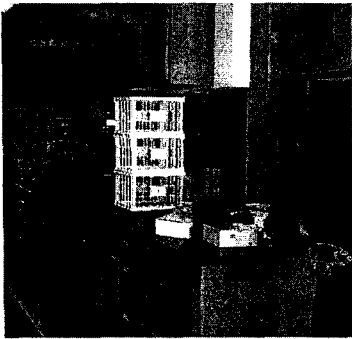
Colostrometer

- A hydrometer measuring specific gravity
- Is a linear relationship between colostrum specific gravity and Ig concentration.
- Specific gravity > 1.050 equates to Ig > 50 mg/ml
- Cutpoints:

Poor = Red:	Ig < 22 mg/ml
Moderate = Yellow:	Ig 22-50 mg/ml
Excellent = Green:	Ig > 50 mg/ml

Colostrometer

- Advantages:
 - Rapid and inexpensive
- Disadvantages:
 - Fragile
 - Highly affected by temperature (calibrated at 20-25 °C)
 - If colostrum cold (0 - 5 °C) will appear as "excellent"
 - If colostrum warm (35 - 40 °C) will appear as "poor"
 - Require method to correct reading for temperature (Mechor, 1991)
 - Tends to overestimate true Ig level
- Overall Utility:
 - If feed 3.8 L at first feeding, cutpoint > 50 mg/ml OK.
 - If feed 2L at first feeding, increase cutpoint to > 100mg/ml (Pritchard et al., 1994)

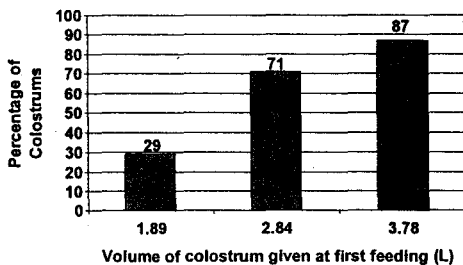


Dr. Mueller measuring IgG in serum & colostrum

2. Quantity

- Goal is ≥ 10 mg/ml serum IgG, but should target 15 mg/ml. (Davis and Drakely, 1998)
- Thumbrule: 100 g of IgG must be consumed ASAP after birth. Considers:
 - Body size (40 kg calf \Rightarrow 2.6 L plasma volume)
 - Efficiency of absorption = 20%-48% within 2 hr of birth (Kruse, 1970; Besser et al., 1985)
- Consider Colostrum Quality:
 - Good (> 60 mg/ml IgG): 1.7 L (1.8 qt) sufficient
 - Poor (35 mg/ml): 3 L required
 - Inflate by 50% if goal is 15 mg/ml in calf serum (Davis and Drakely, 1998)

Percent of colostrum expected to provide 100g of IgG when fed at 3 different volumes



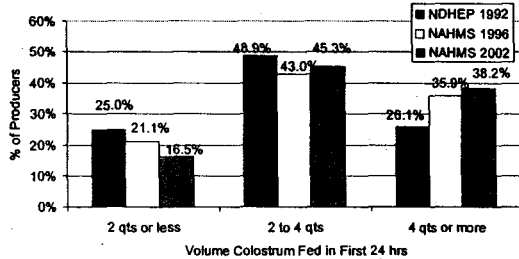
(Adapted from Gay, 1994)

2. QUANTITY

- Bottom Line:
 - 12-15% of body weight at first feeding
 - 4 quarts (3.8 L) for a 90 lb Holstein calf
- Common feeding strategies:
 - 4 qts in one feeding ASAP after birth (<1-6 hr)
 - 4 qts at first feeding, offer 2 qts at 2nd feeding *
 - 2 qts in two feedings at 10-12 hr interval **
- * Second feeding may not be practical, but will provide benefit
- ** Highest rate of FPT with this strategy (Davis and Drakely, 1998)



For Operations Hand Feeding Colostrum,
Amount of Colostrum Delivered to
Holstein Calves During the First 24 hrs.



3. Quickness



3. QUICKNESS

- Ability of the calf to absorb immunoglobulins
- Initial "open gut" in newborn:
 - Non-specific absorption of large molecules & particles
 - Ig's absorbed across GIT by process of pinocytosis
 - Bacteria (pathogens) also absorbed.

3. QUICKNESS

- "Closure of gut":
 - Progressive decrease in ability to absorb Ig's begins shortly after birth
 - By 9 hours of age is 50% decrease in absorptive capacity
 - Closure complete by 24 hours.
 - Earlier feeding of colostrum and Ig absorption may result in earlier 'closure', reducing access by bacterial pathogens
(McCoy et al., 1970; Stott et al. 1979)
- Trypsin inhibitor (TI):
 - Protects IgG from proteolytic degradation
 - TI levels very high in high quality first milking colostrum
 - TI levels fall significantly in lower quality colostrum and milk
(Quigley et al. 1995. JDSci 78:1573)

Achieving Quickness on a Real Dairy Farm

- It's 10:00 PM and the calf just hit the ground.
- Your Options:
 - Milk the cow and feed the calf now
 - Feed fresh refrigerated colostrum from previous cow (refrigerate in 2L bottles for 1-2d max).
 - Thaw and freeze frozen colostrum from previous cow (don't overheat when thawing)
 - Feed a commercial colostrum substitute if available
 - Go finish watching the hockey game and wait until morning to milk the cow and feed the calf *** Wrong answer

Other Factors Reducing Ability to Absorb Ig

- Heat stress
- Severe cold stress / hypothermia
- Severe dystocia
 - Mechanisms unclear (Hypoglycemia? Hypoxia? Glucocorticoids?)
- Results:
 - Delay in time to suckling
 - Reduced efficiency of Ig absorption
 - Delayed 'closure' => prolonged risk of septicemia after absorption of pathogens

(Stott et al., 1976; Olson et al., 1980; Vemorel et al., 1989)

Method of Feeding Colostrum

- A factor affecting quickness and volume
- Options:
 - Natural suckling of the cow (assisted or unassisted)
 - Bottle
 - Tube

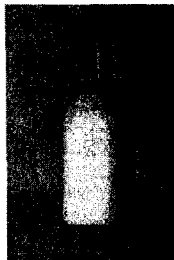


Suckling Mom

- High rate of FPT due to delays in suckling. Many unattended calves fail to suckle by 6 hrs
 - Delay in 11% calves of heifers and 46% calves of older cows.
 - Factors contributing to delayed suckling:
 - Poor suckling drive or delay in suckling if stressed
 - Poor mothering ability
 - Dam injured, has mastitis, leaked prior to calving, etc. (note: mastitis reduced volume but not [Ig]).
 - Older cows: lower udders & larger teats
- Other disadvantages:
 - No way to know volume consumed.
 - Increased risk of pathogen ingestion (dam's coat, udder)

Method: Bottle

- Closure of esophageal groove => rapid delivery to absorptive sites.
- May take 20 - 30 minutes per calf (training involved).
- May bottle feed initially, then force feed volume not voluntarily consumed.



Method: Esophageal Feeder

- Rapid administration of large volume will empty into rumen => presents to abomasum & small GIT in 2-4 hr.
- Some studies report poorer absorption (vs bottle) (Latour-Rowet and Breukink, 1983)
- Other studies report no difference (Besser et al., 1991)



Method: Esophageal Feeder

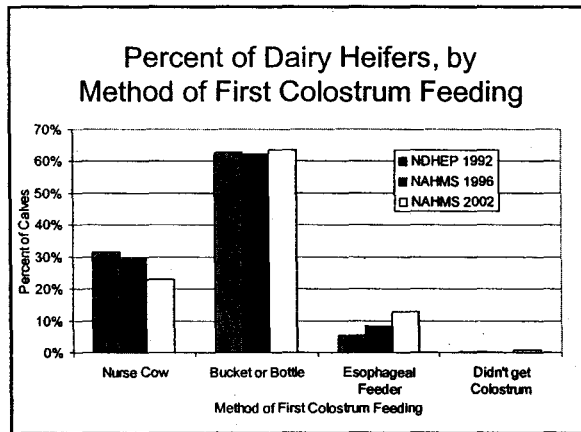
- Speed of delivery
- Deliver fixed volume
- No harmful effects of residual amount left in rumen
- Training involved




Bottle vs Tube?



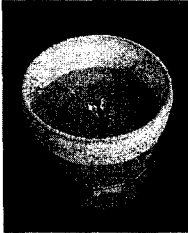
- May come down to personal preference
- With either approach – feed 3.8 L
 - Both methods are successful if large volumes are fed to ensure adequate IgG mass presented to GIT
 - No discomfort, scours, noted with feeding large volumes
 - Calves may not be hungry at 2nd feeding at 6-12 hrs old



Issues with Colostrum Cleanliness




- General bacterial contamination:
 - Interfere with Ig absorption?
 - General increase in risk for infectious disease
- Specific bacterial pathogens (e.g. Johne's disease)



Note: NAHMS 1992 reported < 60% managers clean udders prior to milking the cow.

Issues with Colostrum Cleanliness

- Can high bacteria counts in colostrum interfere with Ig absorption?
 - Possible explanation: Bacteria penetrate the vacuolar tubules of the epithelial cells lining the GIT in much the same way as Ig molecules.




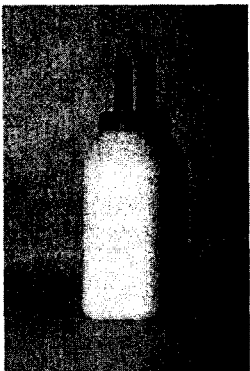
(Staley et al., 1972)

Issues with Colostrum Cleanliness

- Can high bacteria counts in colostrum interfere with Ig absorption?
 - McGuirk, 2003: Reported a negative association between colostrum bacteria counts (total CFU/ml) and calf serum IgG (personal communication, 2003). However may/may not be a causal relationship.
 - MN data (2004): Preliminary analysis of approx. 200 colostrum and calf serum samples showed no relationship.
 - James and Polan, 1978: Reported that the presence of bacteria does not interfere with Ig absorption unless exposure to bacteria occurs prior to colostrum consumption.

- Bacterial pathogens in colostrum may/may not interfere with Ig absorption, but we know they are a disease risk
- Goal: < 100,000 CFU/ml total coliform count
- Recommendations:
 - Attention to udder prep (predip, strip, dry, etc.)
 - Use clean milking equipment
 - Do not pool colostrum
 - Feed ASAP using clean feeding utensils
 - or
 - Chill immediately in clean 2 L containers (up to 24 hr)
 - or
 - Freeze in clean containers
 - Don't feed colostrum from Johne's-positive cows to heifers?
 - Pasteurize colostrum? (not ready yet)

Can we Pasteurize Colostrum?

Issues: - Pathogen destruction
- Fluid characteristics
- IgG loss

Examples of Commercial Pasteurizers

- Batch pasteurizer
DairyTech, Windsor, CO
145F(63C)/30 min



- Small HTST pasteurizer
BetterMilk (Bou-Matic), Winona, MN
161F(72C)/15 sec



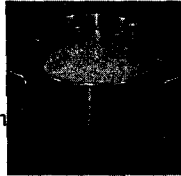
Pasteurizing Colostrum in the Lab

- Two batch designs:
 - 38 batches x 1 gal. (Weck)
 - 10 batches x 8 g (DairyTech)
- HTST
 - 5 batches x 1 gal. (Bettermilk)

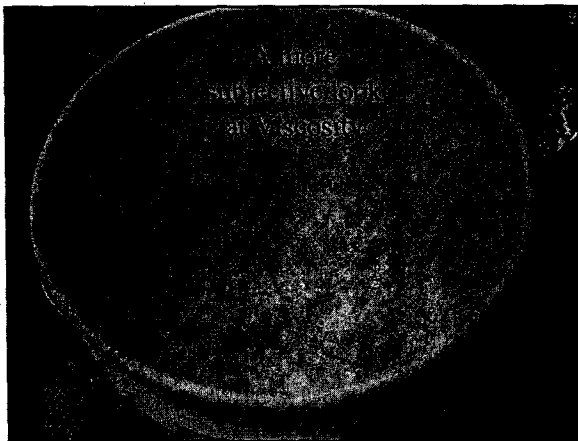
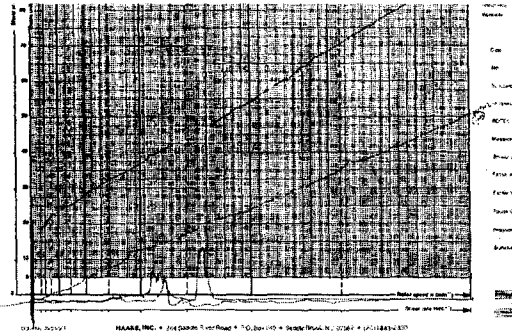


Results of in-lab Colostrum Pasteurization

- Avg. 25 - 30 % IgG loss
- More likely to end up with good quality (> 50 mg/ml) if start with high quality colostrum (> 60 mg/ml)
- Fluid characteristics:
 - Batch: Only slight thickening. Easy to feed & clean
 - HTST: ... don't do this at home



Effects of Pasteurization on Colostrum Viscosity (mPas)



Minnesota - Colorado Field Study Pasteurizing Colostrum (J Dairy Sci, 2003; 86:1503)

- 2000 cow dairy in CO
- March, 2002:
 - 123 Calves fed either fresh or pasteurized colostrum at first and second feedings
- Batch pasteurize 15 gal. batches
 - 145 °F x 30 min (DairyTech, Inc)

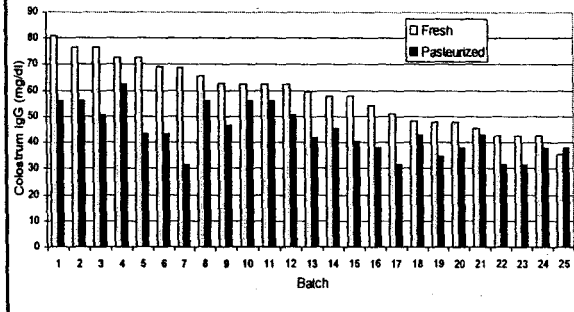


Results of MN-CO Colostrum Study

- Effects on Colostrum:
 - 25 % IgG loss (15 gal. batches)
 - Higher final IgG if start with high IgG colostrum: colostrometer
 - 15 gal. batch still fluid => easy to feed and clean
- Calf serum IgG (mg/ml)

	Fresh	Pasteurized	
- Fed 2 qt, 2 qt	19.1 (n = 40)	9.7 (n = 55)	SD
- Fed 4 qt, 2 qt	16.1 (n = 8)	13.5 (n = 20)	NSD
- Producer still feeding pasteurized colostrum to all calves: Aug '02 - Mar'03: Mean serum IgG 20.4 mg/ml FPT rate = 11%

Bovine IgG Levels Before and After On-farm Batch Pasteurization (15 gal. batches)



So, colostrum can be successfully pasteurized. However....

- I wouldn't recommend it to a producer unless you have all of your ducks in a row:
 - Batch pasteurize (with agitator) small batches (< 15 gal.)
 - Use only high quality colostrum (colostrometer > 60 mg/ml)
 - Collect, store, and chill colostrum under clean conditions
 - Monitor pasteurizer function and cleaning
 - Feed 4 qts ASAP after birth
 - Offer a second feeding of 2 qts at 6-8 hrs.
 - Monitor serum IgG concentrations in calves
 - Minimize infectious disease challenge to calves
- More research on time/temp., colostrum substitutes

Summary of Colostrum Management

- 3 Q's:
 - QUALITY
 - QUANTITY
 - QUICKNESS
- CLEANLINESS
- Goal: Feed 3.8 L of clean, high quality colostrum ASAP after birth (< 1- 6 hrs old)



(Davis, 1998; Morin et al., 1997)

Augmenting the Ig Mass Presented to the Calf



Oral Colostrum "Supplements"

- Traditional Products:
 - Derived from serum, whey, colostrum:
 - Acceptable efficiency of absorption but less IgG mass overall (45-50 g IgG) (e.g. Lifeline™, APC Inc.)
 - If given alone, result in lower serum [Ig] and greater risk of FPT vs if give fresh colostrum. (Quigley et al., 1998)
 - Used as supplement/extender for poor quality colostrum
 - No added benefit if feeding 3-4 L of high quality colostrum (>59 mg/ml).



(Franciso & Quigley, 1993; Zaremba et al., 1993)

Oral Colostrum Substitutes?

- E.g. Acquire™ / Secure™ (A.P.C. Inc)
 - Spray dried bovine plasma
 - Dose 125 g IgG in 2 L warm water
- Early Studies:
 - 16 bull calves: mean serum IgG 13.6 mg/ml (Quigley et al., 2001)
 - Lower IgG than fresh colostrum, but still above acceptable IgG to achieve passive transfer (McGuirk, personal communication, 2003)
- U of MN: Long-term health study in progress



Methods of Augmenting Ig Mass (con't)

- Oral antigen-specific immunoglobulins
 - Bovine Ecolizer (Grand Labs): E. coli K-99 antigen
 - First Defense (Immucell): E. coli, coronavirus
- Injectable immunoglobulins
 - e.g. Ig Solution (APC, Inc): purified from bovine blood, suspended in 0.9% NaCl.
 - SQ injection results in increased circulating [Ig]
 - May be viable option for hypogammaglobulinemic calves that are > 24 hours old ("closure" of GIT has occurred). (Crawford et al., 1995)



Evaluating the Colostrum Management Program on the Farm

- Uses:
 - Herd investigations
 - Ongoing or periodic monitoring by owner/producer
 - Ongoing monitoring by professional dairy heifer grower



Assessment of Passive Transfer of Immunity

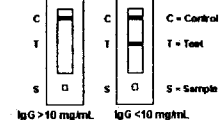
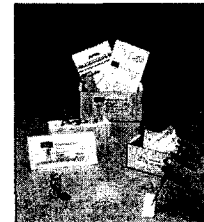
- Monitor disease morbidity & mortality in first week of life (lag involved in data collection):
 - Indirect measure of colostrum management
 - Also affected by environmental exposure to pathogens, nutritional management, seasonal factors, etc.
- Monitoring Ig status of calves:
 - Direct measurement: serum IgG (goal > 10 mg/ml)
 - Indirect measurement: serum total protein (TP)

Laboratory Tests to Measure Serum IgG

- Radial immunodiffusion assay (RIA): gold standard
 - Kit available, expensive, 24 hours to read accurately
- Zinc sulfate turbidity test:
 - 6 ml zinc sulfate solution + 1 ml serum
 - Turbidity, from presence of Ig's, begins at 400 mg/dl
- Sodium sulfite turbidity test:
 - 3 solutions of 14%, 16% and 18% sodium sulfite
 - 1.9 ml of each sodium sulfite solution + 0.1 ml serum:

Commercial Test Kits

- E.g. Midland Bioproducts Whole Blood Test Kit:
 - Measure blood into dilution liquid
 - Place drop in well of test cassette
 - Wait 20 mins.
 - If no line, A = acceptable PT
 - If line, NA = FPT



- Cost: Approx. \$4.50/test U.S.

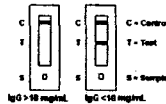
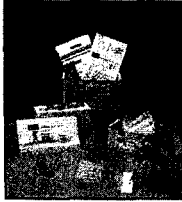
Commercial Test Kits

- Preliminary results of MN evaluation of the Midland Bioproducts Whole Blood Test Kit:

- 110 samples collected 24-48 hrs of age
- Test kit vs true serum IgG
- Positive test: Serum IgG > 10 mg/ml

Sensitivity for = 83.9%
 Specificity = 30.4%
 PV+ = 82.0%
 PV- = 30.4%

If "A", test was correct 82% of time
 If "NA" (FPT), test was only correct 30% of time

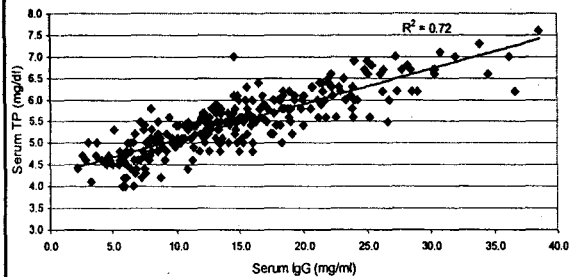


Serum Total Protein



- Refractometer measures index of refracted light
 - Close correlation btw serum total protein (TP) and IgG
 - Inexpensive, fast
 - Done on farm (sit in fridge overnight, don't need centrifuge)
 - Assumes normal hydration status
- Use in calves > 24 hrs - 7 d old
 - > 5.5 mg/dl : very successful
 - 5.0 - 5.5 mg/dl : moderately successful
 - < 5 mg/dl : FPT (IgG < 10.0 mg/ml) (Calloway et al., 2002)

MN Data comparing Serum IgG to TP (12 herds; 265 calves. Bleed 2-8 d old)

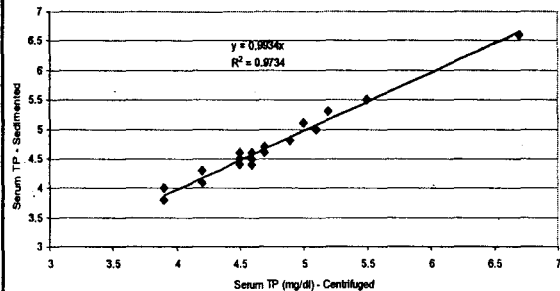


Interpretation of Serum Total Protein Data



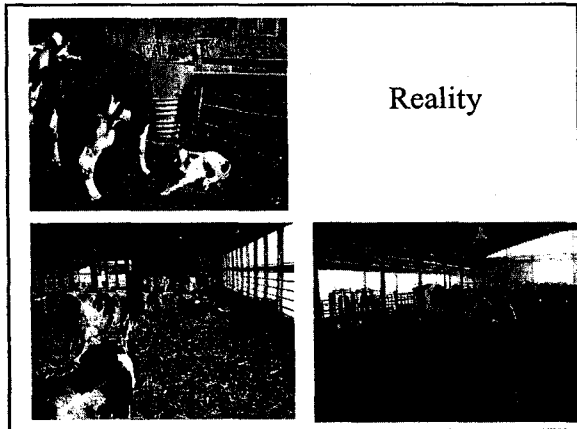
- Less accurate for individual animals:
 - Using 5.0 mg/dl TP as cutpoint for FPT (10.0 mg/ml IgG)
 - Sensitivity = 80-89%
 - Specificity = 84-91%
 - Overall proportion correctly classified = 86-87% (Calloway et al., 2003)
- Use to test the program, not the individual calf:
 - > 90% of calves should be > 5.0 mg/dl (Tyler)
 - > 80% of calves should be > 5.5 mg/dl (McGuirk)
- Becoming widely adopted by professional heifer growers

Serum TP Results: Centrifuge vs Sediment



Nature's
 Maternity Pen





Summary

- The dairy industry is still experiencing unacceptable losses in preweaned heifers
- Colostrum management is the cornerstone of a successful calf rearing program
- Colostrum management depends on:
 - Quality
 - Quantity
 - Quickness
 - Cleanliness
- Monitor the program

