Raising Holstein Steers in the Desert Southwest: Implications of Nutrition and Environment

G. C. Duff
Department of Animal Sciences
College of Agriculture and Life Sciences
The University of Arizona, Tucson

Take Home Message:

- Raising Holstein calves continues to be a big challenge
- Proper quality and quantity of colostrum cannot be overlooked
- Raising milk and feed prices require evaluating use of alternative milk replacer components and/or alternative feeding practices
- Pasteurization capability may be viable for dairy producers; however, calf ranches have fewer opportunities for such technologies. Evaluation of effects of antibiotics on changes in the morphology of the digestive tract and antibiotic resistance is warranted
- Concentrates are needed for ruminal development; however, roughage source and level need to be reevaluated for overall health and performance
- Special dietary considerations may impact overall performance of calves
- Effects of environment of performance of calves remains to be determined

Introduction

Holstein calves (both bulls and heifers) are of great financial importance to both dairies and feedyards in the desert southwest. For steers, their availability and uniformity and overall production have out weighed the potential deficits in carcass characteristics (smaller and elongated ribeye area, increase kidney, pelvic and heart fat, etc.) and increased maintenance costs. In Arizona alone, an estimated 300,000 Holstein steers are raised in beef production facilities. At the current price (http://www.ams.usda.gov/LSMNpubs/PDF_Weekly/WCBS.pdf; accessed 15 SEP 2007) of $0.86/ lb, the live value of the animals is well over $300,000,000. With an additional $5.00 generated (Galyean and Duff, 2002) from allied industries (feed, slaughter house, retail), total value to the Arizona economy approaches $1.5 billion annually. Importance of dairy heifer production far exceeds that of dairy beef production. For dairy heifer, many factors influence costs of raising replacements with milking herd replacement rates and age at first calving having the most influence (Tozer and Heinrichs, 2001) Van Amburgh et al. (2003) suggested that nutrition and management during the first few weeks of life has long-term impacts on animal productivity. Although research has been conducted evaluating nutritional effects on performance of Holstein calves, the majority of the research has been conducted using heifer calves. Therefore, the Holstein bull calf remains one of the most over-looked class of animals. In addition to general performance of the animals, health of the milk-fed calf remains a primary road block to profitability. In 2002, overall death losses of heifers born alive was reported to be 8.7% (USDA, 2002) and although data are not available for Holstein bull calves, death losses alone can be as high as 15 to 20%. Scours, diarrhea, or other digestive problems caused 62.1% of the reported deaths. Morbidity of dairy calves is less available. Therefore, improving performance of neo-natal Holstein calves will have a tremendous impact on the economy in Arizona and research efforts at the University of Arizona have recently tackled this

issue. The objective of this paper is to evaluate nutritional management factors affecting performance of Holstein calves.

Nutrition and Management

Colostrum

Dairy calves must receive high quality colostrums shortly after birth due to maternal antibodies are not capable of crossing the placenta in bovine. In addition, in order to reduce disease transmission, 52.9% of operations immediately remove calves from dams; another 22.5% of producers remove calves after nursing and less than 12 hours of age; 15.9% remove calves between 12 and 24 hours of age with the remaining 8.7% of producers removing calves greater than 24 hours after birth (USDA APHIS, 2002). One problem with allowing the calves to nurse the cows is the amount of colostrum consumed is not known. Franklin et al. (2003) reported that based on 24-hour serum protein concentrations, calves that were hand fed 2.84 L (3 qt) of colostrum followed by 1.89 L (2 qt) 12 hours after the first feeding had greater transfer of passive immunity compared with calves that were allowed to suckle their dams for 3 days. Although it is generally recommended that calves be allowed to consume the colostrum with a nipple, Kaske et al. (2005) suggested that colostrum administered via an esophageal tube is an adequate method. These authors further suggested that failure of the esophageal groove reflex caused no clinical consequences. It is suggested that only experienced personnel administer colostrum via an esophageal feeder and only as a last resort.

For producers reporting data to the USDA (USDA, 2002), 16.5% of calves received 2 qt of colostrum, 45.3% received between 2 and 4 qt, and 38.2% of calves received greater than 4 qt. Hopkins and Quigley (1997) suggested that when 3.8 L (4 qt) of high quality colostrum is fed; either one or two feedings was equally effective in providing passive immunity (as measured by serum IgG concentration). In lactating animals, the amount of colostrum fed during the first hour after birth has influenced subsequent health and lactational performance (Faber et al., 2005). These authors evaluated feeding 2 vs. 4 L of high quality colostrum within the first h of birth. Besides decreasing veterinary costs by approximately ½, the cows fed 4 L of colostrum resulted in $160.00 per cow in additional milk produced over two lactations. Rauprich, et al. (2000) also reported that protein, lipid, and immunoglobulin status of neonatal calves was improved with intake of large amounts of first colostrum during the first week of life.

In bull calves destined for calf ranches, it is unknown the amount of colostrum the animals received shortly after birth, albeit most dairy producers ensure the animals receive adequate colostrum. In addition, it may be advantageous for dairies to provide frozen colostrum for calf ranches to administer to the calves if it was not possible to provide all the colostrum before shipping. Klobasa et al. (1998) reported that freezing or lyophilizing was acceptable means of creating colostrum banks. Another means for calf ranches may be colostrum replacement products. Jones et al. (2004) reported that at 24 hours of age, calves receiving equal amount of IgG from maternal colostrum or colostrum supplement had equivalent IgG concentrations. The colostrum replacement used in this study was derived from bovine serum. Therefore, feeding products containing bovine IgG may be beneficial in health of Holstein bull calves, but economic evaluation of such programs deserves consideration.

Milk Replacers

Until recently, few large commercial dairies have used whole milk for calf production. However, with raising milk replacer costs, commercial dairies have evaluated the option using pasteurized nonsaleable milk for replacement heifer production. Godden et al. (2005) reported higher growth rate and lower morbidity and mortality rates for calves fed pasteurized nonsaleable milk compared to milk replacer. These authors suggested that part of the performance advantage may have been related to crude protein and crude fat concentrations of the two products. The nonsaleable milk averaged 25.6% crude protein and 29.6% crude fat whereas the milk replacer averaged 20 and 20% crude protein and crude fat, respectively. Factors that should be further evaluated include efficiency of pasteurization in destroying pathogens and/or antibiotic resistance of pathogens in the animal as well as effects of antibiotics on beneficial gut microflora. Virtually no producer raising bull calves has this option available.

As with all commodities, milk replacer prices have risen tremendously over the past year. At our facility, the price of a 50 lb (22.68 kg) bag of milk replacer has gone form $49.00/bag to around $73.00/bag. The milk replacer product used has all milk proteins, so our only option is to evaluate alternative protein sources included in the milk replacer. With alternative protein sources used (e.g. wheat gluten protein/all milk blend), prices may be decreased from 64 to 78%. Terui et al. (1996) reported that calves fed milk replacer containing soluble, enzyme-modified wheat gluten was a good source of protein for milk replacers. These authors reported that calves fed milk replacer containing 18% crude protein with 33% wheat gluten gained as much weight as calves fed milk replacers containing 20% crude protein.

Besides the aforementioned wheat gluten protein, other alternative proteins include egg protein, plant proteins (e.g. soy protein isolate, potato protein concentrate, etc), animal plasma, etc. These alternative proteins should decrease cost of milk replacers, however, exact amounts to include to decrease cost without sacrificing overall performance needs to be evaluated. Quigley (2002) evaluated spray-dried whole egg and biotin in calf milk replacer. Results suggested that the spray-dried whole egg used did not provide nutrients to support adequate growth of milk-fed calves. Calves receiving 0% gained 486 g/day (1.07 lb/day)with calves receiving 10 and 20% spray-dried whole egg gaining 369 (0.813 lb/day) and 302 g/day (0.67 lb/day) Likewise, feed conversion reflected the lower gains. However, Touchette et al. (2003) reported that egg is an effective alternative protein source to milk protein when fed up to 10% of the diet in conventional feeding program (1 lb/day). In the third experiment reported by these authors, average daily gain averaged 0.621 kg/day (1.36 lb/day), 0.631 kg/day (1.39 lb/day) and 0.634 (1.40 lb/day) for 0, 5 and 10% egg in diet. There are several factors that producers need to weigh when making these choices including price, feeding rate, product consistency, palatability, calf performance and calf health.

Besides evaluating alternative ingredients, producers may be able to evaluate alternative feeding programs. Before 3 to 4 weeks of age, the calf's gastrointestinal system is equipped to digest milk and it takes time to develop the capacity to digest other nutrient sources (Maas and Robinson, 2007). Therefore, alternative feeding programs may be developed to utilize all milk proteins before 3 weeks of age, followed by plant-based protein sources thereafter. This 2-stage system should decrease costs of production, but more information on such systems needs to be collected. In addition, perusal of the internet revealed some feeding programs advocate feeding calves 0.23 kg (0.5 lbs) of milk replacer in 2 qts water twice daily for up to 35 days, followed by

0.23 kg (0.5 lbs) of milk replacer in 2 qts water once daily until weaning. Such a program would have the added benefit of decreasing milk replacer consumption and labor costs, but care should be taken to avoid increased morbidity as a result of less observation of the calves. Khan et al. (2007) evaluated a step-down method vs conventional milk feeding in dairy calves and suggested that the step-down method may prevent problems of poor body weight gain with conventional feeding dairy calves. More work in this area deserves attention.

Calf Starters

As mentioned previously, there is no doubt that what happens during the neonatal period impacts performance throughout life. Besides milk replacer formulation, starter diets formulation may influence overall performance. However, few research studies have evaluated performance throughout finishing with Holstein steers.

Lesmeister and Heinrichs (2004) suggested that the type of processed corn (whole corn, dry-rolled, roasted-rolled, or steam-flaked) used in calf starter mix influenced intake, growth, and rumen parameters in neonatal calves. In their first experiment, post weaning and overall starter and total dry matter intake were significantly higher in calves fed starter with dry-rolled corn than rolled corn or steam-flaked corn. Likewise, post weaning and overall starter and total dry matter intake were significantly higher in calves fed starter with whole corn than steam-flaked corn. Post weaning average daily gain was significantly greater in calves fed starter with dry-rolled than steam-flaked corn. Papillae length and rumen wall thickness at 4 wk were significantly greater in calves fed starter with steam-flaked than dry rolled or whole corn. In experiment 2, calves fed starter with whole corn had higher rumen pH and lower rumen volatile fatty acid concentrations than calves fed all other starters. Results indicate that the type of processed corn incorporated into calf starter can influence intake, growth, and rumen parameters in neonatal calves. It is known that ruminal VFA concentrations (especially butyrate) influence ruminal development. However, long term impacts of such high concentrate levels on overall feedlot digestive function remains to be determined.

It has been long established that fiber sources plays a roll in performance of calves. Murdock and Wallenius (1980) conducted a study evaluating complete calf starter rations containing either alfalfa hay, cottonseed hulls, or alfalfa-beet pulp as sources of fiber. These authors reported that although growth and development were normal on all diets, calves fed the cottonseed hull ration consumed more starter and gained more body weight than calves fed the other sources of fiber. The similarity of feed efficiencies, rumen pH, and molar ratios of volatile fatty acids between diets indicated no appreciable differences in rumen development or function. In addition, the incidence of scours was less for calves fed alfalfa hay starter, however, the incidence and severity of bloat were higher for that diet. Coverdale et al. (2004) reported that forage of a consistent particle size can be included with success in starter diets for young calves. Diets used in this study included commercial starter either course or ground along with bromegrass hay. In finishing beef cattle, roughage source/level alters dry matter intake and performance (Guthrie et al., 1996) . Sudangrass hay has been reported to consistently increase dry matter intake relative to alfalfa hay in high concentrate finishing diets. The long-term impact of starter diet roughage source/level deserves attention on overall feedlot performance.

Weaning

The average age heifer calves are weaned was 8.4 weeks in 2002 (USDA, 2002). In addition, it has generally been recommended that calves be weaned when they are consuming at least 1.36 kg (3 lbs) of starter for at least 3 days in a row. Other anecdotal data has suggested as low as 1 kg (2.2 lbs) to as high as 1.81 kg (4 lbs) starter intake before weaning. Quigley (1996) evaluated weaning methods for Jersey calves and reported that intake of milk replacer and feed costs were greater when calves were weaned according to intake of starter (1 lb/day for 2 consecutive days. Other methods of weaning have been according to body weight or age (Quigley, 1996).

Feeding Holstein steers from weaning to 125 kg (275 lbs)

Limited research is available evaluating diets for Holstein steers from weaning through 125 kg. Holstein steers are weaned on high concentrate diets; however, growing diets should be higher in fiber and lower in protein than calf starter diets (Maas and Robinson, 2007). In addition, protein sources used during this critical time period should be plant based. Holstein steers may not utilize non-protein nitrogen sources until later in the finishing period (Duff and McMurphy, 2007).

Special Dietary Considerations

Morbidity of dairy calves encompasses several mechanisms. Diarrhea can be a problem at times and if left unchecked, the animals succumb to dehydration and death. In addition, respiratory disease complex may be a problem. Respiratory disease is a viral/bacterial disease. However, Rivera et el (2005) pointed out that exacerbating factors, such as degree of stress, previous plane of nutrition, genetic, and previous health history, interact with exposure to viral and bacterial agents in beef cattle. The long-term consequences of morbidity include lighter final body weight and average daily gain, lighter carcasses, lesser percentage of carcasses grading USDA Choice or better compared with animals never treated for respiratory disease. Several nutrition and management considerations may influence morbidity and mortality of Holstein calves. One common practice for producers to decrease both diarrhea and respiratory disease is use of antibiotics in milk replacer. A total of 55.7% of producers include antibiotics in milk replacer with oxytetracycline and neomycin used most often.

Direct-fed microbials (DFM), also known as probiotics, are live, naturally occurring bacterial supplements (Yoon and Stern, 1995). In the cattle industry, two frequently used DFM are lactate-utilizing bacteria and lactate-producing bacteria, often used in conjunction with each other. The family of lactate-utilizing bacteria most commonly used is *Propionibacterium*. The two families of lactate-producing bacteria regularly used are *Lactobacillus* and *Enterococcus*. Interest in supplementation with DFM has increased rapidly due to the recent concerns regarding the use of antibiotics in production animals. Consumers are worried that the use of antibiotics in production animals may eventually result in pathogen outbreaks in meat and meat products (Krehbiel et al., 2003). In ruminants, it is possible that probiotics improve microbial conditions in both the rumen and the lower digestive tract (Elam et al., 2003), along with having many other benefits.

Direct fed microbials have also been shown to be beneficial to neonatal and newly received, stressed dairy and beef calves. Krehbiel et al. (2003) reported the general importance of feeding

bacterial DFM to young and/or stressed calves, which has been to establish and maintain "normal" intestinal microflora rather than as a production stimulant. The primary objective in dairy calves is quick adaptation to solid food by speeding up the establishment of microorganisms of the gastrointestinal tract and avoiding the establishment of pathogens, which often result in diarrhea. In neonatal and stressed calves, the microbial population is in transition and extremely sensitive. Sudden changes in the calf's diet or environment could be detrimental to microbes in the GIT. It is well known in the cattle industry that diarrhea is one of, if not the most common health problem in young calves. Tannock (1983) attributed this problem to decreases in the population of *Lactobacillus* in the gut. Similarly, Sandine (1979) reported that fecal counts of lactobacilli normally are higher than coliforms in healthy animals and reversed in those suffering from diarrhea. Some species of *Lactobacillus* and *Streptococcus* have been reported to decrease the incidence of diarrhea (Bechman et al., 1977; Maeng et al., 1987; Fox, 1988). More recently, calves fed *L. acidophilus* had a significantly lower scour index, which established the benefits of lactobacilli in reducing the incidence of diarrhea in dairy calves (Abu-Tarboush et al., 1996). It is suggested that the decreased incidence of diarrhea might be related to a consistent increase in shedding of *Lactobacillus* (Gilliland et al., 1980; Abu-Tarboush et al., 1996) as well as an inconsistent decreased shedding of coliforms in feces in response to *Lactobacillus* (Bruce et al., 1979). Previous research has suggested that animals with normal stools are less likely to shed coliforms in feces (Gilliland et al., 1980; Abu-Tarboush et al., 1996). The conclusion that many authors have come to is that supplementing DFM in calves is beneficial only when the calves are experiencing health problems. Morrill et al. (1977) reported that in experiments where there has been no advantage to feeding DFM, calves were generally experiencing no health problems.

Another potential benefit to including DFM in the diet of neonates is to aid in the adaptation to solid food to further develop the rumen. In 1993, Nakanishi et al. (1993) suggested adding lactic acid bacteria to starter diets to affect ruminal function in young calves and the results seemed promising. Dairy calves supplemented with *L. acidophilus* tended to ruminate more than control animals; therefore, *L. acidophilus* may promote ruminal development. The majority of these studies did not report any change in animal performance, although some authors observed an increase in gain and attributed the results to improvement of intestinal conditions because of lower fecal scores in calves supplemented with DFM. Beeman (1985) discovered that calves treated with lactobacilli gained an average of 8.0 kg, while control calves only gained an average of 3.5 kg. In reference to the neonatal calf, performance is not nearly as important as improved health and reduction of diarrhea, and bacterial DFM may be able to achieve these goals.

Other research that has shown promise has been inclusion of allicin (thio-2-propene-1 sulinic acid S-allyl ester) a component of garlic (Donovan et al., 2002). The aforementioned authors fed milk replacers containing antibiotics or a blend of fructooligosaccharides, allicin and gut-active microbes from birth to 5 weeks of age. Results suggested that a the combination of compounds resulted in similar calf performance as milk replacers containing oxytetracycline and neomycin. Likewise, Heinrichs et al. (2003) reported that mannan oligosaccharide can replace antibiotics in milk replacer. Addition of mannan oligosaccharide also improved feed intake compared to antibiotic-fed calves, but this difference did not result in overall growth differences.

Morbidity and mortality may also be decreased with spray-dried bovine plasma. Fecal scores and scour days were improved with spray-dried bovine plasma and spray-dried porcine plasma

compared with calf milk replacer containing all milk ingredients (Quigley and Wolfe, 2003). Likewise, during periods when calves are most susceptible to enteric disease benefited from addition of spray-dried animal plasma or an additive containing spray-dried bovine serum and oligosaccharides (Quigley et al., 2002).

These special dietary considerations have the potential to make significant strides in reducing our losses associated with morbidity and mortality. However, economic analysis needs to be conducted for inclusion of these products under commercial situations.

Environment

Without a doubt, environment has a significant impact on performance and health of dairy calves. However, limited data are available evaluating environmental factors on performance. In addition to direct effects during the neonatal period (e.g. moisture loss in extreme heat at a time when calves may be dehydrated), fetal programming will have an impact on performance. Fetal growth restriction reduces calf survival, permanently stunts postnatal growth and feed efficiency, negatively affects meat quality and impairs long-term health (Wu et al., 2006). Such an impact of heat stress on fetal programming remains to be determined.

References

Abu-Tarboush, H. M., M. Y. Al-Saiady, and A. H. Keir El-Din. 1996. Evaluation of diet containing lactobacilli on performance, fecal coliform, and lactobacilli of young dairy calves. Anim. Feed Sci. Technol. 57:39–49

Bechman, T. J., J. V. Chambers, and M. D. Cunningham. 1977. Influence of *Lactobacillus acidophilus* on performance of young dairy calves. J. Dairy Sci. 60(Suppl 1):74.

Beeman, K. 1985. The effect of *Lactobacillus* spp. on convalescing calves. Agripractice 6:8–10.

Bruce, B. B., S. E. Gilliland, L. J. Bush, and T. E. Staley. 1979. Influence of feeding cells of *Lactobacillus acidophilus* on the fecal flora of young dairy calves. Okla. Agr. Exp. Stn. MP-104:207–209.

Coverdale, J. A., H. D. Tyler, J. D. Quigley, III, and J. A. Brumm. Effect of various levels of forage and form of diet on rumen development and growth in calves. J. Dairy Sci. 87:2554-2562.

Donovan, D. C., S. T. Franklin, C. C. L. Chase, and A. R. Hippen. 2002. Growth and health of Holstein calves fed milk replacers supplemented with antibiotics or enteroguard. J. Dairy Sci. 85:947-950.

Duff, G. C., and C. P. McMurphy. 2007. Feeding Holstein steers from start to finish. L C. Hollis and K. C. Olson, eds. Vet. Clin. Food Anim. Pract. 23:281-297.

Elam, N. A., J. F. Gleghorn, J. D. Rivera, M. L. Gaylean, P. J. Defoor, M. M. Brashears, and S. M. Younts-Dahl. 2003. Effects of live cultures of *Lactobacillus acidophilus* (strains NP45 and NP51) and *Propionibacterium freudenreichii* on performance, carcass, and intestinal characteristics, and *Escherichia coli* strain O157 shedding of finishing beef steers. J. Anim. Sci. 81: 2686-2698.

Faber, S. N., N. E. Faber, T. C. McCauley, and R. L. Ax. 2005. Case Study: Effects of colostrum ingestion on lactational performance. Prof. Anim. Sci. 420-425.

Fox, S. M. 1988. Probiotics intestinal inoculants for production animals. Vet. Med. 83:806–830.

Franklin, S. T., D. M. Amaral-Phillips, J. A. Jackson, and A. A. Campbell. 2003. Health and performance of Holstein calves that suckled or were hand-fed colostrum and were fed once of three physical forms of starter. J. Dairy Sci. 86:2145-2153.

Galyean, M. L., and G. C. Duff. 2002. Feeding growing-finishing beef cattle. Pages 361-288 in Livestock Feeds and Feeding (5th Ed.), R. O. Kellems and D. C. Church. Eds. Prentice-Hall, Upper Saddle River, NJ.

Gilliland, S. E., B. B. Bruce, L. J. Bush, and T. E. Staley. 1980. Comparison of two strains of *Lactobacillus acidophilus* as dietary adjuncts for young calves. J. Dairy Sci. 63:964–972.

Gooden, S. M., J. P. Fetrow, J. M. Feirtag, L. R. Green, and S. J. Wells. 2005. Economic analysis of feeding pasteurized nonsaleable milk versus conventional milk replacer to dairy calves. J. Am. Vet. Med. Assoc. 226:1547-1554.

Guthrie, M. J., M. L. Galyean, K. J. Malcolm-Callis, and G. C. Duff, 1996. Roughage source and level in beef cattle finishing diets. Prof. Anim. Sci. 12:192-198.

Heinrichs, A. J., C. M. Jones, and B. S. Heinrichs. 2003. Effects of mannan oligosaccharide or antibiotics in neonatal diets on health and growth of dairy calves. J. Dairy Sci. 86:4064-4069.

Hopkins, B. A., and J. D. Quigley, III. 1997. Effects of method of colostrum feeding and colostrum supplementation on concentrations of immunoglobulin G in the serum of neonatal calves. J. Dairy Sci. 80:979-983.

Kaske, M., A. Werner, H. J. Schuberth, J. Rehage, and W. Kehler. 2005. Colostrum management in calves: Effects of drenching vs. bottle feeding. J. Anim. Physiol. Anim. Nutr. (Berl). 89:151-157.

Khan, M. A., H. J. Lee, W. S. Lee, H. S. Kim, S. B. Kim, K. S. Ki, J. K. Ha, H. G. Lee, and Y. J. Choi. 2007. Pre- and postweaning performance of Holstein female calves fed milk through step-down and conventional methods.

Krehbiel, C. R., S. R. Rust, G. Zhang, and S. E. Gilliland. 2003. Bacterial direct-fed microbials in ruminant diets: Performance response and mode of action. J. Anim. Sci. 81(E. Suppl. 2):E120-E132.

Jones, C. M., R. E. James, J. D. Quigley, III, and M. L. McGilliard. 2004. Influence of pooled colostrum replacement on IgG and evaluation of animal plasma in milk replacer. 87:1806-1814.

Klobasa, F., M. C. Goel, and E. Werhahn. 1998. Comparison of freezing and lyophilizing for preservation of colostrum as a source of immunoglobulins for calves. J. Anim. Sci. 76:923-926.

Lesmeister, K. E., and A. J. Heinrichs. 2004. Effects of corn processing on growth characteristics, rumen development, and rumen parameters in neonatal dairy calves. J. Dairy Sci. 87:3439-3450.

Maas, J., and P. H. Robinson. 2007. Preparing Holstein steer calves for the feedlot. L. C. Hollis and K. C. Olson, Eds. Vet Clin. Food Anim. Pract. 23:269-279.

Maeng, W. J., C. W. Kim, and H. T. Shin. 1987. Effect of a lactic acid bacteria concentrate (*Streptococcus faecium* Cernelle 68) on growth rate and scouring prevention in dairy calves. J. Dairy Sci. 9:204–210.

Morrill, J. L., A. D. Dayton, and R. Mickelsen. 1977. Cultured milk and antibiotics for young calves. J. Dairy Sci. 60:1105–1109.

Murdock, F. R., and R. W. Wallenius. 1980. Fiber sources for complete calf starter rations. J. Dairy Sci. 63:1869-1873.

Nakanishi, Y., C. W. Arave, and P. H. Stewart. 1993. Effects of feeding Lactobacillus acidophilus yogurt on performance and behavior of dairy calves. J. Dairy Sci. 76(Suppl. 1):244.

Quigley, J. D., III. 1996. Influence of weaning method on growth, intake, and selected blood metabolites in Jersey calves. J. Dairy Sci. 79:2255-2260.

Quigley, J. D., III. 2002. Effects of spray-dried whole egg and biotin in calf milk replacer. 2002. J. Dairy Sci. 85:198-203.

Quigley, J. D., III, and T. M. Wolfe. 2003. Effects of spray-dried animal plasma in calf milk replacer on health and growth of dairy calves. J. Dairy Sci. 86:586-592.

Rauprich, A. B. E., H. M. Hammon, and J. W. Blum. 2000. Influence of feeding different amounts of first cololstrum on metabolic, endocrine, and health status and on growth performance in neonatal calves. J. Anim. Sci. 78:896-908.

Rivera, J. D., M. L. Galyean, and W. T. Nichols. 2005. Review: Dietary roughage concentration and health of newly-received cattle. Prof. Anim. Sci. 21:345-351.

Sandine, W. E. 1979. Roles of lactobacillus in the intestinal tract. J. Food Prot. 42:259–262.

Tannock, G. W. 1983. Effect of dietary and environmental stress on the gastrointestinal microbiota. Pages 517-539 in Human Intestinal Microflora in Health and Disease. D. Hentges, ed. Academic Press, New York.

Terui, H., J. L. Morrill, and J. J. Higgins. 1996. Evaluation of wheat gluten in milk replacers and calf starters. J. Dairy Sci. 79:1261-1266.

Touchette, K. J., M. L. O'Brien, and J. A. Coalson. 2003. Liquid egg as an alternative protein source in calf milk replacers. J. Dairy Sci. 86:2622-2628.

Tozer, P. R., and A. J. Heinrichs. 2001. What affects the costs of raising dairy heifers: A multiple-component analysis. J. Dairy Sci. 84:1836-1844.

USDA, APHIS, VS, NAHMS. 2002. Dairy 2002. Part 1: Reference of dairy health and management in the United States. Available at: http://www.aphis.usda.gov/vs/ceah/ncahs/nahms/dairy/dairy02/Dairy02Pt1.pdf. Accessed June 13, 2007.

Van Amburgh, M. 2003. Calf growth and development: new requirements and implications for future performance. Pages 1-13 in Proc. Southwest Nutrition and Management Conference. University of Arizona, Tucson.

Wu, G., F. W. Bazer, J. M. Wallace, and T. E. Spencer. 2006. BOARD-INVITED REVIEW: Intrauterine growth retardation: Implications for the animal sciences. J. Anim. Sci. 84:2316-2337.

Yoon, I. K., and M. D. Stern. 1995. Influence of direct-fed microbials on ruminal microbial fermentation and performance of ruminants: A review. Asian-Australian J. Anim. Sci. 8:533–555.