Impact of Precision Feeding Strategies on Whole Farm Nutrient Balance and Feeding Management

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ABSTRACT

Impact of precision feeding with feed management software was assessed for whole farm nutrient balance (**WFNB**) and feeding management from January through December 2006. Nine treatment and six control farms were selected in four regions of the Chesapeake Bay Watershed of Virginia. Herd sizes averaged 271 and 390 lactating cows for treatment and control farms while milk yield averaged 30 and 27 kg/d per lactating cow, respectively. Crop hectares grown averaged 309 and 310 ha for treatment and control farms, respectively. Treatment farms purchased and installed feed management software (TMR Tracker, Digi-Star LLC, Fort Atkinson WI) between May and October 2006 and received more frequent feed analysis and feedback. Data were collected for calendar year 2005 and 2006 to compute WFNB using software from the University of Nebraska. On treatment farms, up to five feed samples were obtained monthly from individual feedstuffs and each total mixed ration (**TMR**) fed to lactating cows. Control farms submitted TMR samples every 2 mo. Standard wet chemistry analysis of samples was performed. Data stored in the software were collected monthly from each treatment farm concurrent with feed sampling. Producers from each treatment farm participated in a 24-question personal interview in December 2006 addressing installation, operation, and satisfaction with the software. Daily feeding deviation of all ingredients across treatment farms averaged 173 ± 163 kg/d. This corresponded to average daily overfeeding of CP and P of 17.6 ± 17 and 0.4 ± 0.3 kg/d, respectively. Feeding deviation did not differ between feeders. Milk production was negatively associated with kg total deviation and kg CP deviation, but positively related to P deviation. Whole farm nutrient balance did not differ between treatment and control farms. All producers indicated TMR Tracker met expectations. Change made to the feeding program due to TMR Tracker was correlated (r=0.80) with perceived improvement in ration consistency. In conclusion, producers perceived feed management software as beneficial, but WFNB was not reduced after 3 to 6 mo of using feed management software; however, the large variation in daily over or under feeding indicates potential for future reductions in WFNB through reduced feeding variability.

Keywords: (whole farm nutrient balance, precision feeding, phosphorus, nitrogen)

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Introduction

Centuries of deforestation in the Chesapeake Bay Watershed (**CBW**) for commercial, private, and agricultural development have led to deterioration of water quality in the largest and most productive estuary in the United States. Nutrient pollution is a major contributor to this problem, primarily in the form of nitrogen (**N**) and phosphorus (**P**) contamination. According to information released by the United States Geological Service (USGS, 1999), 95 % of the annual N and 87 % of the annual P entering the Cheseapeake Bay (**CB**) from 1990 to 1998 originated from the Susquehanna, Potomac, and James Rivers. Such large nutrient loadings to the CB have been shown to negatively impact both the environment and human health.

Concern over the impact of eutrophication of the CB led to the signing of the 1987 Chesapeake Bay agreement with the goal of reducing N and P inflows to the CB annually by 40 % (Chesapeake Executive Council., 1987). Although progress was made toward accomplishment of this goal, the reductions were not achieved by 2000. In 2000, a new agreement was signed reaffirming the commitment to 40 % reductions in nutrient loadings to the CB with the additional goal of removing the CB from the list of impaired waterbodies under the Clean Water Act by 2010 (CBP, 1999).

Agriculture is the single largest source of nutrients to the CB, contributing 29 and 49 % of total N and P loads (Boesch et al., 2001). Consequently, agriculture is subject to environmental regulations targeted to reduce nutrient losses to water sources. A dairy farm is required by the Code of Virginia to obtain Virginia Pollution Abatement (**VPA**) permits if the operation has in excess of 300 animal units (DEQ, 2007). Such regulations dictate the quantity of manure and fertilizer that may be applied to each plot of land. Manure containing excess quantities of N and P must be applied at reduced rates, potentially resulting in more manure produced than can legally be applied to the land. Producers strive to maximize the efficiency of nutrient use such that the concentration of N and P in manure does not preclude application to the land is purchased feed. A New York study found 61 % of N and 81 % of P imports were attributable to purchased feed (Klausner et al., 1998). Surveys have documented routine inclusion of supplemental P and overfeeding of CP in dairy rations in the mid-Atlantic and Southern United States (Bertrand et al., 1999;Jonker, 2002;Dou, 2003). Reductions in CP content and removal of supplemental P alone have been shown to increase efficiencies of N and P utilization (Cerosaletti et al., 2004). It has been documented that long term P balance is obtainable if the use of on farm forages is optimized (Rotz, 2002;Cerosaletti et al., 2004;Tylutki, 2004). Accomplishment of net nutrient balance on the farm necessitates a precise feeding program that reduces the amount of overfeeding of CP and P and optimizes use of homegrown forages.

Objectives

- Ascertain the impact of precision feeding using feed management software and monthly feed testing on whole farm nutrient balance (**WFNB**).
- Document current levels of accuracy and precision of feeding on Virginia dairy farms and the influence on milk production, body condition score, and income over feed cost (**IOFC)**.
- Determine normal variation in total mixed ration (**TMR**) and individual feedstuffs across a 12 mo period.
- Assess producer perceptions and satisfaction with feed management software.
- Develop dynamic tools to allow producers use to evaluate the potential financial impact of increased feeding accuracy on farm profitability.

Chapter 1: Literature Review

Impacts of excessive nutrient loading

Eutrophication is one of the leading environmental concerns posed by increased nutrient additions to the CB. Just as fertilizer application enhances crop growth, additional nutrients in the form of N and P lead to a rise in phytoplankton growth in estuaries. However, unlike accelerated crop growth, an overabundance of phytoplankton (also known as algal blooms) is detrimental to the overall health of the CB. Upon death algal blooms sink to deeper waters where decomposition occurs (Sharpley, 2000;Boesch et al., 2001). The degradation process depletes available dissolved oxygen in these deeper waters. The ensuing hypoxic or anoxic conditions jeopardize health of animal populations in this region such as clams and worms. Cooler water temperatures optimal for some fish and shellfish are also destroyed as breakdown of the algal blooms progresses (Sharpley, 2000). It has been hypothesized that much of the decline in prevalence of bottom dwelling or bottom feeding fish species and oysters in the Chesapeake Bay Watershed (**CBW**) can be linked to hypoxic conditions generated from increased eutrophication (Sharpley, 2000;Boesch et al., 2001). Eutrophication of the CB has been occurring for 200 yr, but rates increased substantially in the period from the mid 1950s to mid 1980s. This was a period in history marked by unprecedented use of inorganic fertilizers (Cornwell, 1996) and a near doubling of inhabitants in the CBW (Davidson, 1997).

Algal blooms are not only harmful to the CB during decay of dead algae, but also during growth periods. Survival of submersed aquatic vegetation (**SAV**) depends on adequate light penetrating the water's surface. Overgrowth of algal blooms absorbs much of this vital light before it reaches the leaves of SAV. Algae also reduce SAV light absorption by attaching to the leaves of plants, reducing the surface area for light absorption (Sharpley, 2000). As a result, populations of SAV have dwindled as nutrient concentrations in the CB rose beginning in the 1960s and 1970s. As populations of SAV decrease, habitats and spawning grounds are lost for other CB inhabitants. Loss of SAV attributed to eutrophication removes a valuable habitat for juvenile fish and crustaceans, most notably the renowned blue crab of the CBW (Boesch et al., 2001). The loss of SAV also removes an important mechanism for binding sediment, reducing turbulence from waves near the shore, and a storage source for nutrients (Sharpley, 2000).

Nutrient pollution not only damages water quality, but may also affect human health. Reduced water quality creates growth conditions favorable to harmful microorganisms such as *Pfiesteria piscicida.* In the summer of 1997, an outbreak of *P. piscicida* occurred along the eastern shore of Maryland (Sharpley, 2000; Glibert et al., 2001). One year later, scientists at the University of Maryland and Johns Hopkins University found a possible link between *P. piscicida* exposure and development of difficulties in learning and concentrating (Foundation, 2003). Scientists in this study also found neuropsychological symptoms such as forgetfulness, headaches, skin lesions, and a burning sensation resulted after exposure to water contaminated with *P. piscicida* (Boesch et al., 2001). Glibert et al. (2001) suggested a possible competitive advantage of harmful phytoplankton during periods of high organic nutrient concentrations. High nitrate concentrations in water also can lead to a condition known as methemoglobinemia or “blue baby” syndrome. Consumption of large amounts of nitrate by infants leads to the conversion of nitrate to nitrite, which consequently binds oxyhemoglobin to form methemoglobin. Methemoglobin is incapable of transporting oxygen, leading to oxygen deprivation and development of a blue coloration of mucous membranes and potential respiratory and digestive complications.

Environmental regulations

Growing concern over the health of the CB culminated in the 1978 Chesapeake Bay Study overseen by the Environmental Protection Agency (**EPA**). Five years later, Virginia, Maryland, Pennsylvania, the District of Columbia, and the federal government endorsed the 1983 signing of the Chesapeake Bay Agreement. A committee report in 1986 released findings targeting both N and P removal as paramount to improving water quality in the CB. Signatories of the 1983 agreement renewed their commitment to improving CB water quality with the 1987 Chesapeake Bay Agreement (Chesapeake Executive Council., 1987), calling for “a basin wide strategy to equitably achieve by the year 2000 at least a 40% reduction of N and P entering the main stem of the Chesapeake Bay.” Modeling available at the time in conjunction with subjective evaluation suggested that a 40 % reduction was necessary to return the bay to 1950s condition. This targeted reduction encompassed only controllable loads, not accounting for atmospheric deposition, contributions from non-member states, or from background imports from forested watersheds (Boesch et al., 2001). Total N and P reductions to the CB from this commitment would therefore equate to approximately 24 and 35 %, respectively (Boesch et al., 2001).

Annual meetings of the Chesapeake Bay Executive Committee, comprised of key individuals from each of the signatory groups, resulted in 24 amendments and agreements prior to 2000 designed to assist in accomplishing the goals of the 1987 agreement (Boesch et al., 2001). In 2000, a new agreement was signed reaffirming the commitment to 40 % reductions in nutrient loadings to the CB with the additional goal of removing the CB from the list of impaired waterbodies under the Clean Water Act by 2010 (CBP, 1999). Total maximum daily loads (**TMDL**) were to be calculated and implemented by each state as part of this agreement. Accomplishing water quality improvements sufficient to remove the CB from the impaired waterbodies list by 2010 will likely require nutrient reductions in excess of the 40% goal for some tributaries (Boesch et al., 2001).

Fallout from the 1987 Chesapeake Bay Agreement has shaped the course of environmental policies at both state and national level for the last 20 years. Policies of the USDA Natural Resources Conservation Service (**NRCS**) and state conservation agencies have been directed towards practices limiting nutrient and sediment losses from agricultural land (Boesch et al., 2001). Conservation tillage practices, fencing for streambank protection, grassed waterways, and construction of animal waste storage systems have all been emphasized for reducing soil erosion. Both state and federal agencies have developed programs designed to motivate agricultural producers to implement these practices. The federal environmental quality improvement program (**EQIP**) is one such program. EQIP provides "incentive payments and cost-shares to implement conservation practices" such as those previously mentioned (Service, 2007). State best management practices (**BMP**) were developed to provide cost share opportunities for agriculture producers who utilized techniques or structures aimed to prevent soil erosion, reduce unnecessary nutrient application, and control nutrient movement (Sharpley, 2000;Boesch et al., 2001).

Environmental regulations evolving from efforts to restore the CB to a more pristine state have caused major changes in the way farms operate in the CBW. Nutrient management plans (**NMP**) have been recommended or required for many agricultural producers to aid in achieving farm nutrient balance. According to the Virginia Department of Conservation and Recreation (**DCR**), a NMP is a "written site-specific plan which identifies how the major plant nutrients (nitrogen, phosphorus, and potassium) are to be annually managed for expected crop production and for the protection of water quality (Messick, 2004)." NRCS Standards dictate all cost share programs requiring NMP be developed on both N and P basis (eFOTG, 2001). Many BMP also require the development of NMP prior to receipt of cost share funds. Department of Conservation and Recreation currently requires NMP developed by certified nutrient management planners per NRCS Standards 590 Nutrient Management (eFOTG, 2001) for the following BMP: legume cover crop, animal waste control facilities, loafing lot management system, composting facilities, three-year small grain cover crop practice, sidedress application of N on corn, organic nutrient application to corn, late winter split application of N to small grains, and continuous no-till system (DCR, 2006). The Code of Virginia was modified in 1994 to require all operations with more than 300 animal units obtain Virginia Pollution Abatement (**VPA**) permits (DEQ, 2007). Thus all dairies with 200 or more adult animals are required to obtain VPA permits issued by the Department of Environmental Quality (**DEQ**), complete with whole farm NMP.

Nutrient management plans have been touted as a method to allocate and track nutrients more efficiently on agricultural lands. Originally, plans were based strictly on the N needs of the crops being produced, leading to over-application of P in almost all situations. However, following the 1997 *P. piscicida* outbreak (Sharpley, 2000) in the Pocomoke River, a commission established by Maryland's governor recommended further reducing nutrient loads to prevent future toxic outbreaks. Maryland heeded the suggestions of the commission, passing the first mandatory nutrient management law in 1998 with the Maryland Water Quality Improvement Act (Boesch et al., 2001). The act called for development of N and P based NMP for most farms by 2005. In 1999, Virginia and Delaware passed similar legislation for P based NMP. The Virginia law called for all NMP in use by December 31, 2006 to consider both N and P (DEQ, 2007).

Agricultural nutrient contributions

Annual non-point source (**NPS**) contributions account for approximately 60% and 58% of total N and P inputs to the CB, respectively (Sharpley, 2000). Agriculture has been identified as one of many sources of NPS pollution contributing to the demise of the CB watershed. Reportedly, 80% of NPS N and 50% of NPS P is attributable to agricultural production (Sharpley, 2000) and 39 and 49% of total N and P loads can be traced to agriculture (Boesch et al., 2001). This makes agriculture the single largest source of nutrients to the CB (Boesch et al., 2001). In a survey conducted by Smith and Alexander which was reported by Sharpley (2000), it was reported that agriculture contributes 16% of total N and 25% of total P exported from the Mid-Atlantic region annually. The Virginia Secretary of Natural Resources released a report in January 2002 indicating NPS nutrient loads for 2000 showed a 6% reduction in P and 7% reduction in N loading compared to 1985 levels (Commission, 2003;VGA., 2003).

Much of the agricultural N and P is derived from land applied manure used as a fertilizer for crop fields. Unfortunately, concentrations of P in manure are generally in excess of crop needs leading to accumulation in the soil. In Virginia, 58% of all soil samples analyzed contained levels of P in excess of agricultural requirements (Sharpley, 2000). The instability of N makes it susceptible to losses through volatilization, leaching, and denitrification (Hutson et al., 1998) . A case study of two New York commercial dairies found N losses from manure to be 16 and 19% of excreted manure (Hutson et al, 1998) .

Fertilizer is another significant source of nutrients on the farm that contributes to NPS pollution. The same case study of two New York dairy farms attributed 19 and 22% of total imported N and 19 and 44% of total P imports to purchased fertilizer (Klausner et al., 1998). The first limiting nutrient for crop production is typically N. As a result, available manure is spread to meet as much of the N requirement as possible and supplemental N is applied in the form of commercial fertilizer until crop N needs are met. Water quality is once again threatened by the instability of N applied as fertilizer.

Conservation nutrient management

Two basic mechanisms exist for reducing nutrient flows from the land to water: transport management or source risk management. Research has shown that transport management is an ineffective method for reducing N contamination of water (Sharpley, 2000). Unlike some nutrients, N can be readily transported via multiple routes. Efforts to reduce transport by runoff, for example, will result in higher N concentrations in the soil. As soil N increases, leaching will accelerate removal of N. The end result is the same quantity of N entering the water source, but by a different method. However, transport management is more effective for P due to greater stability of P in the soil. Runoff and leaching of P are the greatest threat shortly after application. Soil microorganisms begin the process of mineralization of organic P shortly after application (Sharpley, 2000). Physical and chemical processes subsequently bind P, making loss of P difficult except by erosion. Erosion control practices such as conservation tillage have greater application for reducing P losses than N.

Source risk management focuses on considering form, rate, timing, and method of application to reduce nutrient losses. It has the most impact on lowering N losses from the farm, but also has application for soils saturated with P. Evaluation of source risk can lead to selection of different cropping strategies that minimize opportunities for volatilization, leaching, or runoff of N. Different crop varieties or rotations may be implemented that maximize N captured in crops. Manure application may also be altered to reduce surface concentrations of N and P. For instance, injection of manure as opposed to surface application would prevent N and P losses from runoff shortly after application.

For years the primary focus of pollution reduction revolved around N, in large part due to the belief that reduction of NPS P loss required only conservation practices to reduce soil erosion. Most P is transported bound to sediment and the runoff potential for P after it is bound in the soil declines substantially. However, recent research has shown that P runoff does occur if P accumulates to the point of saturation in the soil. Furthermore, it has been found that as the water in the CB warms, bound P is released from the sediment on the bottom. Phytoplankton then use not only the N, but the newly released P to support additional growth of algal blooms. It has been found that phytoplankton growth rates are limited by dissolved inorganic P as the water warms in spring, while dissolved inorganic N is growth limiting during the peak growth of summer (Boesch et al., 2001). Phosphorus can therefore further exacerbate the poor health of the already stressed CB. This revelation led to a paradigm shift calling for more vigorous efforts to reduce P loading to CB tributaries.

Dietary nutrient management impacts on whole farm nutrient balance

Nutrient management plans and BMP are one approach to reducing nutrient pollution of water; another effective option appears to be dietary manipulation to improve efficiency of N and P use. A study on four Virginia livestock farms, two of which were dairies, examined the impact of NMPs on reducing nutrient losses (VanDyke et al., 1999). Mineral N was reduced on each of the dairies by 19% and 22% following implementation of a NMP whereas P losses declined by 29%. Only one of the four farms achieved the desired 40% reduction in nutrient losses. The inability of NMP to achieve the desired 40% reduction necessitates improving nutrient efficiency to accomplish this goal.

A case study of a beef feedlot in Nebraska compared changes in farm nutrient balance from four different nutrient management strategies, two mandatory and two voluntary (Koelsch, 2005). The greatest source of P imports was determined to be purchased feed (46,300 kg/yr) while fertilizer accounted for only 2400 kg/yr. Simlarly, a New York study of dairy farms by Klausner et al. (1998) indicated P imports exceeded exports by 59%, with 81% of P imports derived through purchased feed. Implementing NMP in the Nebraska study (Koelsch, 2005) eliminated the need for fertilizer imports; however, utilizing N-based NMP 25% of the manure could not be spread whereas under a P-based NMP 90% remained unallocated. The other mandatory strategy involved a BMP designating a buffer zone from the edges of water sources where manure could not be applied. The end result was an increase in imported commercial P fertilizer, reduction in the land base of 12 ha for manure application, and inconvenience for the farmer. The two voluntary strategies reduced overall farm nutrient imbalance more substantially. Export of manure reduced excess P 17,800 kg/yr. Reduction of by-product feeds in the rations produced the most noteworthy effects; whole farm P balance declined from 37,900 kg/yr to 16,500 kg/yr excess P.

A study of 41 dairies in Utah and Idaho revealed similar conclusions for N reduction strategies (Spears, 2003). Herd N utilization efficiency, the efficiency with which cattle convert N from protein in the ration into milk or meat products, was responsible for 54.2% of the variation observed in whole farm N balance. The implication is that over half of the variation in nutrients remaining on the farm can be attributed to the feeding program. Nitrogen utilization efficiency ranged from 0.126 to 0.362 with an average of 0.213, indicating 21.3% of the N consumed by cattle was converted to milk or meat. Whole farm N balance for a New York dairy farm with 320 lactating cows and 604 acres of crop land revealed N imports exceeded exports by 72%, 61% arriving through feed imports (Klausner et al., 1998). Improvements in efficiency of N utilization through improved ration formulation have the potential to reduce N excesses from the cow and the farm as a whole. Klausner et al. (1998) found a 34% decrease in total N excretion and 13% increase in milk production from 2 percentage reduction in ration CP content. Modifying rations to lower protein fractions and improved grouping strategies to allow for specialized feeding can result in more efficient use of N in the ration.

Studies have been conducted documenting current P feeding rates in the mid-Atlantic and southern United States (Bertrand et al., 1999;Dou, 2003). Over supplementation was reported on 19 of 27 (70%) of South Carolina dairies surveyed in 1999 (Bertrand et al., 1999). Dietary P concentrations were on average 0.48% of diet DM, or 21.2% above NRC recommended rates. Participants in a multi-state study encompassing Maryland, Virginia, Pennsylvania, New York, and Delaware reported dietary P concentrations of 0.44%, 34% higher than NRC recommendations for average milk production of 27.9 kg milk/d (Dou, 2003). These excessive feeding levels create an opportunity to reduce P concentrations in manure through changes in dietary practices. For each additional unit of P fed above requirements, 1.89 g/kg P is excreted in feces, with 1.00 g/kg of water soluble P (Bertrand et al., 1999;Dou, 2003). Water soluble P is most susceptible to runoff or leaching after field application (Dou, 2003); therefore, a reduction in the water soluble fraction is critical to reducing P loading to water sources.

The simplest and most effective way to accomplish significant P reductions is through dietary changes. Previous studies have found diet formulation to be a key area for a reduction in excess dietary P. Cerosaletti et al. (2004) conducted a 28 month study on four dairies in the Cannonsville Reservoir Basin of New York. Two herds served as controls while dietary changes were implemented in the remaining dairies to decrease P in purchased feed. Dietary manipulations reduced predicted P intakes and excretion on average 25 and 33%, respectively, while N imports declined 15%. Whole farm nutrient balance was also calculated pre and post implementation. Following the dietary changes, 49% less P remained on the farm than during the initial assessment.

Improvements in nutrient efficiency are also the most effective means of reducing N losses to water. It has been shown that a 50% increase in herd N utilization efficiency has the potential to reduce N losses to water by 40% (Kohn et al., 1997). Meanwhile, improving efficiency of manure utilization by 100% produces only modest decreases of 10 to 14%. Opportunity exists for improvements in nutrient efficiency via a reduction in N overfeeding. Seventy-one percent of surveyed farmers report overfeeding protein an average of 61 g/d, an 11% excess on a N basis (Jonker, 2002). Each additional g of N in the diet produces on average a decline of 0.05% in N utilization efficiency with no benefit in fat corrected milk production (Jonker, 2002). A decrease in over supplementation of N could improve herd N utilization efficiency from the current range of 24.5 to 32.3%(Jonker, 2002).

Dispelling phosphorus feeding myths

The remaining challenge is to convince producers and nutritional advisors that high P feeding rates are unwarranted. Years of indoctrination have convinced many farmers, nutritionists, and veterinarians that poor reproductive performance, low milk production, and other health aliments can be attributed to a lack of P in the ration. Long term lactation studies have shown that symptoms of P deficiency do not begin to manifest until dietary P concentrations reach 0.31% or less of diet DM (Lopez et al., 2004b). Valk and Sebek (1999) performed a 2-year study of cows on three different dietary P treatments: 100, 80, and 67% of the Dutch P requirement. Results showed that cows did not exhibit reduced DMI, production, or bodyweight for any treatment during the first lactation. Even after the first lactation, only the group receiving 67% of their P requirement showed deficiency signs beginning during the first dry period, continuing through the second lactation into the second dry period (Valk and Sebek, 1999).

Current NRC recommendations suggest lactating dairy cows require between 0.32 and 0.38% P depending on stage of lactation (Lopez et al., 2004b). At these feeding rates, a safety margin of approximately 10 to 20% is included in the diet making deficiency unlikely. In fact, diets as low as 0.25 to 0.37% P have been successfully implemented over a three year time span with no negative effects observed (Tylutki, 2004). No correlations have been found between P feeding rates in excess of NRC requirements and milk production (Bertrand et al., 1999;Dou, 2003;Lopez et al., 2004b). Other studies have suggested alterations in milk composition (particularly protein percent) associated with reduced P concentrations, reportedly due to the phosphate linkages in casein molecules. However, Lopez et al. (2004b) found no difference in milk composition for cows receiving 0.37 or 0.57% P of diet DM. In the same study, body condition of cows did not differ between treatments.

The proposed solution for many reproductive problems in dairy cattle over the years has long been to increase dietary P. A recent study at the University of Wisconsin indicates this may be a misconception (Lopez et al., 2004a). At parturition 134 and 133 Holstein cows were assigned to dietary treatments of

0.37 and 0.57% P diets, respectively. Days to first increase in progesterone, days to first estrus, days to first service, and first service conception rate were not different between treatments. Conception rate at 30 d, days open, pregnancies lost 30 to 60 d, multiple ovulation rate, and incidence of anovulatory condition did not differ between dietary treatments. Wu et al. (2000) likewise observed no reproductive complications from feeding diets as low as 0.31% P. Diets containing 0.31 (n = 8), 0.40 (n=9), and 0.49 (n=9) percent P were fed to lactating Holstein cows over an entire lactation. Reproductive performance was not found to be related to dietary treatment. Cows receiving the two higher P diets excreted more P in urine and feces whereas those on the low P diet conserved more P from the diet (Wu et al., 2000). Additionally, Valk and Sebek (1999) did not observe negative reproductive effects from P feeding rates as low as 67% of required. In light of these findings, it is difficult to justify P feeding rates in excess of requirements, particularly if it strains compliance with environmental regulations.

Dietary modifications to improve nutrient balance

Properly formulated rations that meet the demands of high producing dairy cattle without overfeeding protein and P are the first step in reducing excess N and P excretion. The simplest method for reducing dietary P begins with removal of supplemental mineral P. Sixty percent of farms report inclusion of supplemental P in their rations while another 26% are uncertain (Dou, 2003). Unsupplemented diets typically contain between 0.33 to 0.40% P (Wu et al., 2000), meeting the recommended 0.37% recommended by the NRC. Removal of mineral P from the ration of a large 800 cow dairy in New York was estimated to reduce P imports 6300 kg/yr (Rotz, 2002). Similarly, a case study of two New York dairies revealed that elimination of mineral P alone was sufficient to reduce P overfeeding from 153 to 111% of requirement (Cerosaletti et al., 2004). This 25% reduction in overfeeding resulted in 33% decline in fecal P concentrations. Mineral P supplementation is unnecessary in most cases and removal not only lowers P losses to the environment, but also lowers feed costs.

Incorporation of additional homegrown forages into the diet also aids in reducing P imports to the farm. Optimizing use of homegrown forages increases recycling of nutrients within the farming system and requires fewer feed inputs from off the farm. It has been documented that long term P balance is obtainable if the use of on farm forages is optimized (Rotz, 2002;Cerosaletti et al., 2004;Tylutki, 2004). High inclusion rates of corn silage offer the greatest potential for P reductions (Cerosaletti et al., 2004). Corn silage is typically the forage with the lowest P content, with P content of other forages being highly variable. This variability necessitates frequent forage sampling for accurate ration balancing to be plausible (Cerosaletti et al., 2004;Tylutki, 2004). Greater use of homegrown forages has improved farm nutrient balance by decreasing N loading rate 17% and a 28% annual reduction in P accumulation/ha (Tylutki, 2004).

As forage content of the ration increases, removal of some byproduct feeds may be possible. Many byproduct feeds, particularly those high in CP (such as soybean meal, wheat middlings, and fishmeal) and distillers by products (corn gluten and distillers grains), have very high P levels (Dou, 2003;Tylutki, 2004;Koelsch, 2005). High forage rations consequently have a two-fold effect of reducing P losses through increased P recycling and a reduction in P imports of byproduct feeds. Removal of 3150 Mg corn gluten from a beef feedlot ration generated an improvement in whole farm P balance of 21,400 kg/yr (Koelsch, 2005). Limitations on the quantity of byproduct feeds that can be removed are dependent on economics. Byproducts typically are offered at attractive prices which may inhibit their elimination. Producers must determine if it is economically viable to eliminate these feeds from their program for the gains in nutrient balance.

Economics

Reductions in manure nutrient applications to comply with P-based NMP come at a cost to dairy producers. A 1995 simulation study (Parsons et al.) of representative 60, 100, and 150 cow dairy farms in Rockingham County, Virginia found declines in net worth and net cash income from P-based manure application. Impacts were greatest on 100 and 150-cow farms, with net worth declining $5,640 (1.3%) and $14,230 respectively. Consequently, cash for family living expenses fell $5,290 for 100-cow dairies and $5,790 for 150 cows, both below minimum family living expenses (Parsons et al., 1995). Cash for family living expenses for the 60-cow dairy also declined 16.9% under P limited application, but was still adequate to meet minimum family living expenses (Parsons et al., 1995). This anomaly can be attributed to the very low family living expenses reported for 60-cow dairies, most of which are operated by members of the Mennonite community.

Another study of four Virginia livestock farms, including two dairy farms, found increases in net farm income from implementation of NMP (VanDyke et al., 1999). This positive net income was derived from crediting of animal manure for nutrient content and subsequent reductions in commercial fertilizer purchases. However, it is important to note that this study examined N-based NMP. Application rates are higher when applied to meet crop N requirements than P requirements. Under P-based NMP, it is likely most of the farms examined in this study would have to limit manure application. Costs incurred from compliance with P-based NMP can include manure export costs and additional commercial fertilizer purchases to meet crop N requirements (Sink et al., 2000). These additional expenses could be sufficient to cause a decline in net farm income. Additional studies are needed to examine the impact of P-based NMP on livestock farm economics.

Preventing potential negative economic impacts from mandatory P-based NMP requires a reduction in P content of manure. Manure P can be limited by precise feeding of P to meet true requirements. Initial overfeeding can be partially corrected by removal of supplemental inorganic P from the ration. Sink et al. (2000) calculated increased feed costs compared to feeding for the NRC requirement ranging from $1460 to $2800 for farms feeding P at 0.55 to 0.65% of dietary DM, respectively. A two-fold effect on farm net income results from a reduction in overfeeding P. First, feed cost declines as inorganic P is removed from the ration. Secondly, as manure P content declines, the application rate increases and the need for commercial N fertilizer is reduced (Sink et al, 2000). Ration reformulation utilizing more homegrown feeds was supported 30% higher production and increase net farm income by $40,200 on a central New York dairy farm with 320 lactating cows and 604 acres of cropland (Klausner et al., 1998). Precision feeding of P is one mechanism to maintain an economically viable dairy farm in the wake of P-based NMP.

Precision feeding

Dietary modifications that strictly adhere to the guidelines for protein and P feeding require commitment to a higher level of management often referred to as precision farming. Precision farming involves whole farm management or “the use of precision in feeding management, crop management, animal management, and business management” (Tylutki, 2004). Most important to improving herd nutrient efficiency is the concept of precision feeding. Tylutki (2004) describes precision feeding as follows: using management practices that ensure the diet consumed by the cow is as close as possible to the formulated diet. This concept centers on management beginning with loading and mixing accuracy. Dou et al. (2003) analyzed feed samples from a multi-state region for comparison to the formulated ration. Their findings indicate 67% of samples deviated less than 10% from the formulation for P. The average deviation was 0.086 g P/kg DM above the amount specified in the ration. However, 16% of samples deviated by more than 15%. Once again, an opportunity for improvement exists even if it is a slight gain. Furthermore, production and cow health benefit from greater ration consistency. Tylutki et al. (2004) noted a 2 kg/cow range in variation of daily production during a period of inaccurate diet formulation as compared to a normal range of less than 0.5 kg/cow. Implications that improved accuracy not only benefit producers in terms of obtaining farm nutrient balance, but also in sustaining stable milk production should be sufficient to open the door to discussions about improving daily feeding accuracy across operators.

Crucial to the concept of precision feeding is improving knowledge of the nutritional value of feedstuffs. Variances in nutrient content of feedstuffs are significant. Northeast Forage Testing Laboratory reported a 16% CV for CP of corn silage samples submitted for analysis in their lab (Sniffen et al., 1993). This same lab reported that CV for CP of all forages ranged from 15 to 30% (Kertz, 1998). Contrary to popular belief, grains also vary in their nutrient content. Kertz (1998) observed 5.9 and 8.1% CV for protein in corn and wheat respectively. Byproduct feeds are also subject to much nutrient variability, with protein CV of 5.9% for corn gluten, 4.5 for dried distillers grains, 2.1 for rice bran, and 1.9 for soy hulls (Kertz, 1998).

St. Pierre and Harvey (1986) found increases in net farm income of $0.27/cow/d from instituting a feed analysis program to reduce the variance in feed ingredients. Most producers recognize the importance of routine nutrient analysis for forages, but less so for grains and byproduct feeds. Northeast Forage Testing Laboratory records for a one year period show submission of 1378 high moisture ear corn and 2201 high moisture shell corn samples for analysis, but only 205 samples for wheat, barley, oats, and sorghum combined (Kertz, 1998). Two possible explanations exist for this discrepancy in sample submittal: a lack of appreciation for the variability of grains and the quick turnover time of grains. In some situations, a feedstuff can be completely used before analysis results are available.

Variability of byproducts is impacted by multiple factors including plant genetics, growing conditions, and manufacturing techniques (Weiss, 2004). A California study evaluated the variability of 9 byproduct feeds relative to NRC reported values (Arosemena et al., 1995). Brewers grain exhibited minor deviation of 0.54% from NRC CP values, with NRC reporting 25.40% CP while CP averaged 25.94 ± 1.45% in this study. Variability in brewers grain CP content was small, ranging from 23.82 to 26.92. Mean brewers grain P concentration was 0.44 ± 0.17%. On the other hand, variability of dried distillers grain was substantial, most of which was attributed to type of grain used at each source. Mean CP of dried distillers grains was 24.72 ± 8.84%, 1.72% higher than NRC standards. Likewise, a large discrepancy (0.47 percentage units) was observed between analyzed P content (0.90 ± 0.09%) and NRC values. Soy hull analyses did not deviate substantially from NRC values for CP or P (+0.88 and -0.08% relative to NRC, respectively). Soy hulls varied 12.98 ± 2.09% CP and 0.13 ± 0.05% P.

Arosemena et al. (1995) also examined the impact of inclusion rate of byproducts on ration variability. As the proportion of byproducts in the ration increased from 27 to 50% (including byproducts in concentrate mixtures), nutrient content became more variable with CP ranging from 14.3 to 15.2% (Arosemena et al., 1995). These results suggest the necessity of accurate nutrient analyses for byproducts increases as the inclusion rate increases in the ration. Weiss (2004) recommends development of a database for analyses for each ingredient that is updated upon arrival of a new analysis and use of the mean from this database in formulating rations. Additionally, adjustment of the mean for the standard deviation can reduce the impact of nutrient variability on total TMR variation (Weiss, 2004). For instance, if the mean CP percent for a given feedstuff is adjusted by subtracting 0.5*SD, only 7% of loads received for that ingredient would have a CP value lower than this adjusted mean. Without adjusting the mean, 16% of loads would have CP percentages lower than the mean and TMR would have less CP than formulated. While using this technique reduces the incidence of underfeeding protein, it does not safeguard against overfeeding. However, in most circumstances instead of using the mean nutrient values for a feed, the new analysis is assumed more correct and used alone. This is problematic in that changes could be due to random error instead of real changes in nutrient content (Weiss, 2004). It is recommended that moderate and highly variable byproducts be included in rations with more total ingredients and at reduced rates to limit impact on total nutrient variability (Weiss, 2004).

Process Control

A critical component of successful precision farming techniques is the institution of process control. Currently, there are few, if any, standard operating procedures (**SOP**) or control points for daily procedures on dairy farms. The lack of unambiguous standards or protocols for identifying problem areas makes it difficult for farms to institute precision farming techniques. One potential solution lies in the implementation of process control procedures that follow the structure of the international standards of the ISO 9000 specifications. ISO 9000 is designed to establish a global strategy for improved product quality by implementing measures to limit variation, recording of these measures, and training procedures to ensure universal adoption of these practices (Hoyle, 2001).

The basic premise behind ISO 9000 as described by Hoyle (2001) is that an organization "determines what it needs to do to satisfy its customers, establish a system to accomplish its objectives and measure, review and continually improve its performance." In terms of more precise feeding management, this translates into establishing broad objectives for desired precision (both in feed mixing and reduced variation in feedstuffs), developing written protocols to achieve these objectives, and routinely reviewing compliance with these protocols. Monitoring progress toward these objectives requires collection of appropriate information to gauge success. Feed management software can be an excellent tool for assessing mixing and delivery accuracy while routine feed analysis provides an indication of variability in the nutrient content of feeds used.

Successful implementation of a process control program also requires identification of areas of concern, places where errors typically occur. Hazard Analysis and Critical Control Points (HACCP) procedures refer to these locations as critical control points (**CCP**) and use flow diagrams to document the sequence of events leading to these control points. An example flow chart for the production of meal products from oilseeds is provided in Figure 1. Correct identification of these CCP's allows more effort to be focused on processes with the greatest potential impact on achieving the overall objective. Acceptable ranges can be established for CCP's, with protocols established for actions outside these limits. For instance, a CCP for average daily feeding deviation for a one week period could be established; in the event the average for an operator falls outside this range for the week, a protocol could be established requiring additional training. A visual representation such as the flow chart (Figure 2) also assists in maintaining perspective as to the connectivity of each small event to success not only of the feeding program, but the farm as a whole.

Another approach to achieve better process control is the six sigma technique. The principle behind six sigma is to accomplish accuracy of a process to six standard deviations, or 99.9997% of the time (Pande and Holpp, 2002). Six sigma strives to improve business profitability by focusing on the customer, increasing efficiency, and minimizing product defects (Pande and Holpp, 2002). Applying this approach to just the feeding program of a dairy farm, the consumer of interest is the cow. The objective is to provide the cow (customer) with a consistent ration (minimize defects) from day to day while limiting overfeeding that produces wasted feed and excess nutrients leaving the farm (increased efficiency). Achieving six sigma requires focus on three primary elements: the customer, process, and employee (Eckes, 2000). Once again, using the data collected from feed management software and feed analyses provides an indication of the number of defects and efficiency in the feeding program. Gauging customer satisfaction (in this case the health and productivity of the cow) is reflected in health and milk production records. Development of a flow diagram, as mentioned previously, allows identification of CCP that can be targeted to in this case improve cow health and productivity, efficiency, and to minimize defects in the form of feeding deviations (Eckes, 2000; Pande and Holpp, 2002). Figure 2 demonstrates an example flow chart for the normal feeding regime on a dairy farm. Dairy processors implementing the six sigma approach in Canada and India found marketing opportunities improved with compliance to international standards, processing costs decreased, and employees were more motivated and exhibited greater pride in their work (O'Sullivan, 1994;Kumar, 2003).

Case study of a 650-cow dairy operation in New York revealed the six-sigma approach can be effectively applied at the farm level (Tylutki, 2004). The terminology describing this process was referred to as precision farming, which consisted of “use of precision farming in feeding management, crop management, animal management, and business management (Tylutki, 2004).” Specifically related to the feeding program, the objective was consumption of a diet by the cow as close to the formulated ration as possible. Implementation of precision farming techniques utilized simple statistics (mean, standard deviation, feeder loading deviations) and root cause analysis (I charts or control charts). Use of these techniques resulted in reductions in purchased feed (48%), feed cost per kg milk sold (52%), and total manure N (17%) and P (28%). Meanwhile, increases occurred in animal numbers (26%), milk per cow (9%), and total daily milk sold (45%). These results indicate that institution of simple process control measures increases awareness and correction of efficiency losses on a dairy operation.

Figure 1. Example flow chart for production of meal from oilseeds (Fediol, 2002).

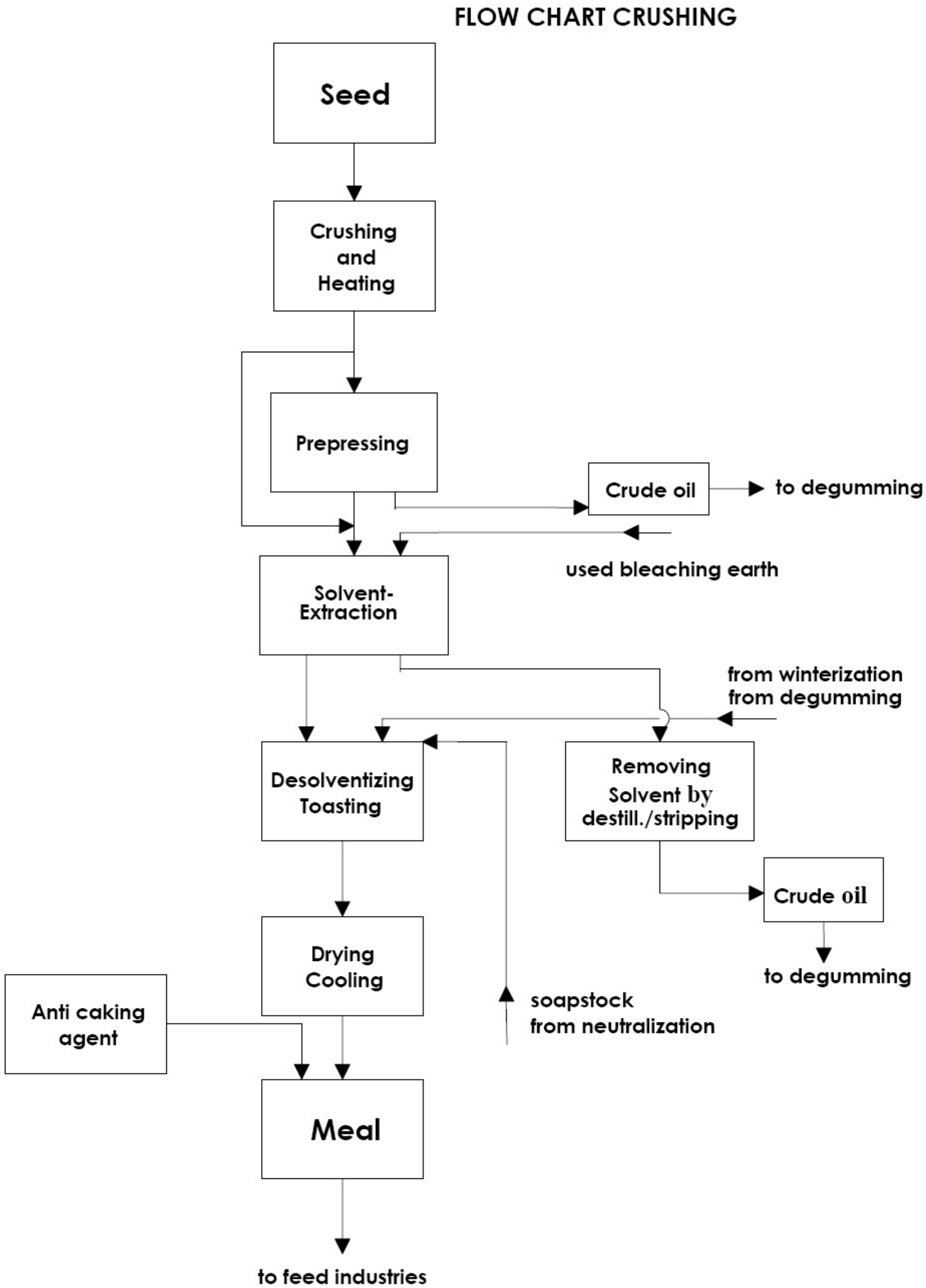
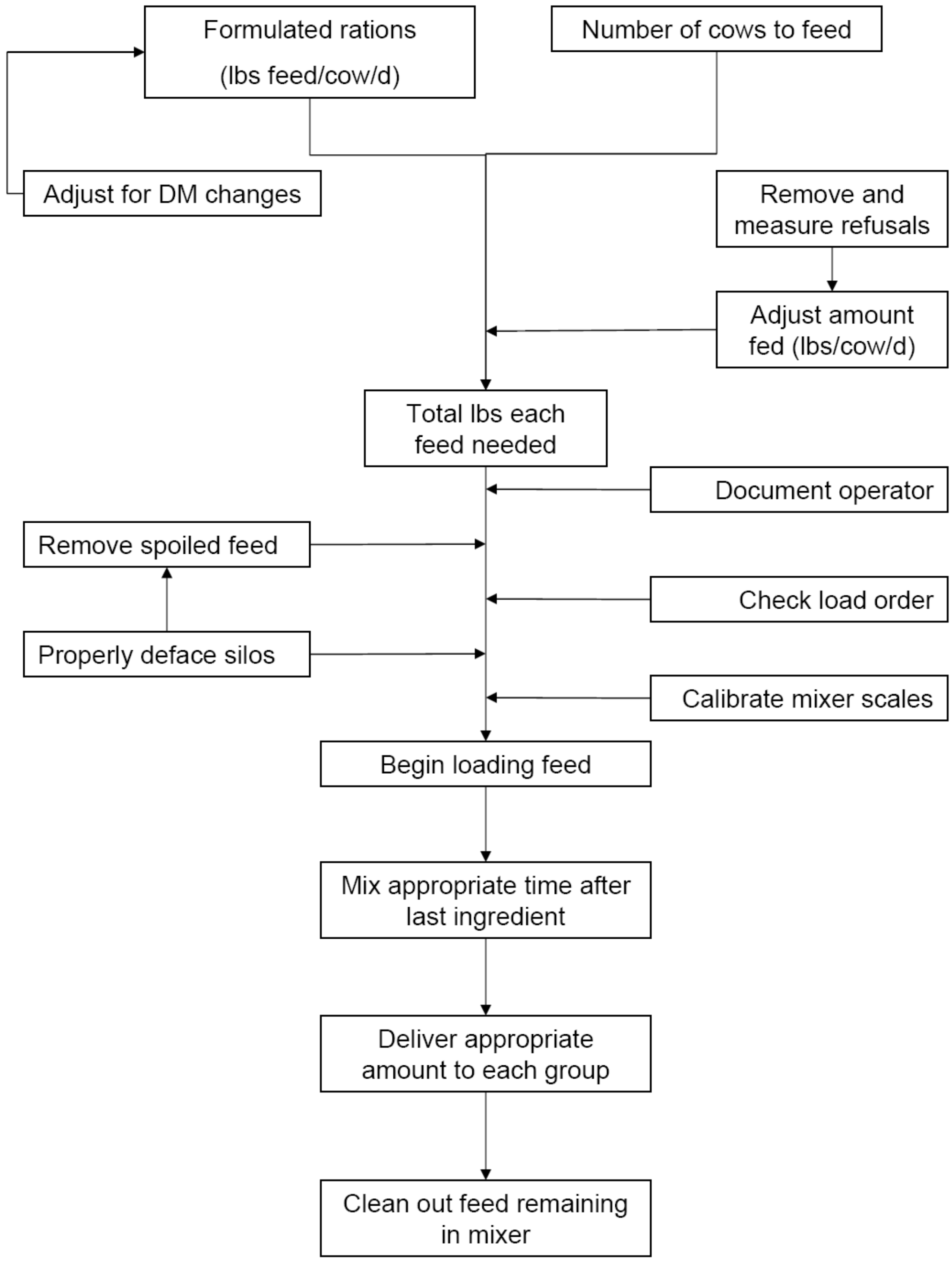


Figure 2. Example flow chart for feeding processes on a typical dairy farm.



Chapter 2: Feeding Management Impact on Whole Farm Nutrient Balance

Objective

Determine effect of implementation of feed management software on efficiency of nutrient use by lactating dairy cattle and overall feed imports to the farm.

Materials and Methods

Nine collaborator herds and six control farms were identified in four regions of the CBW to participate in this study. Collaborator herds were selected based on their willingness to purchase and implement approved feed management software for tracking of feed mixing and delivery on a daily basis, sufficiency of farm records (production, feed, and fertilizer), herd size exceeding 100 cows, and strategic location within the CBW. Herd profiles are in Appendix

Appendix Table . Herds selected were also part of another study involving approximately 200 Virginia dairy farms in the CBW. Incentive payments were offered if average annual P feeding were less than 125% of NRC requirements as assessed by TMR sampling every 2 mo. Feed management software TMR Tracker (Digi-Star, LLC, Fort Atkinson, WI) was installed on all nine cooperator farms beginning May 2006 and continuing through October 2006. TMR Tracker was selected for its ability to record data of interest, proven track record, and competitive pricing. Installation dates are provided in Appendix Table . Whole farm nutrient balances for N and P were computed for calendar years 2005 and 2006 to evaluate pre and post implementation of feed management software nutrient balance. Nutrient balances for N and P derived only from feed and milk were also computed. Nutrient import and export data were collected by researchers from producers, feed, and fertilizer dealers as appropriate. Six control farms were also selected to coincide with the geographic areas of the collaborator herds. Whole farm nutrient balances were calculated as total farm nutrient inputs minus total farm nutrient outputs. Inputs and outputs were categorized as follows: livestock/milk/meat products, feed, fertilizer, irrigation water, and legume N. Nutrient balances reflecting only feed and milk were calculated as total feed nutrient inputs minus total milk nutrient outputs. A WFNB program developed by University of Nebraska (Koelsch, 2002) was utilized for calculation of nutrient balances. Figure 3 diagrams nutrient sources and flow through a dairy operation.

Statistical Analysis

Differences in WFNB and nutrient balances from feed and milk were assessed between control and treatment farms. Control and treatment farms were compared for both farm N and P balance in 2006 with 2005 WFNB as a covariate. Treatment was a fixed effect. Farm nested within treatment was the random error term with only one observation per farm. Consequently, the PROC GLM procedure of SAS (SAS, 2006) was used to analyze data as opposed to PROC MIXED. The same model was used to assess nutrient balances for feed and milk alone. Significance was declared at $P<0.05$ and trends noted at $P<0.10$.

Model: $Y_{ij} = \mu + T_i + b_1w(_i)_j + E_{ij}$

Where

Y_{ij} = 2006 whole farm N or P balance; 2006 feed and milk N or P nutrient balance

μ = mean WFNB or feed and milk nutrient balance

T_i = fixed effect of ith treatment where i = 1,2 for treatment or control

$w(_i)_j$ = random effect of jth farm 2005 WFNB nested in ith treatment

b_1 = change in Y for each 1-unit change in 2005 WFNB

E_{ij} = random error term of jth farm in ith treatment where

i = 1,2 and j = 1,2,3…6 or…9 within i

Treatment farms were evaluated for factors influencing N and P WFNB. The PROC REG procedure of SAS (SAS, 2006) was used to assess the linear relationship between WFNB and the following factors: milk production, crop acres grown, crops sold, percent homegrown forage in the ration, percent total raised feed in the ration, and herd size. Significance was declared at P<0.05 and trends at P<0.10. The full model is outlined below.

$Y_i = b_0 + b_1x_{1i} + b_2x_{2i} + b_3x_{3i} + b_4x_{4i} + b_5x_{5i} + b_6x_{6i} + E_i$

Where Y_i = 2006 whole farm N or P balance (kg) for farm i

x_{1i} = 2006 milk production (kg) for farm i

x_{2i} = 2006 crop acres grown (ha) for farm i

x_{3i} = 2006 crops sold (kg) for farm i

x_{4i} = percent of homegrown forage for farm i

x_{5i} = percent raised feed for farm i

x_{6i} = 2006 herd size for farm i

b_0 = intercept

$b_1 – b_6$ = regression of Y on corresponding x

E_i = random error term for ith farm

Selection via backwards elimination requiring a minimum p-value of 0.05 to remain in the model yielded the following model for 2006 N WFNB. The optimality of this model was confirmed using the maxr selection option (SAS, 2006) to maximize R-Square.

$Y_i = b_0 + b_1x_{1i} + b_2x_{2i} + b_3x_{3i} + b_4x_{4i} + E_i$

Where Y_i = 2006 whole farm N balance (kg) for farm i

x_{1i} = 2006 milk production (kg) for farm i

x_{2i} = 2006 crop hectares grown (ha) for farm i

x_{3i} = 2006 crops sold (kg) for farm i

x_{4i} = percent of homegrown forage for farm i

b_0 = intercept

$b_1 – b_4$ = regression of Y on corresponding x

E_i = random error term for each farm i

The optimal model for farm P balance was also determined by backwards selection for variables significant at $p < 0.05$ with confirmation using maxr selection. The final model for P differed slightly from that for N, as shown below:

$Y_i = b_0 + b_3x_{3i} + b_5x_{5i} + E_i$

Where Y_i = 2006 whole farm P balance (kg) for farm i

x_{3i} = 2006 crops sold (kg) for farm i

x_{5i} = 2006 percent raised feed for farm i

b_0 = intercept

b_3, b_6 = regression of Y on corresponding x

E_i = random error term for each farm i

The relative impact of each model variable on WFNB was determined by creation of standardized regression coefficients. Generation of each regression coefficient required multiplication of the parameter estimate by the quotient of standard deviation of y divided by the standard deviation of x:

Regression coefficient = $b_{Y \cdot x} * (\sigma_y / \sigma_x)$

The absolute value of each coefficient generated was subsequently divided by the total of the coefficients, yielding the percent contribution of each variable to WFNB. Table 9 and Table 10 show the coefficients calculated for each variable and the relative contribution of each to N and P WFNB, respectively.

Results and Discussion

Project farms

All project farms installing feed management software fed between 1 and 3 TMR to lactating animals. Ration formulation was provided by independent nutritionists or nutritionists supplied by feed companies. Control farms exclusively fed TMR to lactating cows. Ration formulation for these farms was also provided by nutritionists supplied through the each farm's feed company. Annual mean lactating herd size and approximate body weights were obtained from producers at the onset of the study (Table 1). Appendix

Appendix Table and Appendix Table provide additional farm profile data for project herds.

The situation on farm 8 was unique in that all feeds, including forages, were purchased. However, corn silage, ryelage, and corn grain purchased were produced on adjacent land by family members and manure returned to these same fields. Data were not available on fertilizer applied to this land. To account for all nutrients on the farm, WFNB was computed by assuming all feeds were purchased and crediting for manure produced as sold manure. It is important to note that manure did not actually leave the property, but was applied to land adjoining the dairy. Crediting for all the manure leaving the farm skews the results to indicate a net export of nutrients. It is expected that if fertilizer data were available for this farm there would be more P imported than exported from the farm. Consequently, after comparing results both with and without inclusion of this farm, it was determined that farm 8 unfairly skewed the results and the farm was eliminated from all WFNB analyses. All results presented in the remainder of this chapter do not reflect data collected on this farm.

Whole farm nutrient balance

There was no difference between control and treatment farms for WFNB expressed as net kg of N per farm or per cow (Table 1). The covariate for 2005 WFNB had a highly significant ($P < 0.0001$) impact on 2006 WFNB. Inclusion of the 2005 WFNB as a covariate showed 94.92 ± 9.77 and 92.32 ± 2.11% recovery of 2005 N in 2006 WFNB per farm for treatment and control farms, respectively. This indicates minimal change in N imports for treatment or control farms in 2006. However, on a per cow basis, recovery of 2005 N was 71.07 ± 23.64 and 80.25 ± 15.44% for treatment and control farms, respectively. The reduction in N imports relative to cow numbers, but not on a total farm basis suggests an increase in farm size for treatment and control farms; this increase was more substantial on treatment farms.

Treatment and control also did not differ in net N balance attributed only to feed and milk. There was a highly significant ($P < 0.0001$) effect of 2005 feed and milk N on 2006 feed and milk N on a per farm basis (Table 3). On a per cow basis, 2005 feed and milk N had a slightly reduced, but still significant ($P = 0.0003$) impact on 2006 WFNB. Recovery of 2005 N from feed and milk only for treatment farms was 96.92 ± 20.36 and 66.53 ± 27.18% on per farm and per cow basis respectively. Control farms exhibited similar N recovery rates on a total farm basis (96.25 ± 4.70%), but recovery per cow was higher (93.95 ± 17.29%). Based on this information, it appears improvements in efficiency of N use (from either reductions in feed imports or increased production) led to lower N balances on treatment farms.

Treatment farms were not different from control farms in mean N balance on per farm or per cow basis, as seen in Table 2. Mean N balances reflecting only feed and milk on a total farm basis (Table 3) were numerically only marginally higher for treatment than control farms (35,100 kg and 34,500 kg N, respectively). Likewise, on a per 100 cow basis mean N imports from feed and milk were comparable for treatment (10,000 kg N/100 cow) and control (9,500 kg N/100 cow).

Comparison of control and treatment farms for farm P balance also indicated no difference between groups (Table 4). The covariate for 2005 WFNB was highly significant on a per farm and per cow basis. Consistent with decreased P imports, recovery of 2005 P was 23.08 ± 21.44 and 90.42 ± 13.66% on a per farm basis for treatment and control farms respectively. Slight increases in recovery rate were observed on a per cow basis with treatment and control farms recovering, 36.99 ± 44.45 and 95.85 ± 41.16% respectively.

Interestingly, mean net P imports on both a total farm and per cow basis were greater for treatment farms when comparing only milk and feed as opposed to WFNB (Table 5). This phenomenon was not observed for control farms. The implication is that exports of P from the farm in the form of manure or crops exceeded the additional P contributed from fertilizer on treatment farms. Two possible explanations exist to explain why this was not witnessed on control farms as well. One is that fertilizer purchases for control farms exceeded those of treatment farms. Another possibility is that export of P from manure or crops sold for treatment farms was greater than control. Recovery of 2005 P per farm from feed and milk was 150.53 ± 24.57 and 102.93 ± 5.78% for control and treatment farms, respectively. Recovery per cow, however, was less with only 103.19 ± 26.81 and 95.48 ± 16.51% for treatment and control, respectively. This is inconsistent with the lower mean total P imports observed for treatment farms compared to controls, indicating reductions in P imports occurred primarily through reduced fertilizer imports and increased nutrient export in crops or manure, not from changes in imported feed or milk production.

Treatment farms used feed management software for 2 to 9 mo during 2006 (Appendix Table), dependent on the speed of adaptation at the individual farm. Assessment of WFNB for 2006 therefore reflected feeding practices both pre and post implementation of precision feeding management tools. Results for treatment farms were confounded by the inclusion of both pre and post phases. Control farms agreed to provide annual information only, preventing comparison of control and treatment pre and post implementation. Consequently, significant differences in WFNB for the first year of implementation were not expected.

Across both years, the ratio of N imports to exports ranged from 1.5 to 7.2 with a median of 3.2 (Table 6). Purchased feed accounted for on average 66% of N imports (Figure 4). This is consistent with findings of Klausner et al. (1998) where 61% of imported N arrived through purchased feed. However, lower percent of N imports from purchased feed was not necessarily correlated with low WFNB. The largest N export source (as observed in Figure 5) was milk and animal products (primarily milk), contributing more than 65% of total exports. More N than P remained on the farm due to large fertilizer purchases required for optimal crop yields. Purchased fertilizer was credited with 29% of total N imports to the farm (Table 6; Figure 4). Klausner et al. (1998) observed that fertilizer imports accounted for only 19 to 22% of N imports for two New York farms. Nitrogen content of stored manure is significantly lower than after defecation due to volatilization of 70 – 80% of N during storage in a lagoon (Havlin et al., 2005). An additional 10 – 25% of N in manure can be lost if manure is not incorporated into the soil within 4 d of application (Havlin et al., 2005). The WFNB calculations do not account for this storage or application loss of N from the farm, leading to inflated values for N balance compared to actual available N remaining on the farm.

The range of ratios for P imports to exports was not as substantial, averaging 1.9 and varying from 0.7 to 3.8. Surprisingly, farm 6 achieved net export of P from the farm in 2005 and 2006 while farm 7 exhibited a net export of P for 2006 only (Table 7). The largest P source was again purchased feed (69%) (Figure 6), while milk and animal products provided the greatest export route for P (77%) (Figure 7). Fertilizer purchases across both years accounted for 31% of total P imported. This is less than the 44% reported by Klausner et al. (1998). Additionally, fertilizer purchases in 2005 were substantially higher (40%) than 2006 (22%). It is believed that awareness of the impact of P imports has precipitated a decline in P fertilization compared to 1998 levels.

Farms 6 and 7 accomplished a net export through low P imports in purchased feed and little if any P fertilization. Purchased feed changes associated with the change in P imports are documented in Table 8. Farm 6 achieved most P reductions through decreased purchase of alfalfa hay (360 kg P) and soybean meal (186 kg P). Lower P imports for farm 7 were accomplished through use of less dried distillers grain (687 kg P) and whole cottonseed (130 kg P). Reductions on Farm 6 and 7 support the findings of Koelsch (2005), where decreased imports of byproducts yielded a decline in farm P balance from 37,900 kg/yr to 16,500 kg/yr.

Contributing factors to WFNB

Interest existed in factors associated with more desirable neutral (closer to zero) WFNB. Regression of several factors on 2006 WFNB demonstrated significant influence of milk production, crop acres grown, crops sold, and percent of homegrown forage in the ration on N WFNB. The resulting linear regression equation to predict WFNB is

$$Y_i = -95417 + 7.73x_{1i} + 110.57x_{2i} - 0.055x_{3i} + 604.69x_{4i}$$

Where y_i = 2006 whole farm N balance (kg)

x_1 = milk production (kg)

x_2 = crop hectares (ha)

x_3 = crops sold (kg)

x_4 = percent homegrown forage in ration

The variables in this model account for 93.18% of the variation in farm N balance. The relative contribution of each variable to farm N balance is shown in Table 9. Amount of crop acres in production and crops sold had the greatest impact on farm N balance, each contributing 32% of the influence on farm N balance. All factors included except crops sold increased farm N balance. This indicates that for each unit increase in milk production, crop acres grown, and percent homegrown forage in the ration, the ratio of N imports:exports increases. This contradicts findings of other studies where farm N balance was found to decrease as use of homegrown forages increased in the ration (Rotz, 2002;Cerosaletti et al., 2004;Tylutki, 2004). Increases in farm N balance from increasing crop acres and the proportion of homegrown forage in the ration may be associated with perceived increase in N fertilizer requirements. It is speculated that rising farm N balance as milk production increases is a function of feeding greater percentages of CP to maintain higher production. This is substantiated by observation of rations for treatment farms formulated in excess of 18% CP.

Two variables were also found to impact farm P balance; namely, crops sold and percent of feed raised on the farm (includes forages and grains). The linear prediction equation for farm P balance developed is

$$Y_i = -1181.52 - 0.005x_{3i} + 80.24x_{5i}$$

Where Y_i = whole farm P balance

x_{3i} = crops sold (kg)

x_{5i} = percent of feed raised

These two variables account for 64.22% of the variation in P WFNB. Each variable contributed approximately equal proportions to farm P balance predictions, with crops sold providing 51% of the influence and percent of feed raised 49% (Table 10). The model is similar to that for farm N balance in that the sale of additional crops was beneficial in reducing farm P balance, while utilization of homegrown feed raised farm P balance.

Impact of precision feeding on whole farm nutrient balance

The hypothesis that precision feeding using feed management software reduces WFNB was evaluated by regression of WFNB on precision. Precision was represented by the percent of days over or under fed, where 95 and 105 represent 5% under and overfeeding, respectively. This is in contrast to accuracy, which relates to the variance from the target load weight for an individual load or day. No relationship was found between 95, 90, or 85% precision and WFNB. Similarly, there was no relationship observed between 105, 110, or 115% precision and WFNB. Partial explanation for the lack of a relationship is the discrepancy in time measured. As mentioned previously, WFNB is designed to be and was calculated as an annual value. However, feed management software was not available for installation until 4 mo into 2006. The earliest installations did not occur until April or May 2006, with some as late as October 2006 due to on-farm resistance to use. Consequently, equivalent time periods are not reflected in WFNB and precision, possibly skewing the results. Data from subsequent years of this study may detect a relationship between these factors that is not detectable with only a partial year's data.

Additionally, there is an adaptation period to feed management software that may also be a factor. Initially, an adjustment was required on the farm to both new hardware and software. During this period, few modifications were made to feeding management as a result of data collected, and much variability existed in feeding accuracy across farms. Moreover, the capabilities of the program are still not fully exploited on most farms, limiting the potential for improvements in feeding management from the program. As operators become more familiar with the program, it is anticipated that both accuracy and precision of the feeding program will improve, potentially yielding reductions in WFNB.

Conclusions

No differences were found in farm N and P balance for treatment and control farms, nor were differences observed in balances using only feed and milk sources. Across both years, N imports exceeded exports 3:1. By far the largest imported N source was from feed (66%) followed by fertilizer (30%). Feed and fertilizer contributed similar proportions of imported P (69 and 31%, respectively), but P imbalance was less averaging 1.9:1. Two farms exhibited a net export of P in 2006 attributed to reductions in purchased feed and to a lesser extent fertilizer.

Preliminary results show no difference in WFNB between farms that did or did not install feed management software. However, these results reflect only 2 to 6 mo of feed management software use and it is believed this is an insufficient time period to witness true impacts. As the software is utilized more to make active changes in the feeding program, reductions in WFNB may be observed. Additional monitoring of these herds is needed to document the effect of time after software use on WFNB.

Quantity of crops sold, crop acres in production, milk production, and percent of homegrown forage in the ration were significant factors in total farm N balance, while only crops sold and percent of raised feed contributed significantly to total farm P balance. Increases in all factors except quantity of crops sold were associated with increases in WFNB. It is believed such increases are due to increased fertilizer purchases as acres in production and utilization of homegrown forages and grains increased and higher CP levels supplied to support greater milk production. Relationships may change as rations are formulated with less safety margin for CP. Additionally, higher fertilizer prices may drive reevaluation of fertilizer needs, resulting in more conservative fertilizer applications.

No relationship was found between feeding deviation and WFNB. Lack of evidence supporting a relationship between feeding deviation is partially a function of feed management software use for only a portion of 2006, whereas WFNB reflects annual values. Consequently, any changes which may have occurred after software use cannot be observed due to inclusion of pre and post implementation data. Continued research is needed to document the impact of precision feeding on nutrient balance over a greater time span.

Figure 3. Diagram of import and export nutrient sources and flow through a dairy farm

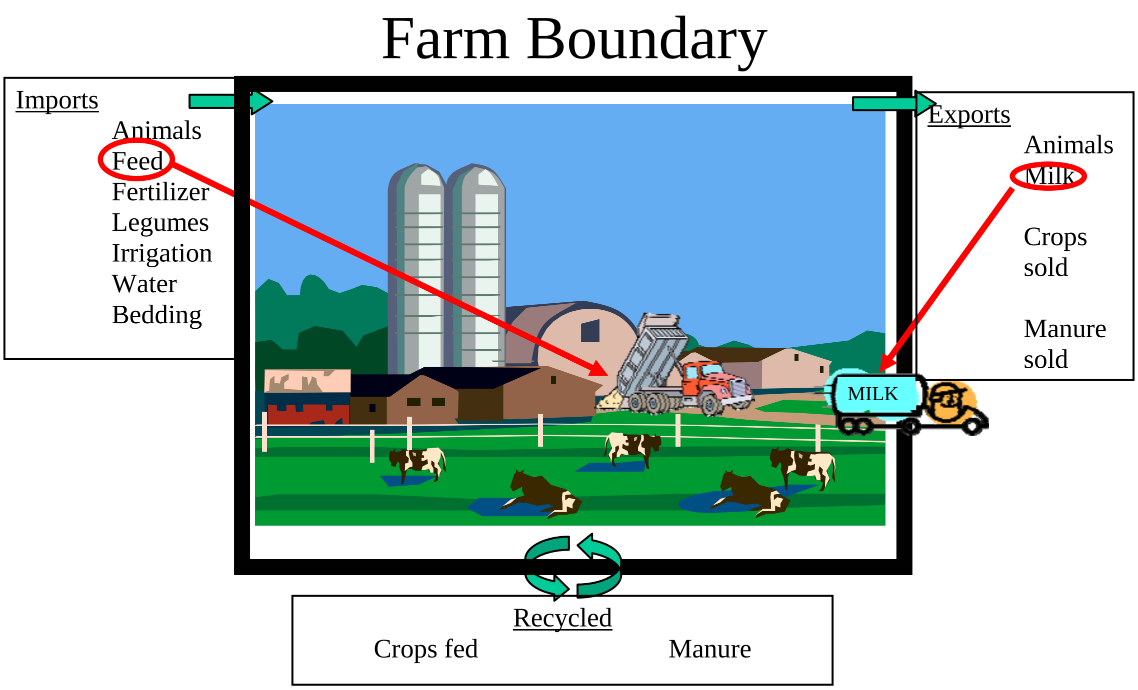


Table 1. Mean herd size and body weight of farms with calculated WFNB.

Farm	Treatment (T) or Control (C)	Lactating Herd Size	Body Weight (kg)
1	T	295	660
2	T	385	682
3	T	135	591
4	T	355	636
5	T	290	636
6	T	165	614
7	C	270	614
8	T	200	636
9	T	210	636
10	T	360	636
11	C	180	659
12	C	1200	659
13	C	220	636
14	C	250	659
15	C	120	600

Table 2. LS Means for 2006 whole farm N balance (kg/yr) on a per farm and per cow basis

	Per Farm		Per Cow	
Treatment†	LSMean	SE	LSMean	SE
1	55500	2100	158	9
2	51300	2200	132	10

†Treatment 1 = treatment farms with installed feed management software
Treatment 2 = control farms with no feed management software
Treatment not significant per farm (P = 0.61) or per cow (P = 0.32)
Signficiant (P < 0.0001) effect of covariate for 2005 N balance
Farm 8 was excluded from analysis

Table 3. LS Means for 2006 N balance (kg/yr) attributed only to feed imports and milk exports

	Per Farm		Per Cow	
Treatment†	LSMean	SE	LSMean	SE
1	35100	2700	100	8.3
2	34500	3000	95	9.5

†Treatment 1 = treatment farms with installed feed management software
Treatment 2 = control farms with no feed management software
Treatment not significant per farm (P = 0.96) or per cow (P = 0.31)
Signficiant (P < 0.0001) effect of covariate for 2005 N balance from feed and milk only
Farm 8 was excluded from analysis

Table 4. LS Means for 2006 whole farm P balance (kg/yr) on a per farm and per cow basis

	Per Farm		Per Cow	
Treatment†	LSMean	SE	LSMean	SE
1	2600	870	8.3	3.1
2	4900	1010	15.0	4.1

†Treatment 1 = treatment farms with installed feed management software
Treatment 2 = control farms with no feed management software
Treatment not significant per farm (P = 0.42) or per cow (P = 0.65)
Significant (P = 0.0003) effect of covariate for 2005 P balance
Farm 8 was excluded from analysis

Table 5. LS Means for 2006 P balance (kg/yr) attributed only to feed imports and milk exports

	Per Farm		Per Cow	
Treatment†	LSMean	SE	LSMean	SE
1	2800	380	6.0	1.1
2	2550	400	6.3	1.3

†Treatment 1 = treatment farms with installed feed management software
Treatment 2 = control farms with no feed management software
Treatment not significant per farm (P = 0.70) or per cow (P = 0.76)
Significant (P < 0.0001) effect of covariate for 2005 P balance from feed and milk only
Farm 8 was excluded from analysis

Table 6. Ratio of whole farm nutrient balance N imports to exports and relative contribution of purchased feed and fertilizer for 2005 and 2006.

	Ratio Imports:Exports		Purchased Feed (% of imports)		Purchased Fertilizer (% of imports)	
Farm	2005	2006	2005	2006	2005	2006
1	3.8	3.9	93.8	95.5	6.2	4.5
2	2.0	2.3	53.3	65.6	37.3	33.7
3	3.1	2.5	56.4	51.1	43.6	42.7
4	1.5	1.5	63.3	59.7	13.5	7.9
5	3.4	5.1	53.4	53.5	46.6	41.8
6	1.7	2.6	85.5	65.6	14.5	34.4
7	1.6	1.9	82.1	62.9	17.9	29.9
9	3.6	3.1	66.4	71.5	33.6	28.3
10	4.5	4.2	55.9	60.7	44.1	39.3
11	2.5	2.2	66.4	66.6	33.6	32.8
12	7.2	6.7	66.8	69.2	33.2	30.8
13	2.8	2.0	39.3	41.5	46.0	56.3
14	3.1	2.7	75.2	75.1	13.9	15.1
15	3.8	3.8	77.1	83.7	22.9	16.3
Minimum	1.5	1.5	39.3	41.5	6.2	4.5
Maximum	7.2	6.7	93.8	95.5	46.6	56.3
Median	3.2	3.2	66.8	65.9	29.1	29.5

Farm 8 was excluded from analysis

Table 7. Ratio of whole farm nutrient balance P imports to exports and relative contribution of purchased feed and fertilizer for 2005 and 2006.

	Ratio Imports:Exports		Purchased Feed (% of imports)		Purchased Fertilizer (% of imports)	
Farm	2005	2006	2005	2006	2005	2006
1	2.2	2.8	96.0	90.6	4.0	9.4
2	2.4	1.1	31.7	91.6	67.8	8.2
3	3.6	2.0	41.2	44.9	58.8	55.1
4	1.5	1.0	41.8	67.1	52.1	31.7
5	3.8	3.2	25.7	39.2	74.3	60.8
6	0.7	0.7	83.2	100.0	16.8	0.0
7	1.6	0.7	60.2	100.0	39.8	0.0
9	2.1	1.5	79.9	90.8	20.1	8.6
10	1.6	1.6	69.6	67.7	30.4	32.3
11	1.8	1.9	59.9	51.7	40.1	48.3
12	3.1	2.9	91.4	100.0	8.6	0.0
13	1.1	1.0	47.1	43.2	52.9	50.2
14	1.3	1.6	73.7	60.4	26.3	39.6
15	2.8	2.6	75.8	88.7	24.2	11.3
Minimum	0.7	0.7	25.7	39.2	4.0	0.0
Maximum	3.8	3.2	96.0	100.0	74.3	60.8
Average	2.1	1.8	62.7	74.0	36.9	25.4

Farm 8 was excluded from analysis

Figure 4. Import sources of N and relative contribution to total N imports for 2005 and 2006

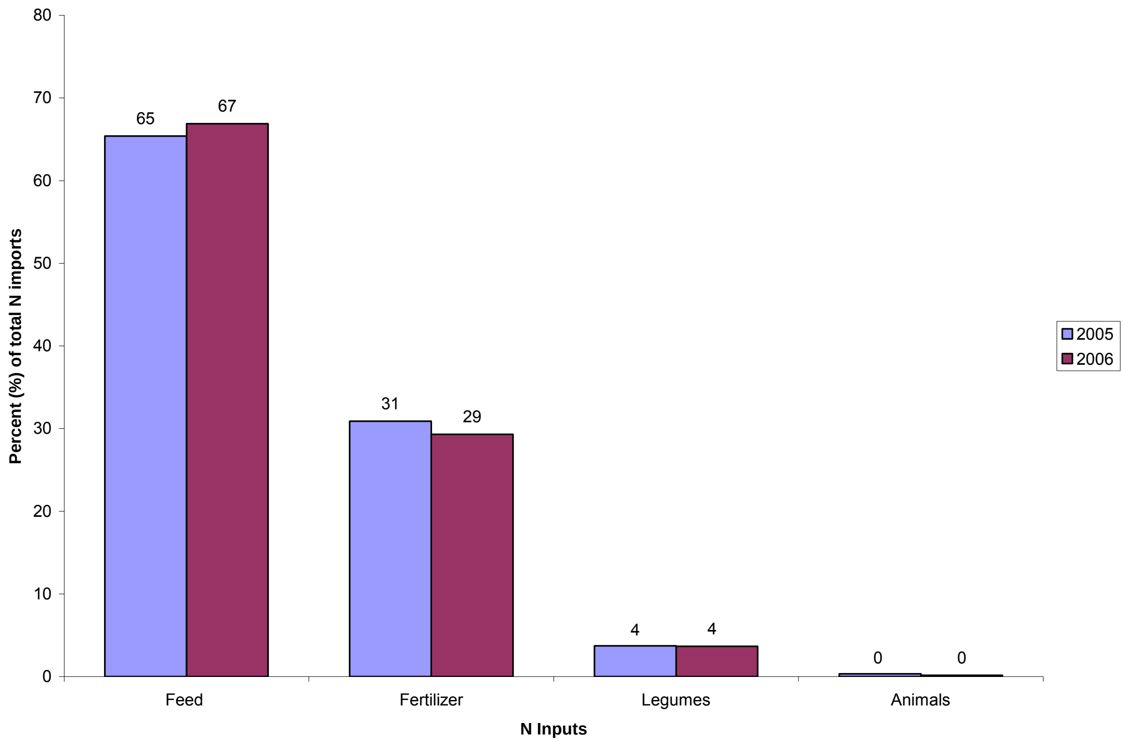


Figure 5. Export sources of N and relative contribution to total N exports for 2005 and 2006

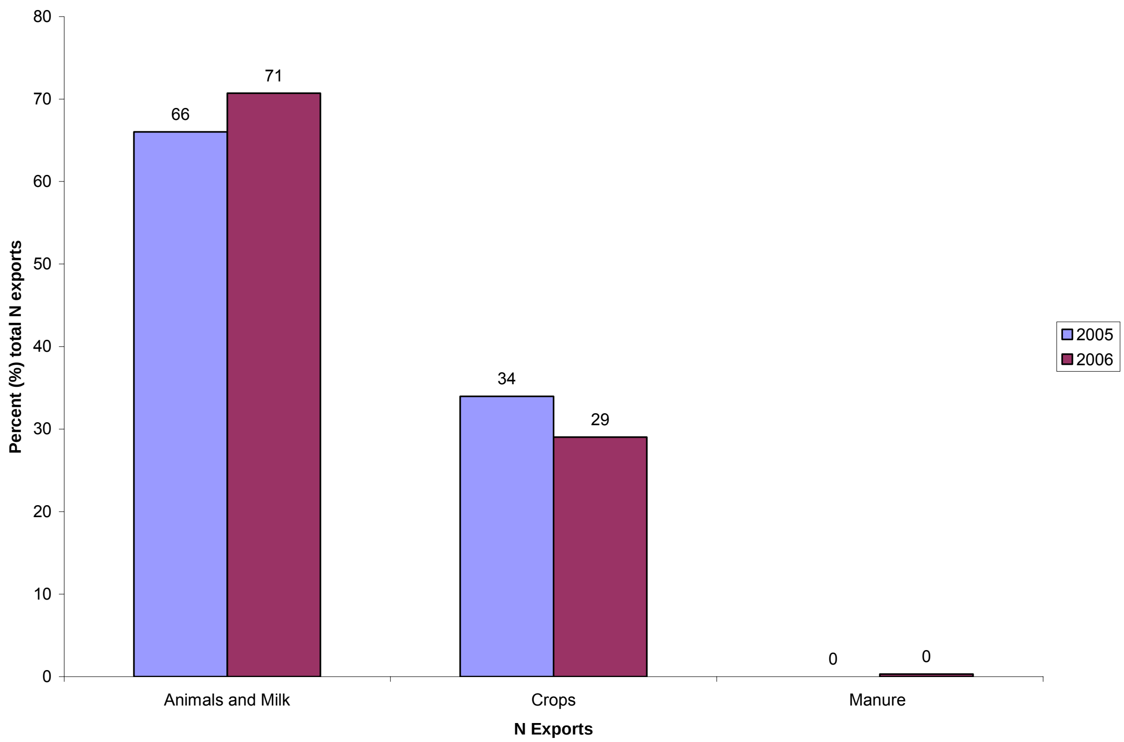


Figure 6. Import sources of P and relative contribution to total P imports for 2005 and 2006

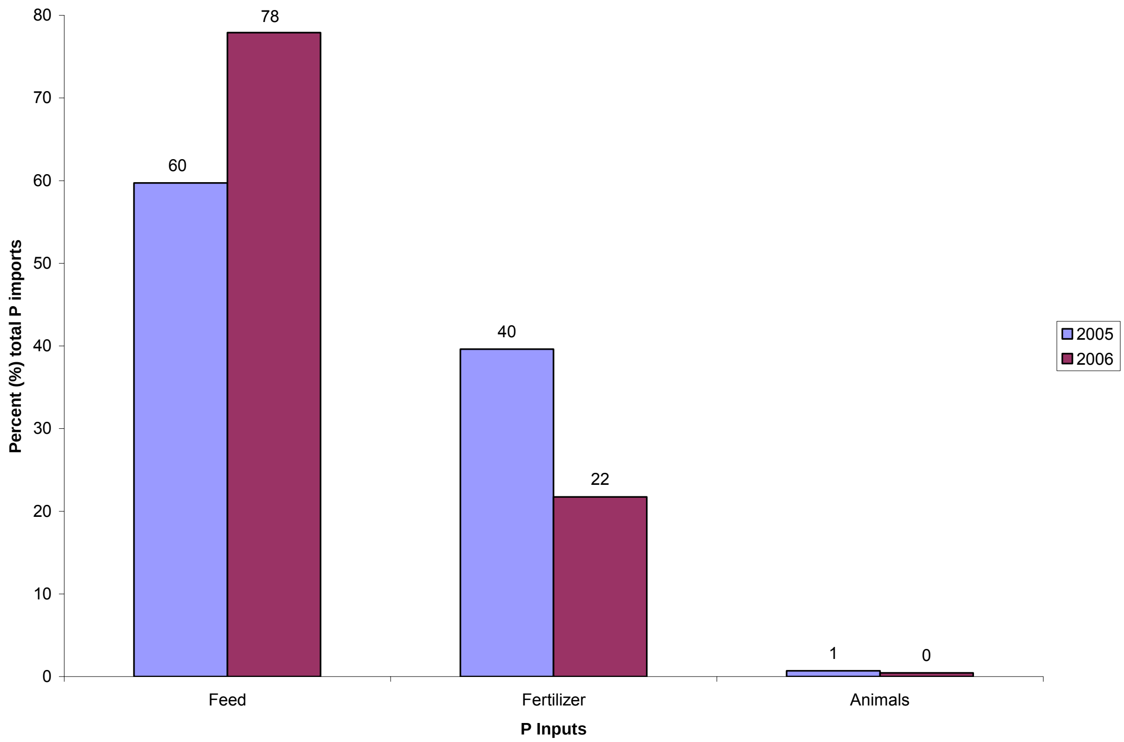


Figure 7. Export sources of P and relative contribution to total P exports for 2005 and 2006

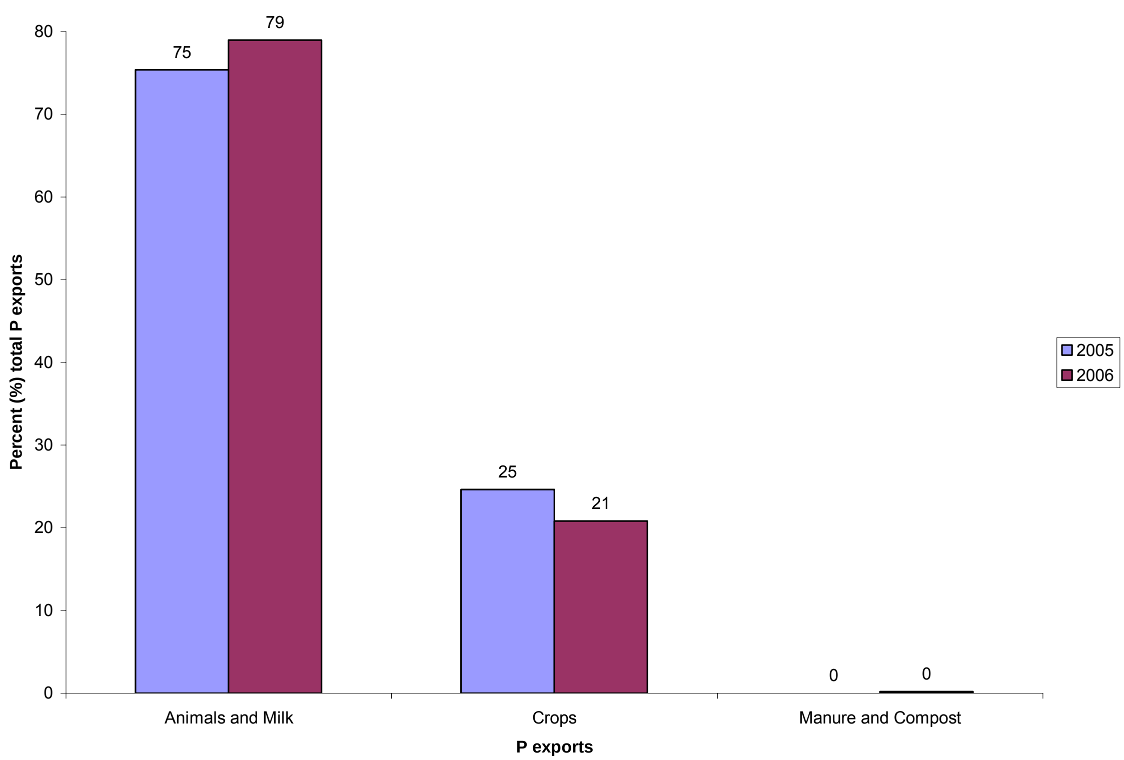


Table 8. Feed changes in 2006 contributing to reduced 2006 whole farm nutrient balance relative to 2005 whole farm nutrient balance

Farm	Feed	2005	2006	Difference
		kg		kg[1]
6	Soybean meal	1542	1171	371
6	Bunk mix	1557	1335	222
6	Soy hulls	438	286	152
6	Alfalfa hay	970	251	719
7	Dry distillers grain	2056	685	1370
7	Whole cottonseed	1552	1294	259
7	Protein supplement	3175	3102	74
7	Alfalfa haylage	0	298	-298
6	Total	2685	1364	1321
7	Total	5759	6364	-605

[1]Difference = = kg feed 2005 – kg feed 2006

Table 9. Regression factors associated with 2006 N whole farm nutrient balance (kg)

Variable	Parameter estimate	Parameter SE	F Value	Pr > F	$\frac{\sigma_x}{\sigma_y}$	Standardized Regression Coefficient	Relative Contribution (%)
Intercept	-95417	27216	-3.51	0.030			
Milk Production	7.73	2.23	3.46	0.030	0.059	0.46	15.64
Crop Hectares	110.57	21.99	5.03	0.007	0.009	0.93	31.94
Crops Sold	-0.05	0.01	-4.90	0.008	17.042	-0.93	31.87
Percent homegrown forage	604.69	138.88	4.35	0.010	0.001	0.60	20.55

Significant at $P < 0.05$
Farm 8 was excluded from analysis

Table 10. Regression factors associated with 2006 P whole farm nutrient balance (kg)

Variable	Parameter estimate	Parameter SE	F Value	Pr > F	$\frac{\sigma_x}{\sigma_y}$	Standardized Regression Coefficient	Relative Contribution (%)
Intercept	-1182	1990	-0.59	0.57			
Crops sold	-0.006	0.002	-2.75	0.03	124.443	-0.71	51.15
Percent raised feed	80.24	30.56	2.63	0.04	0.009	0.68	48.85

Significant at $P < 0.05$
Farm 8 was excluded from analysis

Chapter 3: Variability of Feedstuffs and Total Mixed Rations

Objectives

Determine variability in TMR nutrient content for lactating cow rations assessed monthly for a 12 mo period. Ascertain nutrient variation in individual feed ingredients across this same time period. Assess the degree of agreement between analyzed TMR CP and P content and corresponding formulated CP and P provided by nutritionists. Reveal changes in quantities and types of feeds used in dairy rations to achieve recommended NRC (NRC, 2001) CP and P requirements.

Materials and methods

Feed samples were obtained monthly beginning January 2006 and continuing for the duration of the study for all nine project herds and one control farm. The one control herd tested monthly initially agreed to implement the feed management software, but installation was delayed indefinitely; therefore, this herd was classified as a control herd for WFNB analysis, but feed samples were still analyzed with project herds. Samples were taken by researchers to maintain consistent sampling procedures throughout the duration of the study. Farms could submit up to five samples per month of which they were required to submit a sample of each lactating TMR fed (ranging from 1 to 3 depending on the farm). Producers could select the balance of samples with other forages, byproducts, or grains fed on the farm. Total mixed ration samples were collected in plastic containers at 2 – 3 sites along the feed bunk during ration delivery. Samples were subsequently combined, mixed, and randomly subsampled using the quadrant method until a sample size of approximately 0.5 to 1.0kg was achieved. Silage samples were obtained from 8-10 sites along bunker silo faces or until 2.3 to 3.6kg were collected from the silo unloader of upright silos. Subsampling procedures for silage were identical to those used for TMR samples. Grains and by-products had 5 to 10 grab samples taken from various locations across the bin. All feed samples were sent to Cumberland Valley Analytical Services (Maugansville, MD) for wet chemistry analysis (example analysis in Table 11). Analysis results were sent to project researchers, the farm, and cooperating nutritionists for each farm.

A critical link in improving N and P efficiency through reduced overfeeding is formulating rations to meet, but not exceed NRC (2001) requirements for CP and P. To illustrate the impact of byproduct feeds on protein and P balance, two rations were compared, one with byproducts and the other with only one byproduct. Changes in quantities and types of feed used to meet NRC requirements were assessed by development of two typical rations using NRC Dairy Cattle Program. A ration composed primarily of forages, hereafter referred to as forage diet, contained corn silage, alfalfa haylage, high moisture corn, ground corn, and soybean meal. This is reflective of a typical forage-based diet used on Virginia dairies. The ration referenced as byproduct ration included all ingredients in the forage ration, plus the addition of wet brewers grain, whole cottonseed, and dried distillers grain. Both rations were formulated for a 3rd lactation Holstein, with mean milk production of 32 kg/d and 625 kg BW. Ration summaries are provided in Table 17 (Byproduct diet) and Table 18 (Forage diet).

Statistical Analysis

The PROC MEANS procedure of SAS was used to calculate the mean, standard deviation, variance, minimum value, maximum value, and range for CP and P of all feed samples. However, TMR samples were analyzed both collectively, by farm grouping strategies (i.e. high, low, and one group systems) and by individual farm. Variances (10) for TMR samples from each farm were analyzed for significant differences using the Hartley Fmax test (Ott and Longnecker, 2001), where

N = samples/farm = 12

df = n -1 = 11

t = 10 farms

Largest individual farm σ^2 = 4.738

Smallest individual farm σ^2 = 0.5738

Fmax = (largest σ^2)/(smallest σ^2) = 8.2579

Critical value (α = 0.05) = 8.66

An Fmax value smaller than the critical value indicated no significant difference between TMR variances from one farm to another. Mean CP variance was 2.21 while P variances averaged 0.0014.

Differences between analyzed TMR CP and P and formulated percentages were evaluated using the PROC GLM procedure of SAS (SAS, 2006). Significance was declared at $P < 0.05$. The model is as follows:

$Y_{ijk} = \mu + b_1T_{1i} + F_j + b_1T_{1i}F_j + E_{ijk}$

Where

Y_{ijk} = percent CP or P in analyzed TMR samples

μ = mean

T_{1i} = continuous linear effect of ith formulated ration CP or P percent

b_1 = regression of Y on corresponding T

F_j = random effect of jth farm, where j = 1,2,3…10

$b_1T_{1i}F_j$ = random interaction effect of ith formulated ration CP or P percent and jth farm

E_{ijk} = random error term for kth observation in the ith formulated ration and jth farm

Results and Discussion

Nutrient content and variability of feedstuffs

Developing a feeding program that meets, but does not exceed CP and P requirements begins with selection of feedstuffs with appropriate CP and P percentages for herd nutrient requirements and to supplement forages. Identification of feeds meeting these criteria requires periodic feed analyses to monitor variability in nutrient content and provide the most accurate reflection of the feeding program at different time intervals. In addition to monthly TMR sampling, feed analyses were performed on feedstuffs selected by the producer for each of the nine project herds and one control herd each month during 2006.

Average CP content of feedstuffs analyzed ranged from 3.8 to 39.0% (Figure 8;Table 12). Values were consistent with those reported by Kertz (1998). Low CP (less than 10% CP on a DM basis) feeds were primarily corn based, including earlage, corn silage, high moisture corn, and ground corn (listed in order of increasing CP content). High fiber sources such as straw, cottonseed hulls, and grass hay also exhibited low CP content. Feeds classified as high CP sources (greater than or equal to 25% CP on a DM basis) included: custom supplement mixes, dried distillers grains, brewers grains, okara, and roasted soybeans. These results indicate that appropriate CP diet formulation to meet nutrient requirements should optimize use of homegrown forage, while limiting inclusion of highly variable protein feeds, such as certain byproducts. Byproducts can be an economical source of nutrients for dairy farms and should be considered as part of the feeding program. However, inclusion of appropriate quantities of byproducts is one strategy to optimize nutrient efficiency.

Feeds identified as low P sources in Table 13 and Figure 9 (defined as 0.25% P or less on DM basis) included (in order of increasing P content): straw, cottonseed hulls, corn silage, grass hay, and earlage. Inclusion of these low P sources has additional benefit in terms of cost savings, as all except cottonseed hulls were homegrown forages. In contrast, the highest P concentrations (greater than 0.45% P on DM basis) were found in purchased feeds, namely okara, brewers grain, whole cottonseed, custom supplement mixes, and dried distillers grain. Analyses are consistent with P concentrations reported by Kertz (1998). The only homegrown feed high in P was roasted soybeans, with 0.58% P on a DM basis. All purchased feeds analyzed high in P were also byproducts, except for the custom supplement mixes. However, the primary constituents of the majority of dairy supplement mixes are byproduct feeds. Replacement of high-P byproducts in dairy rations may require substitution of more expensive alternative feeds. Economics may dictate that higher P feeds be included regardless of environmental ramifications.

Variability in nutrient content of feedstuffs must also be considered in conjunction with average nutrient values. Ration formulations based on averages with large standard deviations can translate into increased variability in TMR nutrient content. Standard deviations of less than ± 1.0 percentage point CP were detected for straw, high moisture corn, earlage, wet brewers grain, corn silage, and ground corn (Table 14; Figure 8). It should be noted that wet brewers grain was pressed and from a single source. Likewise, SD of straw, high moisture corn, wet brewer's grain, alfalfa hay, pasture, corn silage, and earlage were less than or equal to ± 0.035% P (Table 13; Figure 9). Highly variable SD for CP content exceeding ± 2.5% CP deviation was documented in alfalfa hay, alfalfa haylage, small grain silage, grass hay, whole cottonseed, and okara. More variability was also noted by Kertz (1998) for legume and grain silages and whole cottonseed. Except for alfalfa hay, these feedstuffs plus roasted soybeans also exhibited SD of more than ±0.05% P.

These results demonstrate better process control in the harvest or manufacturing processes generating low CP and P feedstuffs relative to those with higher CP and P content. Typically, harvesting of corn products occurs during a short window of time, reducing the variability compared to forage harvested continuously from spring to fall such as alfalfa haylage. Additionally, small grain silage nutrient content varies based on the stage of maturity at harvest. Small grain maturity of the whole plant progresses very rapidly once reaching the boot stage. Consequently, a large rain event mid-harvest can result in storing silage at both late vegetative or early boot stage and early dough stage in the same silo or bag. The protein, energy, and fiber content of the resulting silage will vary dependent upon when harvest occurred. Whole cottonseed deviation is influenced by where the cottonseed is produced and the quantity of "gin trash" included. Inclusion of more "gin trash" (plant material included other than the seed and lint) produces higher fiber levels and more diluted CP concentrations. If purchased from the same supplier, greater nutrient consistency of whole cottonseed is expected.

Okara, a byproduct of soy beverage production, has the most variable nutrient content of any byproducts analyzed. While sample size limits interpretation, there are general observations relevant to use of this byproduct in dairy rations. Deviations of ±12.7 and ±0.14% CP and P, respectively, were noted for okara in Table 12 and Table 13. The implication is that either process control is not as stringent in soy beverage production as other manufacturing processes or the raw product is more variable, producing fluctuations in nutrient content. Crude protein ranged from 30.05 to 52.43%, while P varied from 0.39 to 0.63%. All okara samples were from the same supplier and from the same farm. It was determined that the large variability in this feedstuff was partially related to the use of both organic and conventionally produced okara. Certain processes used in conventional processing are prohibited for organic production. Consequently, a greater concentration of nutrients remains in the organically produced okara versus conventionally produced. Given these large variations in byproduct analysis, if possible, only okara produced from the same process should be utilized in the ration. Maintaining ration consistency if both types are used is virtually impossible, especially given the frequent delivery of new product every 1 to 2 d.

TMR nutrient variability

Statistical summary of TMR sample results using PROC MEANS (SAS, 2006) demonstrates both the difficulty of obtaining representative TMR samples and the variability of feed presented to the herd on a daily basis. Mean CP and P content were not different between high, low, and one-group TMR samples (Table 14; Table 15). Ranges for CP were similar between low (6.66%) and one group (6.85%) TMR, while high group TMR variation was substantially higher (11.72%). Similar results were found for standard deviation, minimum, and maximum CP values. Analysis of P content revealed nearly identical values for mean, standard deviation, minimum, maximum, and total range for all samples regardless of grouping. Within farm variances (n = 9) were evaluated utilizing the Hartley Fmax test (Ott and Longnecker, 2001); no differences were found among variances from different farms.

TMR variability relative to formulated rations

Rations formulated by nutritionists for each project farm were obtained corresponding to the date of each TMR sample. Sample TMR analyses were compared to the formulated CP and P from these rations by analysis of variance with PROC GLM, where formulated ration CP and P content was regressed on analyzed TMR CP and P. No difference was found between formulated ration CP and analyzed CP (Figure 10). It can be inferred from these results that the TMR mixed on the farm only approximated the CP content formulated by the nutritionist. Detection of differences may also be prevented by the degree of variation present. It is important to note in Figure 10 the number of rations formulated in excess of 18% CP. This suggests many diets may be formulated utilizing outdated ration balancing software without the latest nutrient requirements or for unknown reasons. Deviation of the sampled TMR from the formulated ration for CP was correlated (r=0.45) with similar deviations for P. For instance, a TMR sample found to have more CP than the formulated ration would also be expected to have more P than formulated.

Analyzed TMR samples were found to vary from formulated rations in terms of P content. In contrast to results for CP, results indicate more variability between the formulated and analyzed ration P content, suggesting greater variation in P content of feeds or inaccurate feed libraries (Figure 11). Correction of this discrepancy requires more frequent analysis of individual feeds to update feed libraries for each farm to reflect current feed available. More frequent analysis could also reduce the influence of sampling or analytical errors on values used for ration formulation.

Comparison rations to NRC P requirements

Two sample rations representative of those fed on Virginia dairy farms were developed using the NRC Dairy Cattle Program (2001). These rations were designed to compare differences in formulated ration CP and P attributable only to byproduct inclusion. The premise was to quantify the contribution of these nutrients from byproducts which were known to be prominent feed components in Virginia dairy rations. The byproduct ration included corn silage, alfalfa haylage, high moisture corn, ground corn, wet brewers grain, dried corn distillers grain, whole cottonseed, and soybean meal. In the forage ration, soybean meal was the only byproduct feed included. Mineral supplementation was not considered, as the issue of interest was uncontrolled P levels associated with feedstuffs added to supply other nutrient requirements. Different P concentrations were achieved between the two rations when balanced for a 650 kg Holstein cow in 3rd lactation producing 31.8 kg milk/d with 3.5% fat (Table 16). In the byproduct ration (Table 17), P concentration was 0.40% of DM whereas forage diet (Table 18) P concentration was only 0.34% P. There was no net change in CP content between diets. The NFC content was higher for the forage diet (43.8%) than the byproduct ration (38.4%). Similarly, ADF and NDF were lower in forage diet (20.5 and 31.3%) compared to byproduct diet (22.8 and 35.3%). However, forage NDF was higher for the forage than byproduct diet, with 27.7 and 23% respectively.

These rations reveal the difficulty of formulating economical, balanced rations low in P content. Large quantities of forages and grain were required to both reduce the P content and provide a balanced diet in the forage ration. This resulted in diets lower in fiber and higher in NFC than desired. In many situations the inferior quantity or quality of forage available may preclude such a basic ration. Furthermore, the current high cost of grains such as corn necessitate formulation of rations using more economical sources of energy and protein, typically byproducts. This example highlights the need to identify economical, lower P byproducts for use in dairy rations to supply ration needs while not supplying excessive P.

Conclusions

Results indicate that TMR variability can be expected to increase as the proportion of more variable feedstuffs such as alfalfa hay, haylages, whole cottonseed, and okara increases. As the proportion of these ingredients increases in the ration, fluctuations in nutrient content of the feedstuff will have a greater impact on total TMR variability. Limiting the impact of these feedstuffs on overall TMR variation requires inclusion of more ingredients in the ration to limit impact of variation in one ingredient.

Little accuracy or precision exists in protein feeding, with substantial numbers of TMR samples demonstrating both under and overfeeding of protein. No difference between formulated and delivered ration CP was observed. However, it is suspected the lack of a significant difference is due to the large amount of variation exhibited. Formulated and delivered TMR P content did differ, indicating inaccuracy of estimates for feedstuff P content or consistent inaccuracy in loading high P feeds. Increased sampling of feedstuffs, including byproducts and grains, is needed to more accurately define the nutrient content of feedstuffs on a farm by farm basis. Additionally, improvements in loading accuracy are needed to reduce variability of TMR nutrient content.

Formulation of two diets, a high byproduct ration and a forage diet with only one byproduct, demonstrate greater overfeeding of P in the byproduct ration. Reductions in ration P content require cautious use of high P byproducts. One challenge for the future is identification of economical feed sources that can be part of a low P diet preventing environmental pollution from dairy farms.

Table 11. Sample wet chemistry analysis performed for all TMR and feedstuffs samples

CUMBERLAND VALLEY ANALYTICAL SERVICES, INC. September 20, 200(
PO Box 669 Maugansville, MD 21767 301-790-1980 Sample No : 629300(

A N A L Y S I S R E S U L T S

Legume	As Sampled	Dry Matter	Unit
Moisture	62.4		%
Dry Matter	37.6		%
Crude Protein	10.0	26.7	% DM
Adjusted Protein	10.0	26.7	% DM
Soluble Protein		68.5	% CP
Degradable Protein (calc.)		84.2	% CP
TDN	24.8	66.0	% DM
Net Energy Lactation	0.26	0.68	Mcal/lb
Net Energy Maintenance	0.26	0.68	Mcal/lb
Net Energy Gain	0.16	0.41	Mcal/lb
Acid Detergent Fiber	10.3	27.3	% DM
Neutral Detergent Fiber	12.2	32.5	% DM
Ash	4.2	11.3	% DM
Calcium	0.51	1.37	% DM
Phosphorus	0.16	0.42	% DM
Magnesium	0.11	0.28	% DM
Potassium	1.18	3.13	% DM
Sodium	0.024	0.064	% DM
Iron	208	552	PPM
Manganese	17	46	PPM
Zinc	12	31	PPM
Copper	4	10	PPM
pH	4.6		
Relative Feed Value (RFV)	194		

Table 12. Mean, standard deviation, and range of CP content (%DM) by feedstuff

Ingredient	N	Mean	SD	Min	Max	Range
Straw	3	3.82	0.36	3.60	4.24	0.64
Molasses	1	4.15		4.15	4.15	0.00
Cottonseed hulls	1	5.38		5.38	5.38	0.00
Earlage	11	7.97	0.42	7.14	8.58	1.44
Corn silage	87	8.39	0.88	6.78	11.23	4.45
Dry hay	5	8.60	3.36	5.22	13.18	7.96
High moisture corn	4	8.90	0.41	8.33	9.27	0.94
Ground corn	3	9.26	0.94	8.49	10.31	1.82
Small grain silage	34	12.11	2.98	8.09	20.25	12.16
Alfalfa haylage	54	19.02	2.87	9.78	23.45	13.66
Alfalfa hay	9	20.48	2.80	16.04	24.17	8.13
Pasture	8	22.29	2.43	18.73	25.13	6.41
Whole cottonseed	3	24.07	4.25	19.88	28.37	8.49
Grain mix	12	28.64	9.68	16.02	40.81	24.79
Dried distillers grain	2	30.35	1.17	29.53	31.17	1.65
Wet brewers grain	5	36.78	0.69	35.90	37.65	1.76
Okara	3	37.76	12.71	30.05	52.43	22.38
Roasted soybeans	5	39.01	1.71	36.66	41.40	4.74

Table 13. Mean, standard deviation, and range of P content (%DM) by feedstuff

Ingredient	N	Mean	SD	Min	Max	Range
Straw	3	0.076	0.004	0.073	0.081	0.008
Molasses	1	0.097		0.097	0.097	0.000
Cottonseed hulls	1	0.152		0.152	0.152	0.000
Corn silage	87	0.223	0.035	0.153	0.358	0.205
Dry hay	5	0.228	0.051	0.183	0.290	0.106
Earlage	11	0.237	0.035	0.159	0.282	0.124
Alfalfa hay	9	0.277	0.030	0.235	0.320	0.085
Small grain silage	34	0.297	0.087	0.147	0.465	0.318
Ground corn	3	0.303	0.040	0.271	0.349	0.077
Alfalfa haylage	54	0.308	0.078	0.180	0.750	0.570
High moisture corn	4	0.317	0.019	0.289	0.328	0.039
Pasture	8	0.370	0.033	0.307	0.400	0.092
Okara	3	0.469	0.141	0.387	0.631	0.244
Roasted soybeans	5	0.584	0.052	0.531	0.647	0.116
Wet brewers grain	5	0.655	0.023	0.634	0.681	0.047
Whole cottonseed	3	0.660	0.096	0.582	0.767	0.185
Grain mix	12	0.826	0.793	0.320	3.305	2.986
Dried distillers grain	2	0.872	0.044	0.840	0.903	0.063

Figure 8. Mean and standard deviation CP content (%DM) of samples obtained in 2006 listed by feedstuff

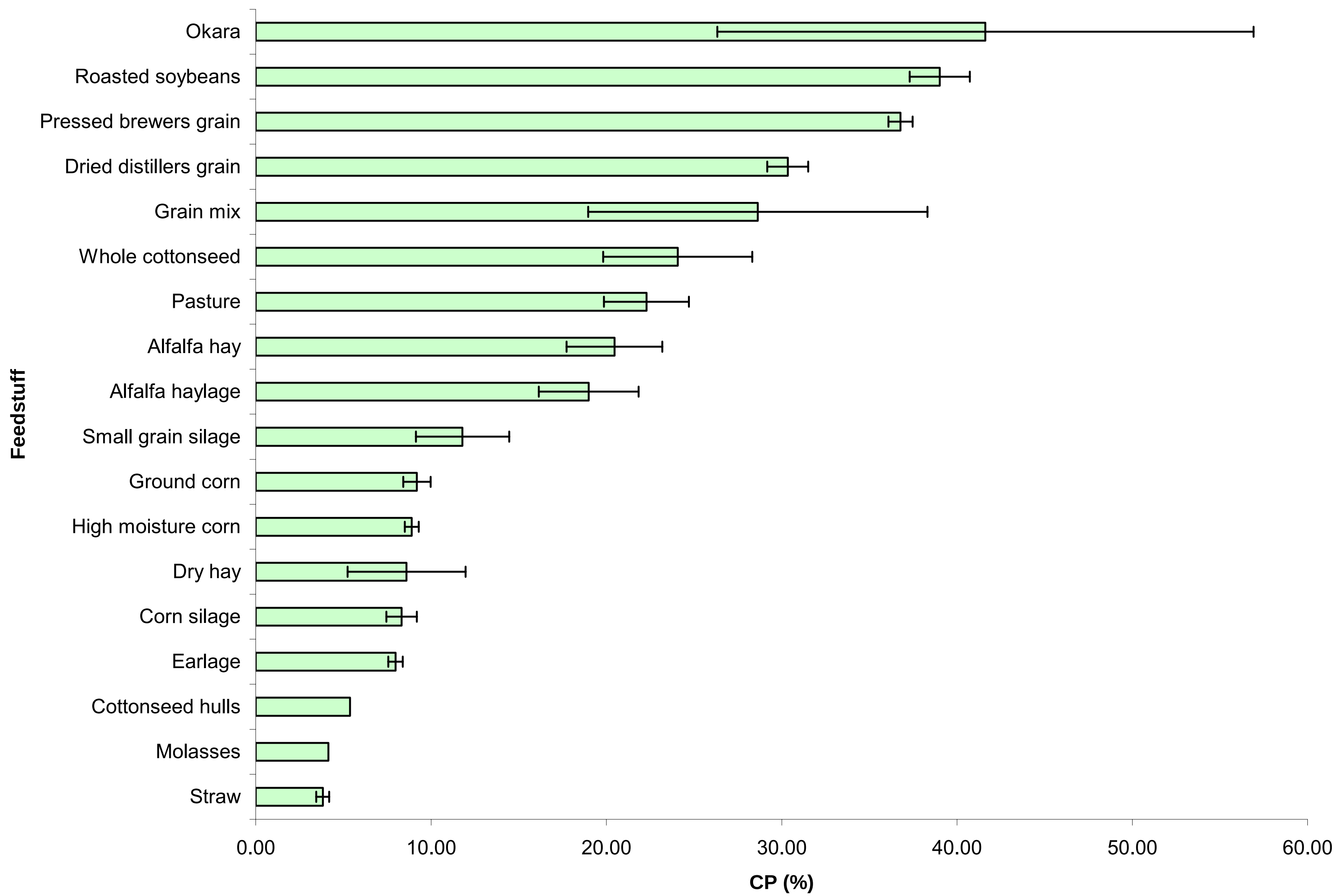


Figure 9. Mean and standard deviation P content (%DM) of samples obtained in 2006 listed by feedstuff

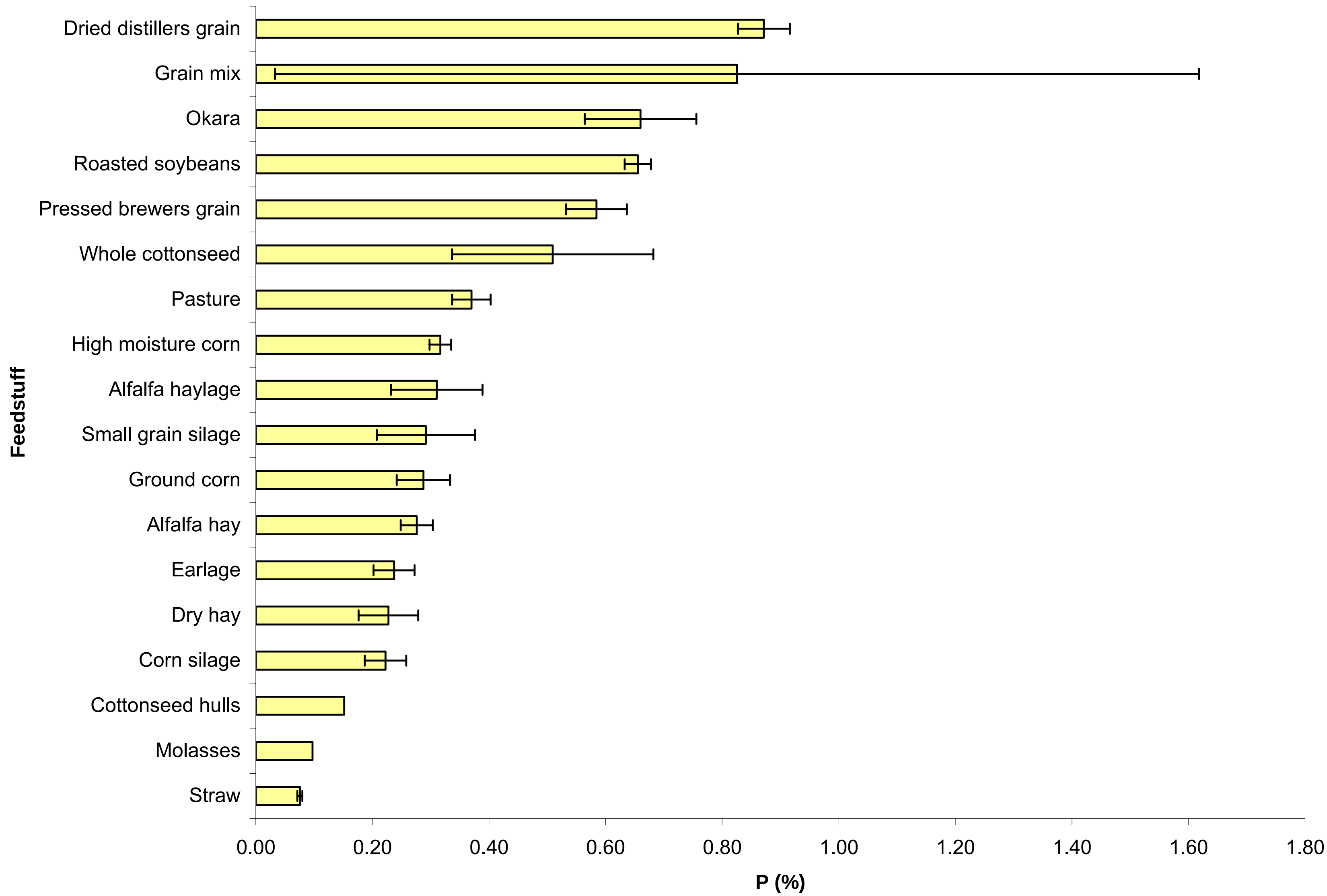


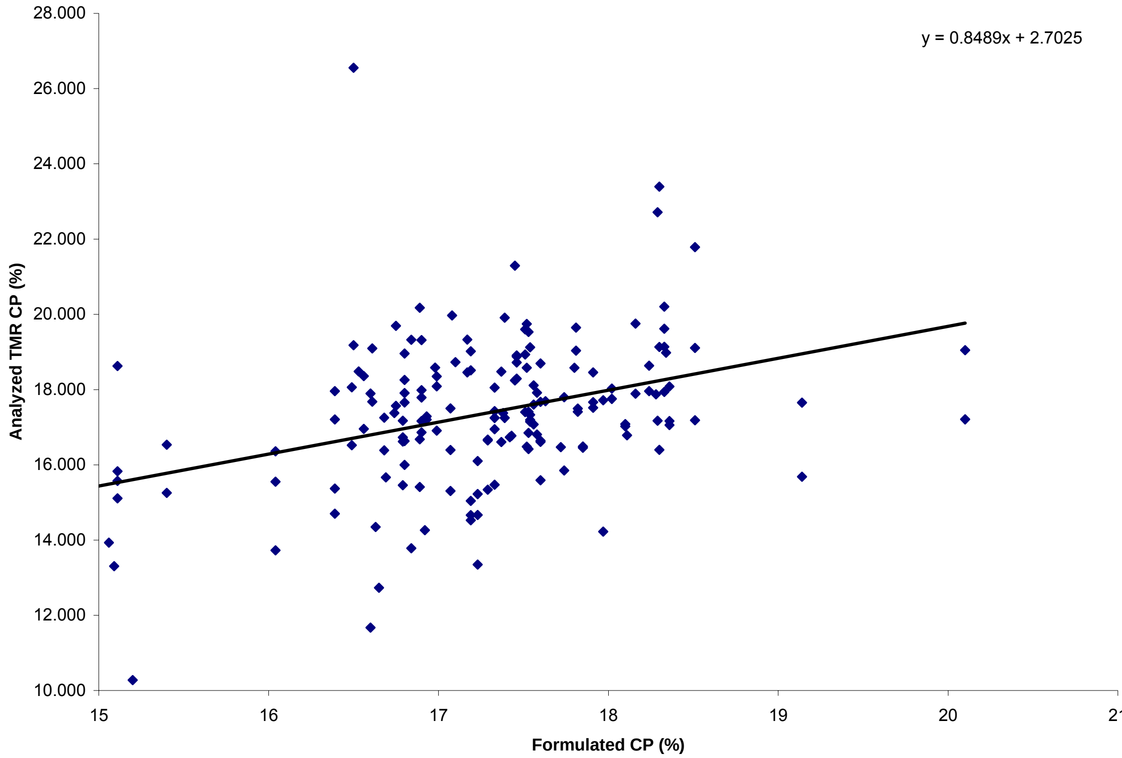
Table 14. Mean, standard deviation, and range of CP content from 2006 total mixed ration samples

Sample type	N	Mean	SD	Min	Max	Range
High group	79	17.34	2.09	11.67	23.39	11.72
Low group	61	17.26	1.55	13.31	19.97	6.66
One group	47	17.13	1.37	12.91	19.76	6.85

Table 15. Mean, standard deviation, and range of P content from 2006 total mixed ration samples

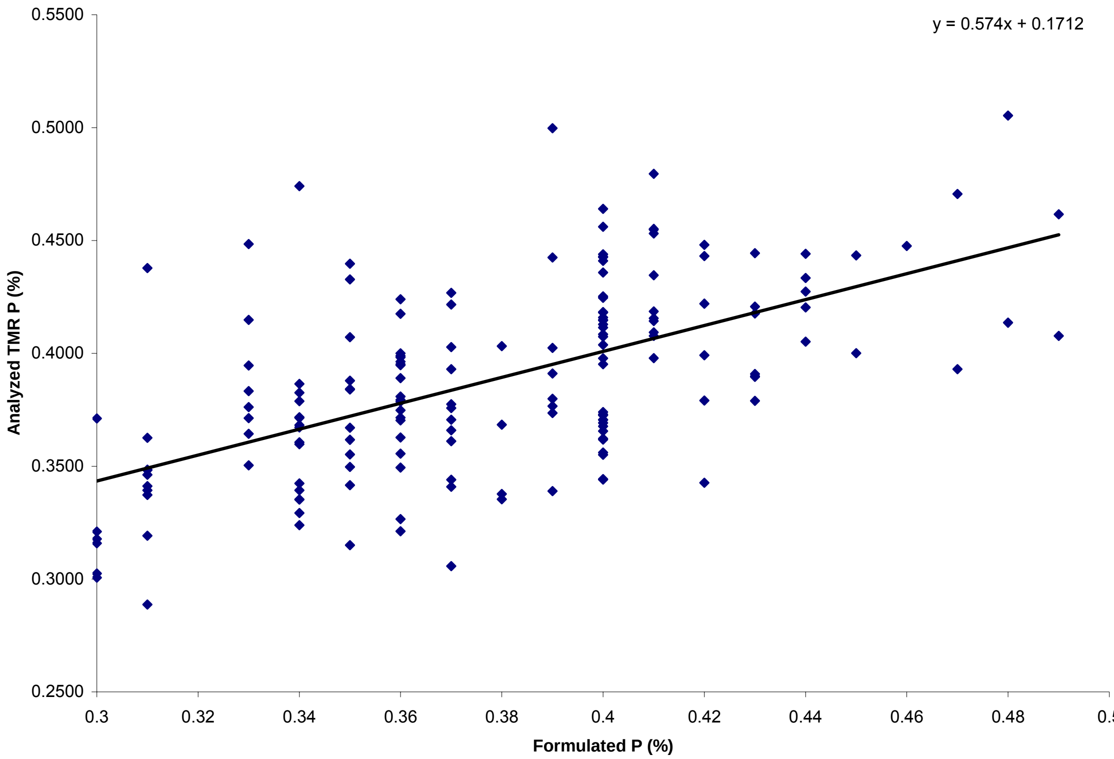
Sample type	N	Mean	SD	Min	Max	Range
High group	79	0.39	0.04	0.29	0.51	0.22
Low group	61	0.39	0.04	0.30	0.50	0.20
One group	47	0.39	0.04	0.31	0.48	0.17

Figure 10. Analyzed total mixed ration CP content regressed on formulated CP content



Not significant (P = 0.5467)
$r^2 = 0.4462$
Deviation from formulated CP is correlated (r = 0.45) with deviation from formulated P

Figure 11. Analyzed total mixed ration P content regressed on formulated P content



Significant ($P = 0.0101$)
$r^2 = 0.4615$
Deviation from formulated P is correlated ($r = 0.45$) with deviation from formulated CP

Table 16. Description of animal estimates used to develop sample Virginia rations

Animal Description	
Target Production (kg/d)	31.8
Milk fat (%)	3.5
Milk protein (%)	3.0
BW (kg)	650
Breed	Holstein
DMI	150
Age (mo)	65
Days pregnant	50

Table 17. Quantity (kg) and nutrient content of Virginia forage and byproduct ration formulation.

Feed	DM kg/d	AF kg/d	% DM	Cost ($/d)
Alfalfa silage	3.11	7.26	16.03	0.15
Corn silage	7.02	15.88	36.12	0.22
HMC	1.50	2.09	7.71	0.14
GC	2.08	2.36	10.70	0.31
SBM	1.22	1.36	6.27	0.30
WCS	1.63	1.81	8.41	0.24
WBG	0.99	4.54	5.09	0.04
DDG	1.64	1.81	8.42	0.31
Calcium carbonate	0.11	0.11	0.55	
Sodium bicarbonate	0.14	0.14	0.7	
Nutrient	**Required**	**Supplied**	**Balance**	
RDP (g/d)	1983	2257	275	
RUP (g/d)	1183	1154	-28	
Nel (Mcal/d)	32.2	32.2	0	
P (g/d)	49	53	4	
Ca (g/d)	59	64	5	
Diet concentrations	**% DM**			
NDF	35.3			
Forage NDF	23.0			
ADF	22.8			
NFC	38.4			
NEL				
CP	17.6			
Ca	0.60			
P	0.40			
Ether extract	5.1			

Table 18. Quantity (kg) and nutrient content of Virginia forage-based ration formulation

Feed	DM kg/d	AF kg/d	% DM	Cost ($/d)
Alfalfa silage	4.28	9.98	21.22	0.20
Corn silage	8.42	19.05	41.73	0.26
HMC	2.12	2.95	10.49	0.19
GC	2.56	2.9	12.68	0.39
SBM	2.56	2.86	12.68	0.63
WCS	0	0	0	0.00
WBG	0	0	0	0.00
DDG	0	0	0	0.00
Calcium carbonate	0.11	0.11	0.53	
Sodium bicarbonate	0.14	0.14	0.67	
Nutrient	**Required**	**Supplied**	**Balance**	
RDP (g/d)	2017	2275	259	
RUP (g/d)	1155	1181	26	
Nel (Mcal/d)	32.2	32.2	0	
P (g/d)	50	47	-3	
Ca (g/d)	59	68	9	
Diet concentrations	**% DM**			
NDF	31.3			
Forage NDF	27.7			
ADF	20.5			
NFC	43.8			
NEL				
CP	17.1			
Ca	0.60			
P	0.34			
Ether extract	2.9			

Chapter 4: Current State of Feeding Management

Objectives

Evaluate the current state of feeding management and the influence of feed management software on the feeding program. Document mean levels of feeding deviation by day, load, and operator across all farms. Assess the impact of feeding precision on milk production and body condition score utilizing farm records.

Materials and methods

Nine collaborator herds and six control farms were identified in four different regions of the CBW to participate in this study. Herds were selected based on their willingness to purchase and implement approved feed management software for tracking of feed mixing and delivery on a daily basis, the sufficiency of on farm records (feed purchased and production), and location within the CBW. Herd profiles are found in Appendix

Appendix Table and Appendix Table . Feed management software TMR Tracker (Digi-Star, LLC, Fort Atkinson, WI) was installed on all nine cooperator farms beginning May 2006 and continuing through October 2006. Installation dates are provided in Appendix Table .

Data recorded by feed management software were collected monthly concurrent with TMR feed sampling. Data stored included individual ingredient call (calculated pounds of each ingredient needed) and loaded (actual pounds of each ingredient fed) weights for each load mixed, total daily load weights desired and loaded, and call and load weights for each load identified by operator. Call weights were the total weight for each ingredient based on quantity of the ingredient per cow (per formulated ration) and number of cows fed. Actual weights were recorded at the mixer during loading. Software from Digi-Star referred to as eTracker (Digi-Star, LLC, Fort Atkinson, WI) designed for use by consultants was utilized to store data from the farm. These data were later exported to Excel for organization and analyzed with SAS (SAS, 2006). A dataset was compiled with data for all loads on all farms. The use of a lag variable in a SAS data step identified loads and dates with incomplete load records. These loads and dates were individually evaluated by researchers to determine if records were accurate or a program or operator error occurred using the program. Program or operator errors were defined as loads with overlapping loading times, partial recording of a load, or loads where ingredient deviations for all ingredients approached 100 %. Errant loads confirmed as program or operator error were blanked, with only the date and farm number remaining, and excluded from analysis.

Body condition scores (**BCS**) of 15 to 20 cows were taken every 3mo beginning February 2006. Cows were identified in each lactating group for BCS. Insufficient dry cows or location off the farm precluded consistent scoring of dry cows. Using the method of Wildman et al. (1982), cows were evaluated on a scale of 1 to 5 with 1 being emaciated and 5 severely obese.

Daily milk weights shipped were obtained from the respective milk cooperatives to which each farm sold milk. Milk weights were compiled in an Excel spreadsheet and coded by farm and date. Data were later exported to SAS (SAS, 2006) for analysis.

Statistical Analysis

The PROC UNIVARIATE procedure of SAS (SAS, 2006) was used to calculate the mean, standard deviation, and quartiles for average daily load deviation (kg), average daily CP deviation (kg), and average daily P deviation (kg). Data were found to be normally distributed. The impact of these daily loading errors on milk production was assessed by regression of daily milk production on daily total, CP, and P load deviations and the interactions between each. The model is provided below.

$$Y_{ij} = \mu + F_i + b_1x_{1j} + b_2x_{2j} + b_3x_{3j} + b_4x_{1j}x_{3j} + b_5x_{1j}x_{2j} + b_6x_{2j}x_{3j} + E_{ij}$$

Y_{ij} = daily milk production (kg) for ith farm, jth day

μ = mean

F_i = random effect of ith farm, where i = 1,2,3…10

x_1 = total daily deviation from formulated ration (kg)

x_2 = daily CP deviation from formulated ration (kg)

x_3 = daily P deviation from formulated ration (kg)

$x_{1j}x_{3j}$ = interaction of total daily error (kg) and daily P error (kg)

$x_{1j}x_{2j}$ = interaction of total daily error (kg) and daily CP error (kg)

$x_{2j}x_{3j}$ = interaction of daily CP error (kg) and daily P error (kg)

$b_1 – b_6$ = regression of Y on corresponding x

E_{ij} = random error term for jth observation in ith farm

PROC MIXED procedure of SAS (SAS, 2006) was also employed to compare the effect of operator and day of the week on load deviation. Class variables included farm (random), day of the week (fixed), and operator (fixed). Operator classified up to 3 feeders per farm as primary, relief, or sporadic feeders. The model examined the effect of each fixed class variable and the interactions of each on total farm load deviation. The complete model is illustrated in the table below.

$y_{ijk} = \mu + O_i + W_j + OW_{ij} + F_k + \varepsilon_{ijk}$

y_{ijk} = average load deviation (kg)

μ = mean

O_i = fixed effect of ith type of operator on average load deviation, i = 1,2,3

W_j = fixed effect of jth day of week on average load deviation, j = 1,2,…7(Saturday)

OW_{ij} = interaction effect of ith operator and jth day of week on average load deviation, i = 1,2,3 and j = 1,2,…7

F_k = effect of kth farm on average load deviation, k = 1,2,3,…9

ε_{ijk} = random error term for kth farm in ith operator and jth day of week

Rudimentary process control analysis of daily load deviation was evaluated with the assistance of PROC MEANS and PROC FREQ procedures of SAS (SAS, 2006). The standard deviation for feeding deviation for all farms and by individual farm was computed with PROC MEANS. Subsequently, the frequency each individual feeder and each farm varied by more than ±1.5 SD from the mean was counted using PROC FREQ. The majority of observations fell within this SD interval. Observations outside this range indicate unacceptable feeding deviations that should be addressed.

Impact of precision feeding techniques on BCS was assessed by analysis of variance using the PROC MIXED procedure of SAS. Class contained both the period/quarter BCS was determined and farm. The model determined the effect period/quarter, farm, and the interaction of farm and period/quarter exerted on BCS.

$$Y_{ij} = \mu + P_i + F_j + PF_{ij} + E_{ij}$$

Y_{ij} = average BCS, farm i, period j

μ = mean

P_i = fixed effect of ith period/quarter on average BCS, i = 1,2,3,4,5

F_j = random effect of jth farm on average BCS, j = 1,2,3,…9

PF_{ij} = interaction of ith period and jth farm on average BCS,

i = 1,2,3,4,5 and j = 1,2,3,…9

E_{ij} = random error term of jth farm in ith period/quarter

Results and Discussion

Farm profiles

Farm 1

Approximately 295 lactating cows averaging 660 kg BW were segregated into four groups: high, mid, low, and pack barn cows. Lactating animals were housed in 250 freestalls bedded with sand and a pack barn bedded with straw and sawdust. A separate TMR was formulated for the high group only and all other groups received the low group ration; free choice salt was available. Rations were evaluated based on changes in individual ingredients as indicated by wet chemistry feed analysis. Moisture adjustments were made as individual ingredients changed based on DM determination with a Koster tester (Nasco, Fort Atkinson, WI). An independent consultant formulated rations, with updates occurring as ingredients changed or new ingredients added.

Training for new feeders consisted of verbal instructions demonstrated during ride along sessions. No written standard operating procedures (**SOP**) existed, but verbal SOP stressed accurate loading according to feed weights expressed on feed charts and proper operation and maintenance of equipment. Lactating animals were fed twice daily, each feeding requiring approximately 20min for loading and 10min for delivery.

Owners perceived accuracy of feeders to be greater than 90 % for loading, but had no indicator of delivery accuracy. There were two primary feeders (one morning, one evening), employed by the farm for 28 and 4yr respectively. Both worked 6d per wk with relief feeding provided by the owner. This farm purchased a new Harsh mixer (Harsh International, Eaton, CO) at the beginning of 2006, which received on-farm servicing biweekly or monthly.

Farm 2

Average herd size for farm 2 was 385 lactating cows with an average BW of 682 kg. Lactating cows were divided into five groups: 3X milking (fresh to 90 DIM), breeding, high somatic cell count (**SCC**), pregnant, and treated. All lactating cows were housed in a 384 stall freestall barn bedded with sand.

The feeding program utilized a TMR with free choice salt available. Rations were evaluated based on visual appraisal in the feed bunk and daily discussion of refusals between the owner and feeder. Moisture adjustments were made on a weekly basis or after a heavy rain event. Refusals were estimated daily before feeding to heifers. An independent consultant was responsible for ration formulation, with approximately 3 new rations generated annually.

Written instructions for new feeders were not available and training focused on verbal instructions coupled with demonstration. A hand-written feed sheet was generated each day indicating the amount to be fed. No SOP were relayed to the feeders in written or verbal form. Lactating cows were fed 3 times daily, with approximately 15min each required for both loading and delivery. Initially, one ration was fed to the entire herd, but a change to a two-group feeding system occurred 6mo into the project.

Owners perceived the primary feeder's mix accuracy to be within 13.6 kg on a 4545.5 kg load, or about 99 % accurate. There was no clear perception of accuracy for delivery, except an ambiguous assertion that the morning driver was more accurate than the afternoon driver. One employee was responsible for the majority of the feeding. This employee worked 6 d per wk and had been employed on the farm for 4 yr. Owners provided relief feeding on his day off. A Knight Reel Augie mixer (Kuhn Knight Inc., Brodhead, WI) approximately 10 yr old was the primary mixer for the farm. It was serviced on the farm weekly with repairs as needed.

Farm 3

Approximately 135 lactating cows with a typical BW of 591 kg were fed and managed in a one-group system. All lactating animals were housed in a 142-stall freestall barn bedded with rubber mats covered in shavings.

The feeding program was entirely comprised of a TMR. Ration evaluation was not performed on a routine basis except by visual appraisal for consistency, quantity delivered, and ration sorting by cows. Adjustments for moisture occurred only as visual changes in ingredients occurred, typically about twice per mo. A nutritionist provided by the feed company was utilized for ration formulation, with a change in feed company and nutritionist occurring 5 mo into the project. Rations were reformulated as feeds changed or upon request, occurring approximately once per mo.

Written employee training procedures for feeding were not available. Instead, new employees were trained by demonstration of how to operate equipment and to read the feed list. Only verbal SOP were used on the farm, emphasizing the importance of balancing the scales and loading ingredients in the order specified on the feed chart. Lactating cows were fed twice daily, with an average mix time of 1 hr and 10 min for delivery. Multiple upright silos were responsible for the long loading time.

Accuracy of feeders was perceived to be 98 % for loading with no measure of accuracy for delivery. Most morning feedings were loaded and fed by the owner while afternoon feeding was the responsibility of one of two employees, one employed for 4 yr and one for 4 mo. A 9 yr-old Knight Reel Augie mixer (Kuhn Knight Inc, Brodhead, WI) was used for feeding and serviced on-farm once per month. Servicing primarily involved lubricating the mixer, with repairs as needed.

Farm 4

Farm 4 was comprised of approximately 355 lactating cows averaging 636 kg BW. Four groups were used on the farm: fresh, high, low, and middle. Cows in the middle group were housed on a separate farm and pasture fed with a TMR delivered once per day. All other lactating animals were housed in freestall barns bedded with sand, with a total of 340 freestalls available.

All lactating cows were fed a TMR, but only the middle group received pasture as well. Ration evaluation consisted of monthly testing of individual ingredients in combination with biweekly nutritionist visits and Penn State Particle Separator (Nasco, Fort Atkinson, WI) testing. Moisture adjustments occurred on a weekly basis based on DM determination with a Koster tester (Nasco, Fort Atkinson, WI). Ration formulation was performed by a nutritionist provided by the feed company with new rations developed about 6 times per yr.

Written employee training procedures were nonexistent, but expectations were reviewed with employees monthly. Only verbal SOP were available, dealing primarily with the order groups were to be fed. Lactating groups were fed twice daily (except the middle group received TMR only once), with about 30 min each required for mixing and delivery. There was one primary and one relief feeder, employed for 2 yr and 8 mo respectively. A Knight Reel Augie mixer (Kuhn Knight Inc., Brodhead, WI) purchased 1 yr prior was used for mixing, which was lubricated every 3 wk.

Farm 5

Approximately 290 lactating cows with an average BW of 636 kg were subdivided into 3 groups: group 1(mid lactation), group 2(<22.7kg milk and pregnant), and group 3 (<30d post fresh/>50kg milk). Groups 1 and 2 were housed in freestall barns bedded with chopped newspaper and straw with a total of 225 stalls whereas group 3 resided in a pack barn (135'x50') bedded with shavings.

All animals were exclusively fed a TMR, with group 1 receiving 2 loads per d and groups 2 and 3 fed once per d. Separate rations were fed to each group. Rations were evaluated based on lab analysis of TMR, visual appraisal, and use of the Penn State particle separator (Nasco, Fort Atkinson, WI) if necessary. Moisture adjustments routinely occurred (on average every 2wk) as a new silo or bag was opened or when feed changes were noticed. Refusals were not recorded. Ration formulation was provided by an independent consultant, with new rations typically no more than 3 times per yr.

Employee training procedures were deemed unnecessary as all feeding was performed by experienced family labor. Likewise, SOP were not available on the farm. Feeding took approximately 30min including both mixing and delivery.

Loading and delivery accuracy were perceived to be greater than 95 %. Feeding responsibility lay solely with a co-owner of the farm performing this task for 30yr. A truck-mounted 17-yr-old Oswald mixer was used for all feeding. This mixer had been rebuilt twice and received new scales 4yr prior. It was lubricated every 2wk with repairs as needed.

Farm 6

Farm 6 averaged 165 cows with an approximate BW of 614 kg. Lactating cows were separated into a fresh cow group and the main herd. Fresh cows were housed in a pack barn bedded with straw while the remainder of the herd was located in a 170-stall freestall barn bedded with sawdust.

All lactating cows were fed a TMR with no supplemental feeds available. Employee training procedures consisted of 4 to 5 d of demonstration by the owner. Rations were evaluated based on visual observation or the occasional use of the Penn State particle separator. Moisture adjustments were not routinely made (primarily due to the exclusive use of upright storage for forages) and refusals were not recorded. A nutritionist provided through the feed company was responsible for ration formulation, usually developing new formulations once per yr.

Verbal, but not written, SOP included monitoring the feed belts for problems, visual observation of the feed bunk, and proper tractor maintenance. Lactating cows were fed twice daily with the exception of fresh cows who were fed once daily. Mixing required approximately 30 min and delivery generally was complete in 10 min.

Loading accuracy was perceived by the owner to be approximately 80%. Feeding responsibility fell on two individuals, one employed for 3 yr and the other 1 yr. Seven mo into the study, the feeder employed for 3 yr left for a different job and was replaced with a new employee. Two mixers were used on the farm: one

Harsh (Harsh International, Eaton, CO) and a Monomix. Both were approximately 5 yr old and had maintenance performed as needed.

Farm 8

Two hundred lactating cows averaging 636 kg were divided into three groups: post fresh (<30d), high, and low. All lactating animals resided in a 258-stall freestall barn bedded with sawdust and were fed a TMR. Milk weights were monitored as an indicator of ration accuracy and milkers monitored feeding time. No adjustments were made for moisture and refusals were not recorded. Ration formulation services were provided through a nutritionist employed by the mineral supplier and were reformulated monthly (as a new bag or bunker silo was opened).

Employee training procedures were mostly verbal for equipment operation and directions for removing molded feeds. A check list was provided in the form of the ration with directions written for each ingredient. No written SOP existed, but verbal instructions were supplied for feed order. All lactating cows were fed twice daily, with 15min estimated for mixing and another 5min for delivery.

Accuracy for loading was perceived by the owner to be approximately 97%, but no estimate was provided for delivery accuracy. Feeding was performed primarily by the owner and one employee of 1 yr. A 14-yr old Roto-mix 7016 (Roto-mix, Dodge City, KS) was the main mixer with a Roto-mix 354 (Roto-mix, Dodge City, KS) as a backup. Mixers received weekly lubrication and servicing in addition to repairs as needed.

Farm 9

On average, 210 lactating cows averaging 636 kg BW were separated into three management groups: fresh and breeding cows, pregnant cows, and a sick cow group. All animals were housed in 250 freestalls bedded with sawdust, except for a bedded pack used for sick cows (30’x30’). All groups exclusively received an identical TMR. Rations were evaluated approximately every 60 d as feeds changed with a Penn State Particle Separator (Nasco, Fort Atkinson, WI). Adjustments were made for DM after heavy rain events or as feed analyses indicated changes. Modifications for rain were based on past experience, not moisture testing and rebalancing. Refusals were not recorded. Ration balancing was provided through a feed company representative, with reformulation as feed changes occurred.

Employee training procedures consisted of 2-3 d of ride alongs with no written instructions. Verbal SOP were expressed for strict mixing times and loading order, but written SOP were not available. Groups were fed 3 times daily, with mixing requiring approximately 20 min and delivery 10 min.

Owners had no estimate for either loading or delivery accuracy of TMR. Three individuals were responsible for feeding: 2 hired employees and 1 owner. Hired feeders had been employed for 2.5 yr and less than 1 mo. Both laborers worked 12 d shifts followed by 2 d off. Two Luck-Now mixers (Helm Welding, Lucknow, Ontario Canada) with Digi-star scales (one primary and one back up) were used for feed mixing. The primary mixer was 3 yr old and received regular on-farm servicing every 30 d with scale maintenance once per yr.

Farm 10

Farm 10 was comprised of 360 lactating cows averaging 636 kg BW. Animals were divided into 3 groups: high, low, and heifer groups. All animals resided in a 300-stall freestall barn bedded with sawdust. Two different lactating rations were fed, with the 'high' ration being fed to both high and heifer groups while the low group received a separate 'low' ration. Moisture adjustments were routinely made as visual changes in the feed occurred or when a new bunk was used, with Koster testing (NASCO, Fort Atkinson, WI) providing updated DM. Refusals were not recorded. Ration formulation was performed by an independent consultant, with new rations occurring every 4 – 6 wk.

Employee training consisted of verbal instructions and demonstration, with no written protocol. No written SOP were available. All groups were fed twice daily, with the low group receiving the high cow ration during the second feeding. Mixing required approximately 45 min whereas delivery was accomplished in 5 min.

The owner had no estimate of feeder loading or delivery accuracy. Two employees were responsible for feeding. The primary feeder worked 6 d per wk and had been employed for 15 yr. Relief feeding was the responsibility of the herdsman, who also worked 6 d per wk but had only been employed for 7 yr. A Knight Reel Augie mixer (Kuhn Knight Inc., Broadhead, WI) with Digi-star scales (Digi-Star LLC, Fort Atkinson, WI) was used to mix all TMR. The mixer was 11 yr old and received maintenance as needed with routine lubrication.

Milk production and BCS response from feeding accuracy

Nutrition is a critical factor in determining the level of milk production achieved. To assess the effect of feeding accuracy on milk production, daily milk shipments were compared via regression to the daily feeding deviation, or error. Daily deviation in total kg fed was negatively associated with milk production, indicating an increase in milk production as feeding accuracy increased. This agrees with the findings of Tylutki et al. (2004) that daily milk variation increased from 0.5 to 2.0 kg/d per cow during periods of inadequate feeding management. Similarly, there was an increase in milk production as accuracy of CP feeding increased. Again, these results highlight the ineffectiveness of overfeeding in increasing milk production and correspond to the 13% increase in production from a 2% decrease in CP documented by Klausner et al. (1998).

Conversely, increasing kg of P fed demonstrated a positive association between milk production and daily percent deviation in P fed. However, while this relationship is significant, this association may be due not to the increased level of P in the diet, but changes in the diet that promote higher production associated with higher P levels. A moderate correlation (r = 0.27) was found between ration NEL and P, indicating increases in NEL concurrent with P increases. It is believed that the association between increased milk production and P content is due to the related increase in energy density of the ration from larger amounts of these high P content feeds.

No difference in BCS was observed between periods/quarters across all farms. Least squares means further substantiate the lack of change in BCS throughout the project, with values for all 5 periods falling between 3.09 and 3.51.

Feeding accuracy

One unique feature of feed management software is the ability to track feeding across ingredients, loads, days, and among operators. Data recorded in this program were analyzed for mean feeding deviation, where feeding deviation is reflected by the kilograms loaded above or below the specified call weight. Examination of raw data showed that total load deviations in excess of 15% or deficits more than 10% of the call weight were indicative of recording error. It was suspected (and confirmed by operators) that most recording errors resulted from operator error, such as accidentally starting the wrong load or inadvertently exiting the program before a load was complete. Confirmed program errors were excluded from analysis.

Least squares means for feeding deviation demonstrated that with the exception of farms 6 and 8, all farms deviated on average by no more than 25 kg for the total load. On a daily basis, mean feeding deviation was 173 kg/d (

Table 19) for a mean desired weight of 12268 ± 4919 kg fed daily, or 1.4% overfeeding daily. However, comparison of means is inadequate to reveal the full story of loading variability. Including the standard deviations, it quickly becomes apparent that little precision currently exists in dairy feeding programs. While the mean across all farms was 173 kg, the corresponding standard deviation was 163 kg/d. The 95% confidence interval of $48 < x < 298$ kg/d translates into a range of

250 kg/d feeding deviation for the average farm or -0.4 to 2.43% deviation. While these fluctuations do not sound substantial, it is sufficient to provide little consistency in ration content presented to the cows. Furthermore, calculation of the contributions of CP and P provided by these feeding deviations (using nutrient values from feed analyses or NRC (2001)) demonstrates the impact of imprecise feeding on the nutrient content presented to the herd. Variations in CP and P deviations were 17.6 ± 17 and 0.4 ± 0.3 kg/d, respectively (

Table **19**). Crude protein ranged from – 0.4 to + 51.6 kg/d; similarly, P content varied from -0.05 to +0.98kg/d. Desired CP and P averaged 1022 and 21 kg/d, respectively. Thus 1.7 and 1.9% deviations in CP and P from formulated rations were found to occur on Virginia dairies.

Analysis of variance of monthly loading deviation by month post TMR Tracker installation using PROC MIXED procedure of SAS (SAS, 2006) illustrated a trend toward reductions in overfeeding as time progressed. No difference was found between feeding deviation per 30 d period for 7 mo (Figure 12). The large increase noted at mo 3 is associated with two factors. First, two farms which typically exhibited lower loading deviations only used the software for 2 mo during 2006, resulting in a lower mean during the first two periods. Additionally, the increase at mo 3 is largely related to extreme overloading, particularly of corn silage and brewers grain, on farm 4 during this period. Similarly, the sharp decline at mo 5 is associated with underfeeding of corn silage on farm 6 by approximately 100 kg for each load during this period. It appears a slight decline occurred from mo 3 to 7. It remains to be seen if this decline will persist as additional time progresses.

Lack of consistency has ramifications in terms of cattle health, productivity, overall farm profitability, and environmental concerns. One driving force behind milk production is an adequate supply of protein in the diet. Large fluctuations in the amount of CP presented can translate into greater variability in daily production, with decreases experienced during periods of inadequate protein supply. In an effort to prevent such decreases, a safety margin is typically included when formulating rations to provide excess protein. However, excessive quantities of protein cannot be utilized by the cow, and are subsequently excreted in milk, urine, and feces, primarily urine and feces. This excretion represents a two-pronged loss to the farm: financial and environmental. High protein feeds tend to be the more expensive purchased feeds; therefore, feeding excess which does not improve production is a net loss. Additionally, this excreted protein in the form of N in urine and feces poses a disposal problem. Application of too much N jeopardizes water quality from losses to leaching and runoff, making compliance with environmental regulations more difficult. Many high CP byproducts are also high in P. Just as excess protein is excreted, overfeeding of P results in elimination primarily in feces. Again, financial and environmental impacts of this overfeeding are a net loss to the farm.

Just as nutrient analysis revealed certain feedstuffs to be more variable, loading deviation varies considerably based on the ingredient loaded. Comparison of deviation means for all ingredients demonstrates loading of forages and byproducts with lower DM is less precise than other ingredients. The six feeds with the highest mean and standard deviation included all silages used in addition to brewers grain and okara, the two byproducts with the lowest DM content (Figure 13). Precise loading of these ingredients is complicated by the high moisture content, causing large clumps to routinely fall into the mixer. In terms of nutrient content of the ration, this is particularly troublesome for brewers grain and okara. Both ingredients are high in CP and P, further exacerbating the nutrient imbalance observed on most farms.

Sources of feeding deviation

Identifying the underlying cause of feeding deviations begins by evaluating individual operators. Each batch recorded in the feed management program identifies the operator mixing that batch. PROC MEANS was used to evaluate differences among primary, relief, and sporadic feeders on each farm. Primary feeders were defined as the individual(s) mixing the largest percentage of loads for each farm. In the case of farm 3 and 9, multiple feeders mixed approximately equal numbers of loads and the top three were assigned as feeder 1 to 3 based on total loads mixed. Relief feeders were individuals primarily involved in other parts of the operation, but fed when the primary feeder was unavailable (typically the weekends); they were responsible for less than 40% of all loads mixed. Sporadic feeders mixed only when no one else was available and accounted for the remainder of loads.

More differences were anticipated between primary and relief feeders than were observed. Primary feeders deviated on average 1.57 ± 0.54% whereas relief feeders averaged 1.26 ± 0.59% deviation per load. The inclusion of a third operator responsible for a small portion of total loads found mean deviation to be 1.97 ± 0.69% per load. This equates to 43.39 ± 12.95, 35.43 ± 14.34, and 55.16 ± 17.47 kg deviation per load for operators 1, 2, and 3, respectively. It was expected that the additional experience gained by the primary feeder would result in a lower mean and standard deviation compared to relief feeders. However, no difference was observed. Possibly this is attributable to development of poor mixing habits as frequency of mixing increases, such as overall sloppiness or too much haste. On all farms except farm 9, the frequency of feeding by feeder 3 was sporadic. Consequently, the experience of these operators was substantially less than both the primary or relief feeders and logically accuracy suffered from inexperience.

The impact of feeder (primary or relief) and day of the week on average load deviation was assessed using the PROC MIXED procedure of SAS (SAS, 2006). Feeding status and day of the week had no significant impact on daily load deviation (Figure 14). No relationship was observed between deviation of relief feeders and total farm deviation. Intuitively, it would be anticipated that the primary feeder would have a greater impact on load deviation due to the large percentage of loads mixed by this individual. However, these results show no difference in impact of any one feeder on average load deviation. All employees impact total farm variation; consequently, attention should not be focused on one particular group. Small improvements in any group can lead to more consistent rations delivered to the herd. However, on an individual farm basis, each individual operator should be evaluated for potential feeding problems.

Comparison of loading accuracy by day of the week showed no significant difference in loading accuracy by day of the week. Additionally, no trends were noted in improvements or declines in accuracy by period of the week, such as weekdays versus weekends. Likewise, no association between feeder accuracy and day of the week were observed (Figure 14), except for a trend (P = 0.08) for operator 2 to exhibit superior accuracy only on Friday. According to these results, there does not appear to be a particular time of the week when loading accuracy consistently suffers.

Farms 6 and 8 provide a unique perspective on feeding accuracy. The farms fall at differing ends of the spectrum in terms of mean feeding deviation. Farm 6 represents the lower 10% (-71.3 kg/d) and farm 8 the upper 10% (589 kg/d) in terms of mean daily feeding deviation. Least squares means for the farms fall outside of the range observed for the other 7 herds, with underfeeding exhibited on farm 6 and overfeeding on farm 8. Logically, both farms also comprise the upper and lower 10% in terms of kg CP and P deviation. Overfeeding of CP and P respectively on farm 8 was calculated as 56.7 kg and1.1 kg daily. On the other hand, calculations revealed farm 6 underfed 0.5 kg CP daily while P feeding deviation was less than 0.05 kg from desired P content. However, both exhibit high standard deviations of -71 ± 168 and 589 ± 380 kg/d (Figure 15) for farm 6 and 8, respectively. Feeding on farm 6 was performed almost exclusively by hired labor (93.9% of loads mixed) whereas the owner mixed 93.6% of loads on farm 8. Possible explanations for the unusual nature of these operations are detailed below.

Intuitively, it would be expected that the owner would recognize the financial impact of greater accuracy and precision more than a hired employee. However, farm 8 demonstrates this is not always the case. This farm consistently overfed large quantities for 8 mo in spite of the owner mixing 94% of loads. Observation of this farm over the course of 2006 leads to the conclusion that much of this deviation resulted from haste and low standards for accuracy. The full impact of large fluctuations in loading accuracy on production and profitability were not perceived. Additionally, reports for loading accuracy were not utilized to the extent of other farms. Given that the owner almost exclusively did all loading, he thought he knew his accuracy without looking at the reports. It is believed that accuracy could be improved substantially simply by realization of the large range compared to other farms and taking additional time loading. Another factor in the large deviations observed on farm 8 was the type of feeds used. The byproduct okara was a constituent of the rations on this farm. The low DM content of this feed makes handling and precision much more difficult. The material naturally clumps together with a tendency to fall into the mixer in large blocks. Deviations to the tune of over 100 kg occurred with this byproduct, substantially limiting the precision possible from day to day.

Two individuals were responsible for feeding on farm 6, both hired employees. Accuracy on this farm was almost identical for both operators. The low mean and large standard deviation (-71 ± 168 kg/d) compared to other farms in large part is associated with feed storage facilities on this operation. All feeds produced on the farm, including high moisture corn and all silages, were stored in concrete stave or sealed silos. Controls for the various silos were located at different ends of the feed room. The indicator was not always visible during loading, necessitating turning unloaders off based solely on alarms signifying a tolerable range was achieved. Accuracy consequently shifted considerably from day to day, leading to more underfeeding than other farms experienced. Another factor in the large amount of underfeeding was the unreliability of bottom unloaders in the sealed silos. These unloaders frequently broke midway through a load, requiring advancement to the next ingredient before loading of the previous ingredient finished. Equipment location and failure were the driving forces behind underfeeding on this operation.

Process control for feeding deviation

Frequencies of feeding deviations outside of a tolerable range were assessed by comparison of the number of loads average load deviation was outside the range of ±1.5 standard deviations of the mean. One standard deviation was equivalent to 53.5 kg. Table 21 demonstrates there were on average 44 loads underfed by at least 1.5 standard deviations, while 61 loads were overfed by 1.5 standard deviations or more. As a proportion of total loads fed, 8.12 and 11.22 % of all loads fed deviated ±1.5 standard deviations (Table 21). Results are depicted graphically in Figure 16. In practical terms, cows received less than formulated about 8% of total loads while another 11% of loads overfeeding occurred. An opportunity for process control improvement exists by reducing percent of loads deviating more than ±1.5 standard deviations to within 5% versus the current 8 or 11%.

Conclusions

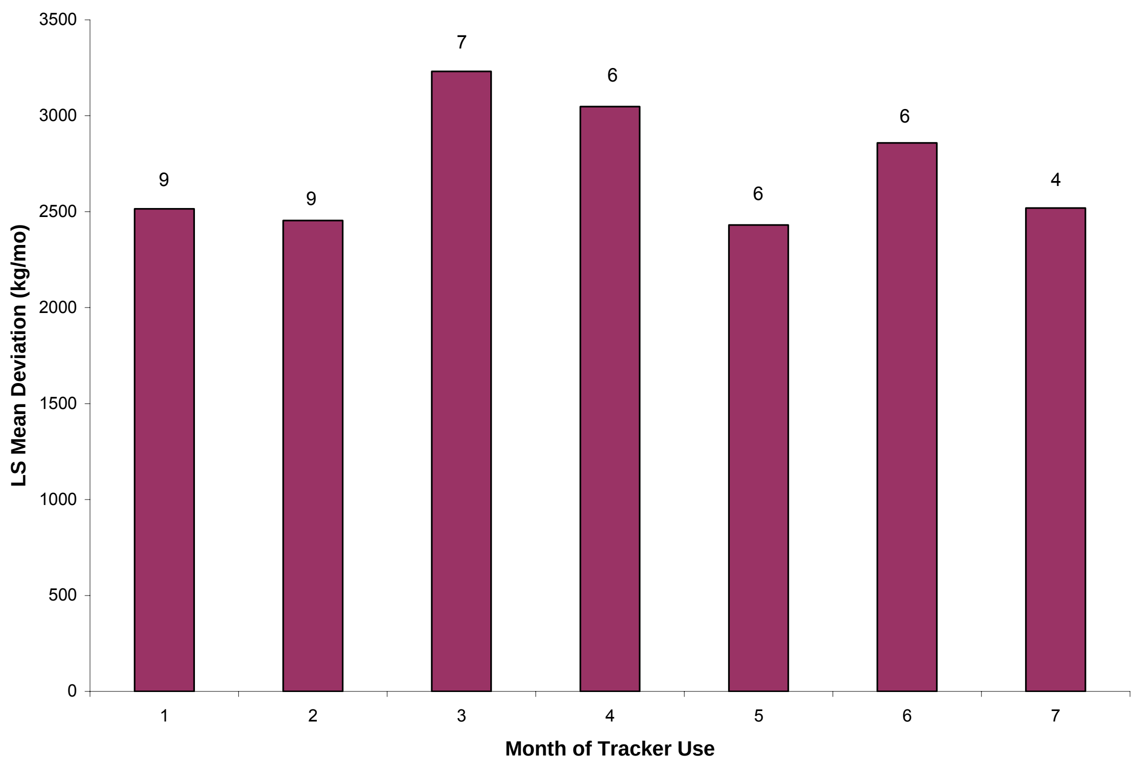
Mean daily feeding deviation of 173 ± 163 kg/d was observed for all farms. Increased feeding deviation as well as increased CP deviation was negatively correlated with milk production. No production benefits of overfeeding were found from these data. As P deviation increased, milk production was also shown to increase. However, increases were attributed to the associated increase in energy added to the ration from high P feeds. Loading accuracy suffered as DM content of feedstuffs decreased (Figure 13). Difficulty of handling feeds with more moisture led to more imprecise loading, perhaps associated with the perception low DM feeds are less expensive. Feeding deviation did not differ by feeder or day of the week. Consequently, all employees should be evaluated equally to impact change in feeding deviation.

Process control analysis demonstrated 8% of all loads were underfed more than 1.5 standard deviations, while frequency of overfeeding in excess of 1.5 standard deviations was 11%. Implementation of six sigma (Eckes, 2000;Pande, 2002) should begin by reducing this deviation initially to within 1 standard deviation (92kg/load). Utilizing 2006 feeding data as baseline, farms should be evaluated for areas of improvement. Strategies for each individual farm are needed to target specific weaknesses of each operation. Future research efforts should document the adoption and success of six sigma approach to improving feeding management.

Table 19. Mean and standard deviation for total kg feed, kg CP, and kg P deviation by day

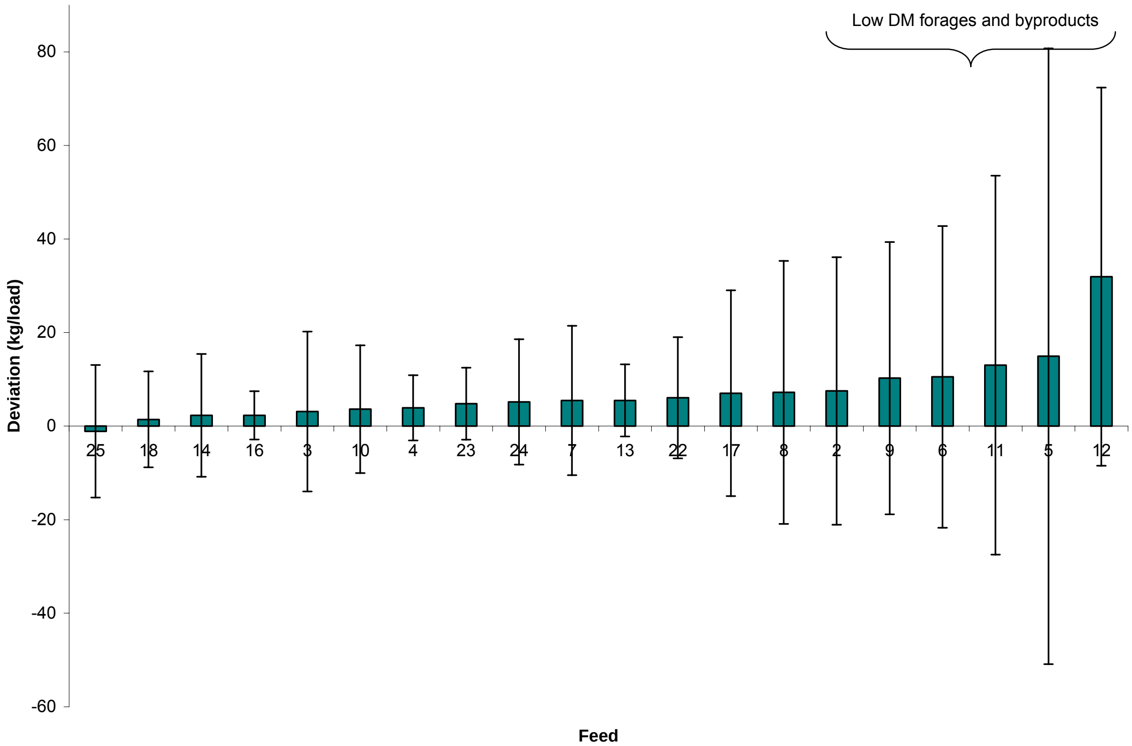
	Mean	SD	% of ideal
Total Deviation (kg/d)	+172.8	162.6	101.4
CP Deviation (kg/d)	+17.6	17.0	101.7
P Deviation (kg/d)	+0.4	0.3	101.9

Figure 12. LS Means for 2006 monthly feeding deviation (kg/mo) by month of feed management software use.



***Significant difference between monthly deviation and month of tracker use at $p < 0.05$**

Figure 13. Mean and standard deviation for load deviation by feed ingredient for 2006.

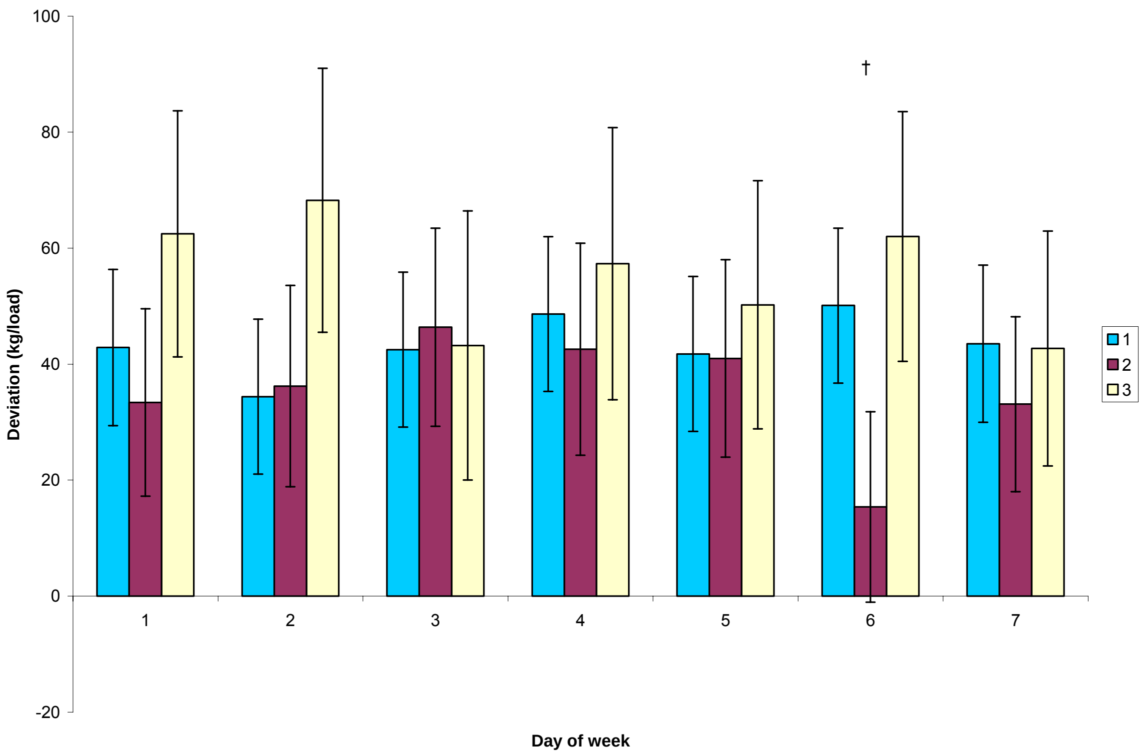


†Feed:

25: Corn gluten
18: Mineral
14: Molasses or BCS
16: Straw
3: Grain mix
10: Whole cottonseed
4: Dry hay
23: Citrus pulp
24: Soy hulls
7: Alfalfa hay

13: Roasted soybeans
22: Soybean meal
17: Ground corn
8: High moisture corn
2: Alfalfa haylage
9: Wet brewer's grain
6: Small grain silage
11: Earlage
5: Corn silage
12: Okara

Figure 14. Mean and standard deviation for total load deviation (kg/load) by day of week and feeder for 2006



Day of week:
1: Sunday
2: Monday
3: Tuesday
4: Wednesday
5: Thursday
6: Friday
7: Saturday

Feeder:
1: Primary
2: Relief
3: Sporadic

Feeder, day of week, and interaction of feeder with day of week were all insignificant at $p < 0.05$
†Trend ($P = 0.08$) that significant difference between feeders within day

Table 20. Frequency of loading by feeder and day of the week.

Feeder	Weekday	Frequency (# loads)	Total loads	% Loaded
1	1	485	639	76
2	1	112	639	18
3	1	42	639	7
1	2	579	671	86
2	2	63	671	9
3	2	29	671	4
1	3	567	670	85
2	3	76	670	11
3	3	27	670	4
1	4	602	678	89
2	4	50	678	7
3	4	26	678	4
1	5	580	689	84
2	5	73	689	11
3	5	36	689	5
1	6	583	707	82
2	6	88	707	12
3	6	36	707	5
1	7	431	698	62
2	7	214	698	31
3	7	53	698	8

Figure 15. Mean and standard deviation of daily feeding deviation (kg/d) by farm for 2006

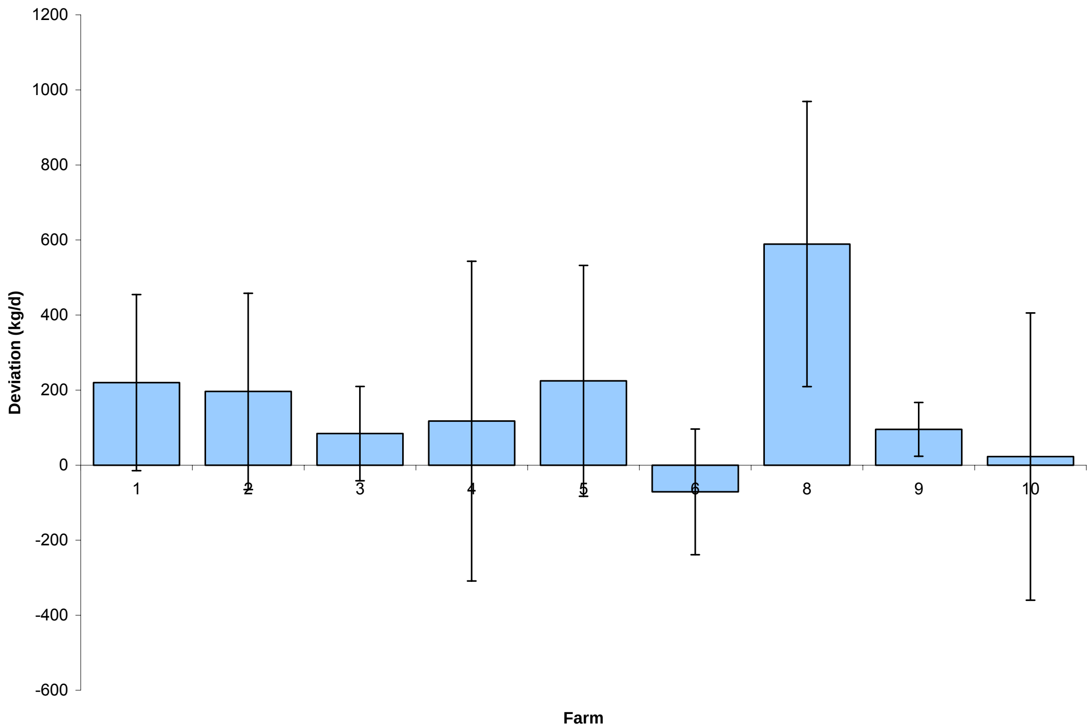


Figure 16. Scatterplot of loading deviation by day versus critical limits of ±1.5 standard deviations.

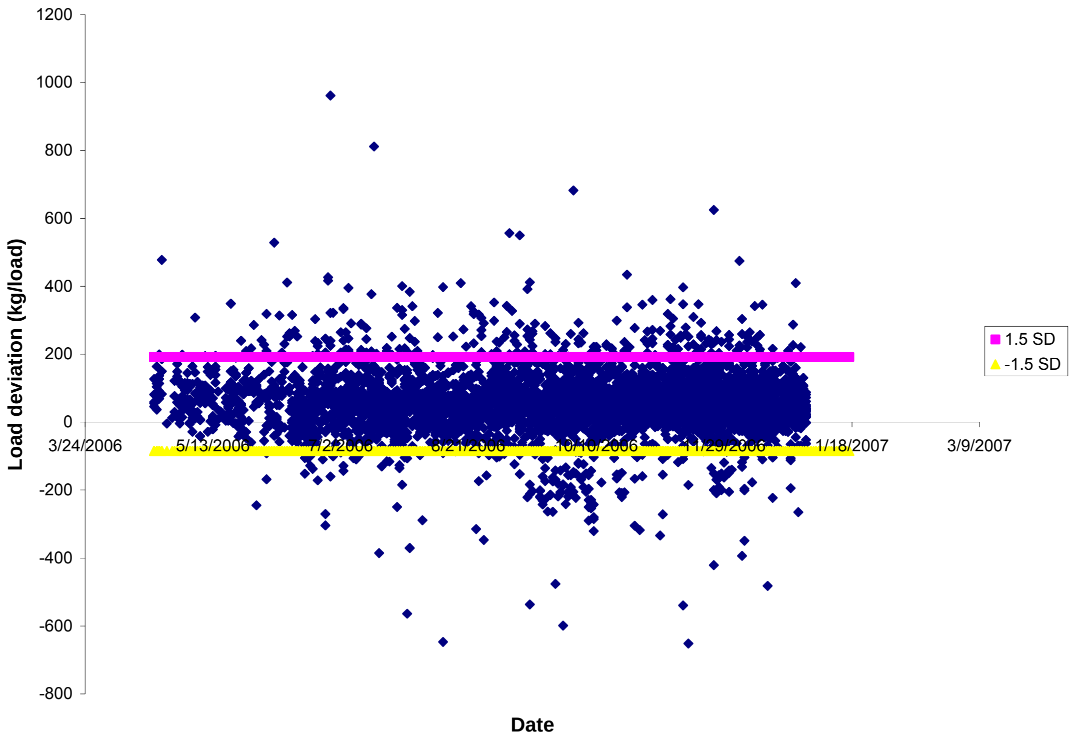


Table 21. Loads fed outside critical limit of ±1.5 standard deviations, sorted by farm

Farm	Total loads	Loads under 1.5 SD	% Loads under 1.5 SD	Loads over 1.5 SD	% Loads over 1.5 SD
1	423	5	1.18	5	1.18
2	273	1	0.37	20	7.33
3	403	30	7.44	21	5.21
4	459	54	11.76	71	15.47
5	748	23	3.07	47	6.28
6	535	105	19.63	0	0
8	1131	38	3.36	343	30.33
9	248	7	2.82	5	2.02
10	647	132	20.40	34	5.26
Mean		43.89	8.12	60.67	11.22

Chapter 5: Perceptions of Feed Management Software

Objectives

Ascertain producer satisfaction with and use of feed management software 2 to 6 mo post installation. Classify the most common uses of the program, ease of use and installation, and degree of fulfillment of expectations. Document perceived effects of feed management software on feeding management, ration consistency, and quantity of purchased feed.

Materials and methods

A 24-question survey was administered in October 2006 to evaluate producer perceptions of feed management software after initial installation. Questions pertained to operation, installation, and general satisfaction with the program. Format of the questions included multiple choice selections, yes/no, short answer, and ranking. Survey questions as presented to producers are provided in Table 22 and Table 23.

Beginning in December 2006 and continuing through January 2007, 9 producers were asked to complete the survey. B. G. Cox personally interviewed and recorded survey responses with each producer. Survey results were entered in an Excel spreadsheet. Yes/no responses were recorded as 1 and 0, respectively, whereas yes/unsure/no questions received scores of 1, 0, and -1. Short answer responses were categorized and assigned a numerical score. Similarly, multiple choice questions were assigned a number to represent each letter. Question 3 allowed for multiple responses, with each answer treated as a separate yes/no question in the Excel database. Each farm also received a rank of -1, 0, or 1 for farm N and P balance status, where -1 indicates greater than or equal to 1SD from the mean, 0 within 1SD, and 1 greater than 1SD difference.

Statistical Analysis

PROC FREQ and PROC CORR functions of SAS (2006) were utilized to analyze survey results. Frequencies for each response were calculated for every question to determine pattern responses. Additionally, correlations provided insight into potential relationships between questions and also between farm P and N balance rankings.

Results and Discussion

Frequency of use of the program for different functions is depicted graphically in Figure 17. Review of reports generated by the program ranged from sporadic use to daily use. All producers reported using the program to monitor operator efficiency. Producers sporadically viewing reports typically used only the operator efficiency report in the program. The most valuable information from the program was operator accuracy (5 of 9), while dry matter intake estimates were also deemed important (2 of 9). To that point in time, the program was not consistently being used for inventory control on any farms, where inventory control implies recording of feeds received in the program for reorder reminders and shrink estimates. Two farms did report using the program for inventory control, but use was intermittent. More accurate shrink estimates were not available due to the lack of recording weights of feeds received.

Effects of using feed management software on the overall feeding program were assessed and are also represented in Figure 17. Improvements in overall feeding management were recognized by 6 of 9 producers surveyed. However, producers did not attribute these improvements to conscious changes made in the feeding program, as only 3 actively changed feeding management after using the program. Despite the lack of proactive changes, ration consistency was noted as improving by 5 of 9. Three of the four remaining thought ration consistency improved, but could not document changes. Producers noting improved ration consistency were associated with lower N balance ($r = -0.79$) and showed a tendency to have lower P balance ($r = -0.60$). Improvements in feeding management were correlated with improved ration consistency ($r = 0.80$). Changes in quantities of purchased feed were not detected after implementing the program. However, not recording weights of feed received in the program made it difficult to assess the frequency feed had to be reordered and total amounts used relative to before the study. Slight decreases could easily go unnoticed.

Ease of installation and operation as well as the availability of technical support are critical to the success of any new hardware or software. Producers were asked to rate this program on a scale of 1 to 5 for each of these parameters, with 1 strongly disagree or 5 strongly agree (Figure 18). Installation of the software and indicator were both deemed simple (6 of 9). No producers found the indicator difficult to use while only 1 noted difficulty operating the software. Evaluation of ease of installation and operation may be influenced by personal installation and assistance offered by B. G. Cox which is not available to most producers. The sufficiency of phone support was esteemed adequate by 6 of 9, while 3 remained indifferent to phone service. Use of manuals provided varied by farm; those producers who utilized the manuals more found them sufficient (5 of 9) whereas the remainder were indifferent (2 of 9) or strongly disagreed that they were useful (2 of 9). Those strongly disagreeing were also less likely to fully explore the manual for solutions.

B. G. Cox provided in-person assistance during monthly visits for ration sampling as well as via phone. The perception of necessity of this on-farm support was mixed. While four expressed agreement that this support was necessary for success of the program, four others found it unessential. This discrepancy can be explained by the degree of difficulty experienced adjusting to the program. Producers requiring the most assistance in initial setup and subsequent operation corresponded to the individuals finding in-person assistance essential. Without additional support, these producers indicated abandonment of the program. On the other hand, the producers able to install and learn to operate the system after only one demonstration required little additional support. These producers believed their concerns could be addressed via phone support and operation of the program would not cease without routine in-person support.

A primary concern of producers prior to implementing the program was their computer ability. To determine the effect computer ability has on successful use of feed management software, producers were asked to rate their computer ability on a scale of 1 to 5, 5 being best. The frequency distribution of responses to this question can be found in q14 of Figure 18. Six of 9 rated their ability below 3. However, no correlation was found between computer ability and the frequency of installation or operational problems. The greatest challenge to implementation was actually related to employee training (5 of 9) rather than computer operation and most problems resulted from operator error (4 of 9).

Overall satisfaction with the program after 2 to 9 months of use was also of interest. Initial expectations of greater knowledge of operator accuracy and improvements in feeding management from the program were either met or exceeded in all situations (q26 of Figure 18). Likewise, all producers indicated willingness to reinvest if given the opportunity and would recommend this software to other producers (q23 of Figure 17). However, it is important to note that producers were given a subsidy of $1,600 for a portion of the total program cost of approximately $3,000 for agreeing to participate in the project. A subsequent question assessing willingness to invest if purchased at full cost revealed that 4 of 9 were unsure or would not invest without the subsidy (q24 in Figure 17). This signifies that improvements made from the program were not perceived to justify the full cost in all situations. Slightly contradictory to this hesitation, all but one producer believed feed management software was an economically beneficial investment (q22 in Figure 17).

Conclusions

Overall, producers were satisfied with operation and information available from feed management software. A positive correlation was observed between changes to the feed program and improvements in ration consistency. Additionally, lower farm N balance was associated with and lower farm P balance tended to be related to improved ration consistency. Economic benefits were acknowledged, but uncertainty existed that benefits outweighed costs.

The degree of satisfaction is largely thought to be a function of the extent of use of the program. As producers become more familiar with features of the program, satisfaction is expected to further increase. The lack of changes in purchased feed is associated with inadequate use of the program to make changes in feeding management. It is thought that feed losses from shrink and overfeeding can be reduced if the information is used to actively change feeding procedures; consequently, the amount of feed used should decline. Likewise, additional improvements in ration consistency are possible from more accurate and precise feed mixing. Perceptions of the economic benefits as well as overall satisfaction are expected to continue to improve as producers gain more experience with feed management software. Continued observation of these herds is needed to document long-term success of the program on Virginia dairies.

Table 22. Sample of TMR Tracker operational questionnaire.

TMR Tracker Survey

Operational assessment

1. How often do you look at reports in TMR Tracker?
    a. Daily
    b. Weekly
    c. Monthly
    d. Other: ____________________________
2. What information is most valuable to you in the program?
3. Do you use TMR Tracker for (circle all that apply):
    a. Inventory control
    b. Controlling shrink
    c. More accurate feed cost estimates
    d. Evaluating operator efficiency
    e. Other____
4. Has TMR Tracker improved your feeding management?
    a. Yes
        How? (improved accuracy, more efficient, decreased feeding time, improved record keeping, etc.)
    b. No
5. Have you made any changes to your feeding program as a result of TMR Tracker? If so, what?
6. Have you noticed a change in quantity of purchased feed following installation?
    a. Increase
    b. No change
    c. Decrease
    d. Do not know

    If a change has occurred, which feeds were impacted and how much?
7. Has ration consistency improved following use of TMR Tracker?
    a. Yes
    b. Unsure
    c. No
8. Do you estimate refusals? (Y/N) How much?
9. Who is responsible for updating information in the computer?
10. How would you rate your computer ability on a scale of 1 – 5?
    (1 = no knowledge and 5 = proficient)

Table 23. Sample of TMR Tracker installation and general questionnaire

Installation assessment.
Please rate the following on a scale of 1 to 5

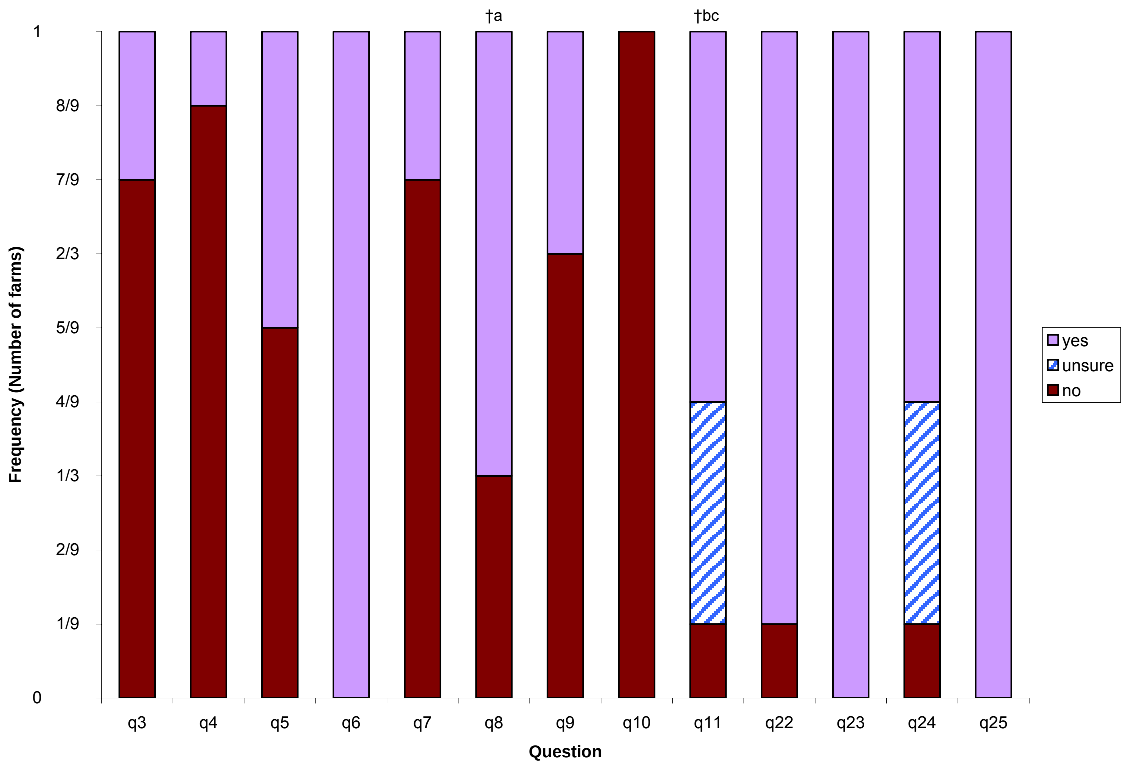
11. TMR Tracker software installation was simple	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
12. Installing and formatting the new indicator was easy	1	2	3	4	5
13. Learning to operate TMR Tracker software with the computer was easy	1	2	3	4	5
14. Learning to operate TMR Tracker with the indicator was easy	1	2	3	4	5
15. Regular in-person assistance was essential for me to continue to use TMR Tracker	1	2	3	4	5
16. The instruction manuals provided were useful	1	2	3	4	5
17. Phone support was effective in resolving problems	1	2	3	4	5
18. TMR Tracker software installation was simple	1	2	3	4	5

General Assessment

19. Do you believe purchasing feed management software is economically beneficial?
    a. Yes
    b. Unsure
    c. No
20. If you could go back, would you invest in TMR Tracker?
    a. Yes
    b. Unsure
    c. No
21. Would you invest in TMR Tracker if purchased at the full price ($3795 – $6509)?
    a. Yes
    b. Unsure
    c. No
22. Would you recommend this feeding management software to other dairy farmers?
    a. Yes
    b. No
23. How would you rate TMR Tracker as a feed management tool?
    a. 1 – does not meet any expectations
    b. 2 – does not meet some expectations
    c. 3 – meets expectations
    d. 4 – exceeds expectations
    e. 5 – far exceeds expectations
24. What has been the biggest challenge in implementing this program?
    a. Adapting to computer use
    b. Learning to use the indicator
    c. Training employees to use the new indicator
    d. Software problems
    e. Dedicating time to the program
    f. Other: ________________________________

What problems have you encountered when using TMR Tracker?

Figure 17. Frequency distribution for perception of feed management software survey responses to categorical yes/unsure/no questions.

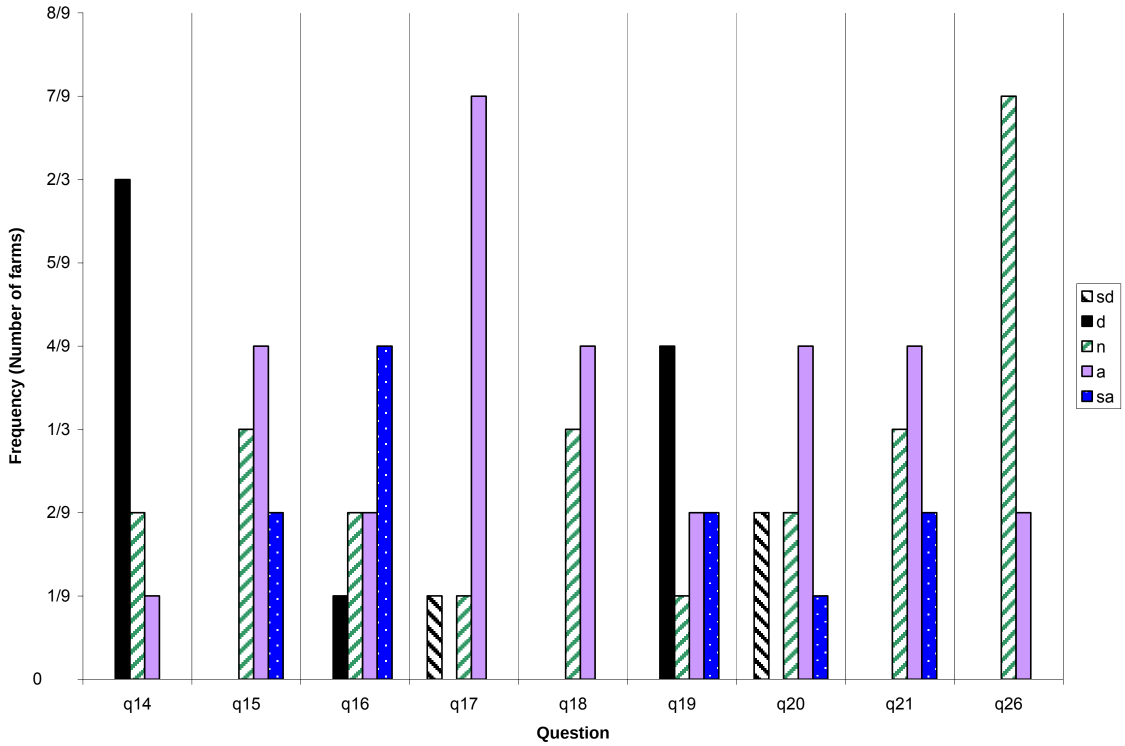


† Significant (P = 0.0092) correlation (r = 0.803) between improved feeding management and improved ration consistency
a Tendency (P = 0.1036) for farm N balance rank and farm P balance rank to be correlated (r = -0.577) with improved feeding management
b Significant (P = 0.0105) correlation (r = -0.795) between farm N balance rank (high, medium, low) and improved ration consistency
c Tendency (P =0.0903) for farm P balance rank to be correlated (r = -0.596) with improved ration consistency

Question:

Q3: Used for inventory control
Q4: Used for shrink management
Q5: Used to obtain accurate feed cost estimates
Q6: Used to monitor operator efficiency
Q7: Used to estimate DMI
Q8: Feeding management improved
Q9: Changes made in feeding program
Q10: Quantity purchased feed changed
Q 11: Ration consistency improved
Q22: Program is economically beneficial
Q23: Would invest in program again
Q24: Would invest in program at full price
Q25: Recommend program to other dairymen

Figure 18. Frequency response to perceptions of feed management software survey questions with a five point scale.



Scale:

SD: strongly disagree
D: disagree
N: neutral
A: agree
SA: strongly agree

Question:

Q14: Computer ability rating (SD = no knowledge, SA = proficient)
Q15: Software installation was simple
Q16: Indicator installation was simple
Q17: Software was easy to operate
Q18: Indicator was easy to operate
Q19: In-person assistance was essential
Q20: Instruction manuals provided were useful
Q21: Phone support was effective in resolving problems
Q26: Feed management tool rating (SD = met no expectations, SA = far exceeds expectations

Chapter 6: Financial Impact of Feed Management Software

Objectives

Determine the financial impact of feed management software implementation using standard milk and feed prices across all farms. Develop dynamic tools for use by producers to discern potential financial impacts of increased feed precision.

Materials and Methods

Prices used for calculation of income over feed cost (**IOFC**) were standardized across all farms. Standard feed prices for grain and byproduct feeds were obtained from the December 24, 2006 issue of *Feedstuffs (Feedstuffs)*. Costs associated with the production of homegrown forages were assigned using the average price/ton reported by all producers. The December 2006 Class I milk price of $18.12/cwt reported by Maryland-Virginia Milk Producer's Association (MD-VA, 2006) was used to calculate income for all farms.

Monthly IOFC were calculated by month of feed management software use, with one month equaling 30 d of use. The PROC MEANS procedure of SAS (2006) was used to sum total feed weights by ingredient and total milk production for each 30 d period by month. Unequal days used for each 30 d period of feed management software use and month necessitated division of feed used and milk sold by the number of days in each combination. The daily averages were multiplied by 30. Standardized feed prices were imported from Excel into SAS and merged by feed ingredient with monthly feed usage. A variable was created for monthly feed cost and calculated by multiplication of the quantity of feed used per 30 d by the respective feed cost. Likewise, income for each 30 d period was computed by multiplication of milk shipped by the standard milk price. PROC MEANS was subsequently utilized to sum total feed cost and income for each month. A variable for IOFC was equal to total milk income minus total feed cost for each 30 d period.

An Excel spreadsheet (Figure 21) was developed to determine the potential feed savings generated from use of feed management software. The spreadsheet was designed to allow flexible input by the user including: lactating herd size, TMR fed (lbs/cow/d), cost of lactating ration ($/cow/d), loads mixed (#/d), DM content of the ration (% of as-fed), use of refusals for heifers (yes/no), TMR fed (lbs/heifer/d), number of heifers fed, cost of a heifer ration ($/heifer/d), software cost ($/system), discount rate (%/yr), maintenance and labor cost ($/yr), and years of system life. These variables were then incorporated into the spreadsheet to determine the potential cost or benefit of feed management software with these parameters. Cost savings per day were calculated based on current load deviations without feed management software and expected load deviations after implementation of the software. Additionally, a payback period (mo) was calculated based on current and expected load deviations entered by the operator.

Several assumptions were made in developing the feed savings spreadsheet. First, it was assumed that the pounds TMR fed/cow/d represented the optimal intake to achieve desired production based on a balanced ration.

Furthermore, each 1 pound decrease in pounds fed per cow under the optimum intake was associated with a 2.9 pound decrease in milk production. However, overfeeding was not credited with increased production; it was determined that feeding above the optimal intake would result in increased refusals, but not production increases. Finally, the quality and DM of refusals presented to heifers was assumed to be equivalent to the original TMR. In actuality, refusals have a higher DM content due to exposure to air and reduced nutrient value due to cow sorting compared to the original TMR. The impact of more ration consistency was not quantified in this simulation.

Statistical Analysis

Data were analyzed for changes in IOFC throughout the study using PROC MIXED procedure of SAS (SAS, 2006). Farm, period of software use, and month were included in the class statement, with farm random while period of software use and month were fixed. The model used is described in more detail below. Significance was declared at $P < 0.05$ and trends at $P < 0.10$.

$$Y_{ijk} = \mu + T_i + F_j + M_k + TF_{ij} + TM_{jk} + FM_{jk} + E_{ijk}$$

Y_{ijk} = IOFC for the ith 30 d period for farm j in month k

μ = mean

T_i = fixed effect of ith 30 d period of software use,

$i = 1,2,3,\ldots 7$

F_j = random effect of jth farm on monthly IOFC, $j = 1,2,3,\ldots 10$

M_k = fixed effect of kth month of year while using software,

$k = 4,5,6,\ldots 12$

TF_{ij} = random interaction effect of ith period and jth farm

TM_{ik} = fixed interaction effect of ith period and kth month of year

FM_{jk} = random interaction of jth farm and kth month of year

E_{ijk} = random error term for kth month in ith period and jth farm

Results and Discussion

Month of year influenced IOFC, with maximum production occurring in April 2006 and a steady decline for the remainder of the calendar year (Figure 19). This coincides with peak production typically observed during late spring or early summer. A large proportion of dairy cows in Virginia calve in spring, leading to maximum production from April to June as observed in this study.

No effect of period of feed management software use on monthly IOFC was observed (Figure 20). These results conflict with the observation of Tylutki et al. (2004) of 50% reductions in purchased feed cost per 45.4 kg milk resulting from precision feeding strategies. However, values reported for Tylutki et al. (2004) represented a 5-year intensive study on only one dairy and reflected dietary modifications to increase use of homegrown forage. Changes in IOFC as use of software increased were not anticipated in this study given the lack of substantial changes to feeding programs and absence of changes in overfeeding observed throughout the study.

Figure 21 displays potential costs and benefits of feed management software. Maximum benefit as displayed in this figure is achieved by increased feeding to the optimal level (indicated by zero pounds deviation) in the scenario where current feeding deviation is negative. The magnitude of savings appears greater for underfeeding situations due to the inclusion of milk production increases as optimal feeding is accomplished. A limitation of this spreadsheet is no corresponding adjustment for any production or health impacts from overfeeding. Improvement of this tool requires incorporation of such parameters. It is suggested that benefits from improved ration consistency in terms of changes in milk production and health impacts be quantified and included in the cost savings formulas. This will require additional data on milk production response and the incidence of metabolic diseases associated with changes in ration consistency. A more complete reflection of cost savings would also include adjustments for changes in shrink facilitated by use of feed management software.

Conclusions

Standardization of feed and milk prices for calculation of IOFC prevented influence of external factors unrelated to feeding precision from influencing the data. The IOFC values reported are reflective of changes in milk production and feed usage only. Consequently, these results indicate there was no difference in feed use as month of software use progressed. Furthermore, differences in mean milk production did not result from use of the software. Realization of economic improvements from feed management software will require active changes to the feeding program utilizing the information in the program. This may necessitate changes in the types of feed used, feed storage, loading equipment, and additional training or reassignment of feeders. Refinement of the spreadsheet tool developed may provide assistance for producers in determining potential profitability of feed management software. Changes desired in the spreadsheet tool include allowances for changes in milk production and metabolic diseases as ration consistency improves and inclusion of an adjustment for changes in shrink associated with software use.

Figure 19. Income over feed cost LS means for April - December 2006

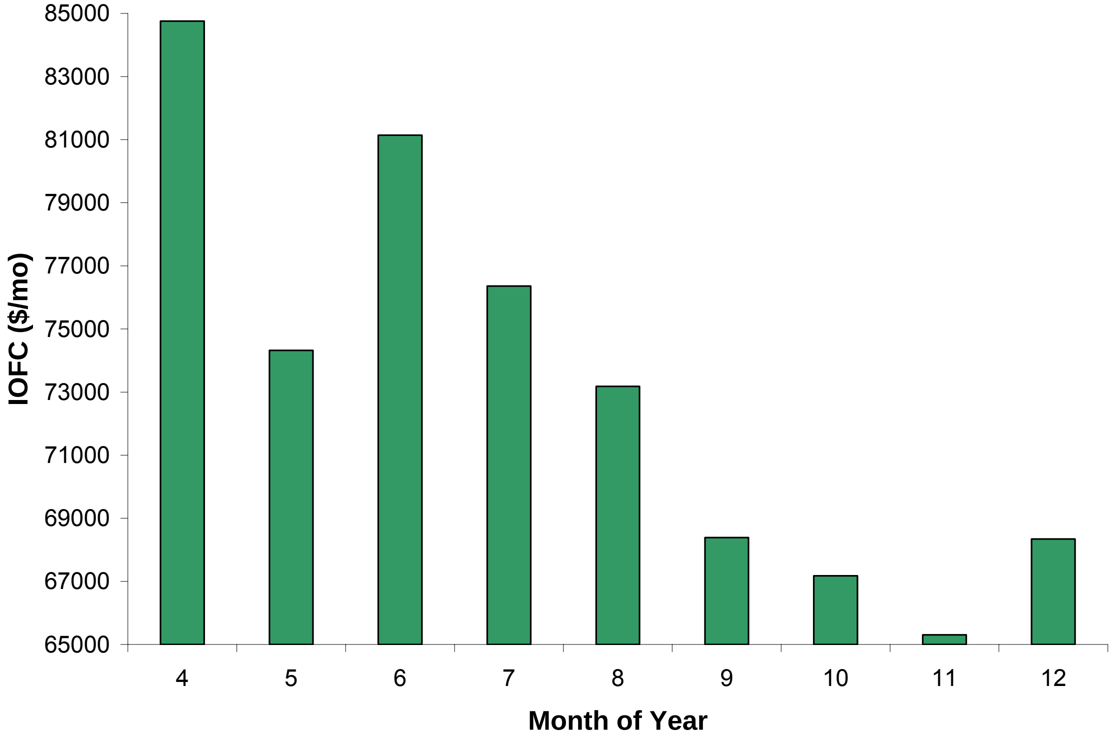


Figure 20. Income over feed cost LS Means for each 30 day period of feed management software use

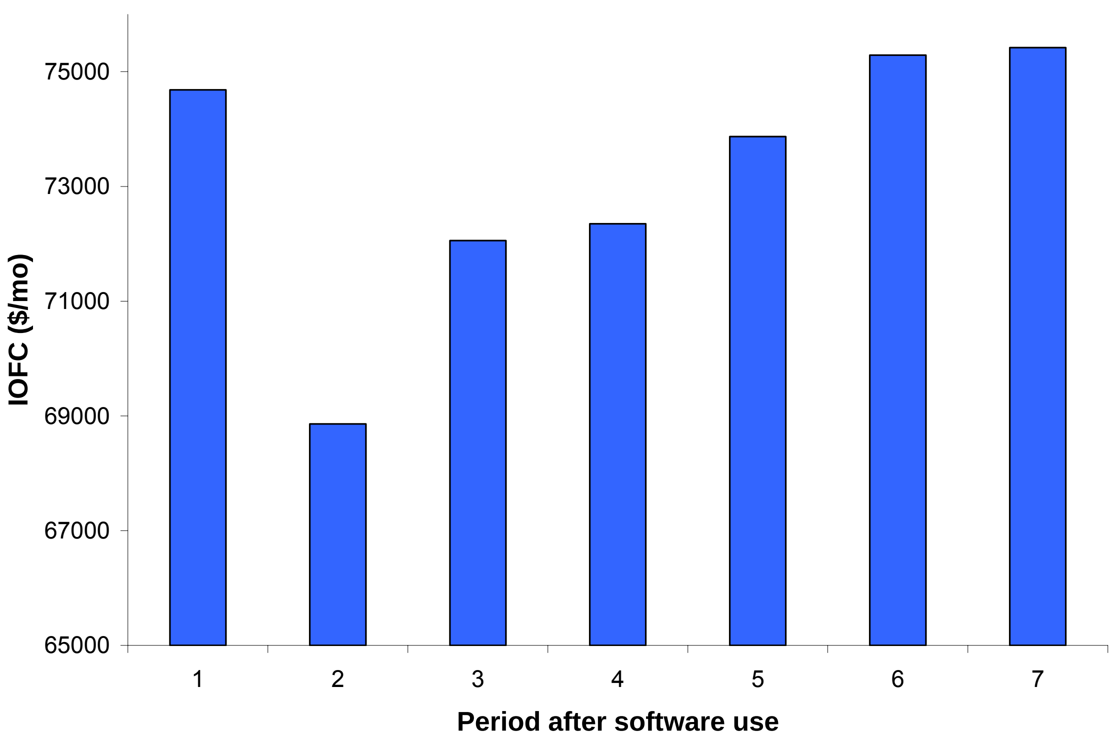


Figure 21. Cost and benefits Excel spreadsheet for feed management software.

Feed Management Software Profitability Analysis

**Cells in blue require user input

Ration Cost and Milk Price	
Ration cost($/cow/d)	3.5
Milk price ($/cwt)	16.5
Heifer ration cost	1.5

Software expenses	
Software cost ($)	5000
MARR (% annually)	0.06
Years of life	9
Maintanence and labor	100

Deviations should match those in the chart below

Payback period (mo)	
Current deviation	200
Desired deviation	100
$ saved per day	7.11
Payback period (mo)	17

Heifer Feeding Information	
Refusals fed to heifers yes=1 no=0	1
lbs TMR/heifer/d	20
% of feed from lactating refusals	50
Heifers to feed	80

Lactating Cow Feeding Information	
lbs TMR/cow/d	110
Milk cows fed	100
Number loads/d	2
DM (%)	50

Assumptions:
1. TMR consumption reported is balanced to provide optimal production.
2. Refusals fed to heifers have the same DM and quality as the original TMR.
3. Each 0.35 lbs. DM fed below optimum reported results in 1.0 lbs. decrease in milk production

Limitations:
1. Does not account for production increases due to increased consistency.

Daily Savings ($/d) from Software Use

Current Deviation Load deviation (lbs/load) without software	Desired Deviation Load deviation (lbs/load) with software: -100	-50	0	50	100	150	200	250
-100	0.00	20.39	40.78	14.78	11.59	8.41	5.23	2.05
-90	(4.08)	16.31	36.70	13.06	9.87	6.69	3.51	0.33
-80	(8.16)	12.23	32.62	11.33	8.15	4.97	1.79	(1.39)
-70	(12.23)	8.16	28.55	9.61	6.43	3.25	0.07	(3.11)
-60	(16.31)	4.08	24.47	7.89	4.71	1.53	(1.65)	(4.83)
-50	(20.39)	0.00	20.39	6.17	2.99	(0.19)	(3.37)	(6.56)
-40	(24.47)	(4.08)	16.31	4.45	1.27	(1.91)	(5.09)	(8.28)
-30	(28.55)	(8.16)	12.23	2.73	(0.45)	(3.63)	(6.81)	(10.00)
-20	(32.62)	(12.23)	8.16	1.01	(2.17)	(5.35)	(8.54)	(11.72)
-10	(36.70)	(16.31)	4.08	(0.71)	(3.89)	(7.07)	(10.26)	(13.44)
0	(40.78)	(20.39)	0.00	(3.18)	(6.36)	(9.55)	(12.73)	(15.91)
10	(40.89)	(20.50)	(0.11)	(1.80)	(4.98)	(8.16)	(11.34)	(14.52)
20	(40.26)	(19.87)	0.52	(1.16)	(4.34)	(7.52)	(10.70)	(13.89)
30	(39.62)	(19.23)	1.16	(0.52)	(3.70)	(6.89)	(10.07)	(13.25)
40	(38.98)	(18.59)	1.80	0.11	(3.07)	(6.25)	(9.43)	(12.61)
50	(38.35)	(17.96)	2.43	0.75	(2.43)	(5.61)	(8.80)	(11.98)
60	(37.71)	(17.32)	3.07	1.39	(1.80)	(4.98)	(8.16)	(11.34)
70	(37.07)	(16.69)	3.70	2.02	(1.16)	(4.34)	(7.52)	(10.70)
80	(36.44)	(16.05)	4.34	2.66	(0.52)	(3.70)	(6.89)	(10.07)
90	(35.80)	(15.41)	4.98	3.30	0.11	(3.07)	(6.25)	(9.43)
100	(35.17)	(14.78)	5.61	3.93	0.75	(2.43)	(5.61)	(8.80)
110	(34.53)	(14.14)	6.25	4.57	1.39	(1.80)	(4.98)	(8.16)
120	(33.89)	(13.50)	6.89	5.20	2.02	(1.16)	(4.34)	(7.52)
130	(33.26)	(12.87)	7.52	5.84	2.66	(0.52)	(3.70)	(6.89)
140	(32.62)	(12.23)	8.16	6.48	3.30	0.11	(3.07)	(6.25)
150	(31.98)	(11.59)	8.80	7.11	3.93	0.75	(2.43)	(5.61)
160	(31.35)	(10.96)	9.43	7.75	4.57	1.39	(1.80)	(4.98)
170	(30.71)	(10.32)	10.07	8.39	5.20	2.02	(1.16)	(4.34)
180	(30.07)	(9.69)	10.70	9.02	5.84	2.66	(0.52)	(3.70)
190	(29.44)	(9.05)	11.34	9.66	6.48	3.30	0.11	(3.07)
200	(28.80)	(8.41)	11.98	10.30	7.11	3.93	0.75	(2.43)
210	(28.17)	(7.78)	12.61	10.93	7.75	4.57	1.39	(1.80)
220	(27.53)	(7.14)	13.25	11.57	8.39	5.20	2.02	(1.16)
230	(26.89)	(6.50)	13.89	12.20	9.02	5.84	2.66	(0.52)
240	(26.26)	(5.87)	14.52	12.84	9.66	6.48	3.30	0.11
250	(25.62)	(5.23)	15.16	13.48	10.30	7.11	3.93	0.75
260	(24.98)	(4.59)	15.80	14.11	10.93	7.75	4.57	1.39
270	(24.35)	(3.96)	16.43	14.75	11.57	8.39	5.20	2.02
280	(23.71)	(3.32)	17.07	15.39	12.20	9.02	5.84	2.66
290	(23.07)	(2.69)	17.70	16.02	12.84	9.66	6.48	3.30
300	(22.44)	(2.05)	18.34	16.66	13.48	10.30	7.11	3.93

Project Synopsis

Precision feeding management was not found to impact whole farm nutrient balance on nine Virginia dairy farms. Deviations of actual kilograms fed from kilograms of feed desired on these farms were documented at 173 ± 163kg/d, indicative of routine overfeeding. Milk production was found to decrease in association with increased total kg overfed and kg CP overfed; however, increases were observed as kg P increased, confounded with increased NEL in association with higher P. No effect of feeding management software was observed on reductions in feeding deviation or on IOFC for the first 7 mo post software installation for the six farms using software for at least 6 mo.

Findings indicate the need for active changes to the feeding program based on data from feed management software in order for effects in feed savings to be realized. Suggested changes may include but are not limited to development of improved training protocols, routine operator evaluation, alternative handling of ingredients, and development of SOP for the feeding program. Additionally, use of SOP and process control measures consistent with six sigma protocol are warranted to improve feeding management. Continued observation of the 9 farms with installed feed management software should focus on utilization of information to accomplish these goals.

Appendix

Appendix Table 1. Treatment [†] group herd profiles.

Farm	Herd size (lactating cows)	BW (kg)	Average Production (lbs/cow/d)	Bedding Used	NMP (Y/N)	Lactating Groups		Housing		Manure storage	
						Description	Number	Description	Number	Type	Capacity (Gal)
1	295	660	33.6	Sand	Y	High	88	Freestalls	250	Earthen	1.2 mill
						Mid	80	Pack barn		lagoon	
						Low	65				
						Lot	65				
2	385	682	34.9	Sand	Y	Fresh - 90d	90	Freestalls	384	Concrete	832,500
						Breeding	110			lagoon	
						High SCC	75				
						Pregnant	105				
						Treated	5-8				
3	135	600	26.3	Shavings	Y	Milking	135	Freestalls	142	Earthen	900,000
										lagoon	
4	355	636	28.9	Sawdust	Y	Fresh	27	Freestalls	340	Earthen	
				Sand		High	120			lagoon	
						Low	75			Concrete	
						Middle	118			pit	
										Slate barn	
5	290	636	25.9	Chopped	Y	Mid lact	83	Freestalls	225	Concrete	1.6 mill
				newspaper		<50 lbs.&P	179	Pack barn	135x50	Pit	
				Straw		Post fresh	31			Earthen	750,000
				Shavings						lagoon	
6	165	614	30.3	Sawdust	Y	Fresh	18	Pack barn		Concrete	1.7 mill
				Straw		Main herd	139	Freestalls	170	Earthen	1 mill
8	200	636	29.3	Sawdust	Y	Post fresh	30	Freestalls	258	Concrete	822,000
						High	100				gal.
						Low	70				
9	210	636	34.5	Sawdust	Y	Pregnant	100	Freestalls	250	Earthen	750,000
						Fresh/breeding	100				gal.
						Sick	10	Pack barn	30x30		
10	360	636	32.2	Sawdust	Y	High	135	Freestalls	300	Earthen	
						Low	110				
						Heifer	115				

[†]Treatment = farms installing feed management software

Appendix Table 2. Treatment† group feeding group profile.

Farm	TMR (Y/N)	Number TMR fed	Ration Evaluation	DM Adj (Y/N)	Record Refusals (Y/N)	Feeding Frequency (times/d)	Time required (min)		Perceived Error (%)		Number Operators		Mixer
							Loading	Delivery	Loading	Delivery	Total	Primary	
1	Y	2	Feed analyses	Y	N	2	20	10	<10	-	3	1	Harsh 375
2	Y	2	Visual	Y	N	3	15	15	<1	-	1	1	Knight
3	Y	1	Visual	Y	N	2	60	10	<1.5	-	3	2	Knight Reel Augie 3450
4	Y	1	Monthly analyses Bimonthly nutritionist Penn State Shaker box	Y	N	2	30	30	-	-	2	1	Knight Reel
5	Y	3	TMR analyses Penn State Shaker box	Y	N	2 (mid) 1 (post fresh, <50)	30	-	<5	<5	1	1	Oswald
6	Y	2	Visual Penn State shaker box	N	N	2 (main herd) 1 (fresh)	30	10	20	-	3	2	Harsh Monomix
8	Y	2	Feeding time monitored Monitor milk weights	N	N	2	15	5	2.5	-	3	1	Rotomix
9	Y	1	Penn State shaker box every 60d	Y	N	3	20	10	-	-	3	3	Luck-now
10	Y	2	Visual	Y	N	2	1	5	-	-	2	1	Knight Reel Augie

† Treatment = farms installing feed management software

Appendix Table 3. TMR Tracker installation date

Farm	Installation Date	Months Used
1	10/26/2006	2
2	11/01/2006	2
3	06/13/2006	7
4	06/06/2006	7
5	06/27/2006	6
6	05/12/2006	8
8	04/20/2006	9
9	09/20/2006	3
10	06/13/2006	7

Works Cited

Arosemena, A., E. J. DePeters, and J. G. Fadel. 1995. Extent of variability in nutrient composition within selected by-product feedstuffs. Anim. Feed Sci. Technol. 54:103-120.

Bertrand, J. A., J. C. Fleck, and J. C. McConnell, Jr. 1999. Phosphorus intake and excretion on South Carolina dairy farms. Prof. anim. sci. 15(4):264-267.

Boesch, D. F., R. B. Brinsfield, and R. E. Magnien. 2001. Chesapeake Bay eutrophication: scientific understanding, ecosystem restoration, and challenges for agriculture. J environ. qual. 30(2):303-320.

CBP. 1999. Subject: Chesapeake 2000. http://purl.access.gpo.gov/GPO/LPS22937 This resource online Accessed April 26, 2007.

Cerosaletti, P. E., D. G. Fox, and L. E. Chase. 2004. Phosphorus reduction through precision feeding of dairy cattle. J. Dairy Sci. 87(7):2314-2323. Online. Available: http://jds.fass.org/cgi/content/abstract/87/7/2314

Chesapeake Executive Council. 1987. 1987 Chesapeake Bay Agreement : final draft. Chesapeake Executive Council, S.l.

Cornwell, J. C., D. J. Conley, M. Owens, and J. C. Stevenson. 1996. A sediment chronology of the eutrophication of Chesapeake Bay. Estuaries. 19:488-499.

Davidson, S. G., J. G. Merwin, Jr., J. Capper, G. Power, and F. R. Shivers, Jr. 1997. Chesapeake waters: four centuries of controversy, concern, and legislation. Tidewater Publ.

DCR. 2006. Subject: Virginia agricultural BMP manual. http://192.206.31.57/agbmpman/toc.pdf. Accessed February 26, 2007.

DEQ. 2007. Subject: Confined animal feeding operations. http://www.deq.state.va.us/vpa/cafo.html. Accessed February 26, 2007.

Dou, Z., J. D. Ferguson, J. Fiorini, and J. D. Toth. 2003. Phosphorus feeding levels and critical control points on dairy. J. Dairy Sci. 86(11):3787-3795.

Eckes, G. 2000. The six sigma revolution: how General Electric and others turned process into profits. John Wiley & Sons, Inc., New York, NY.

eFOTG. 2001. Subject: Field Office Technical Guides. http://efotg.nrcs.usda.gov/treemenuFS.aspx. Accessed February 26, 2007.

Fediol. 2002. Subject: Code of practice for the manufacturing of feed materials from oilseed crushing and refining plants. http://www.scopa.org.uk/PDF%20files/crushing%20and%20refining.pdf. Accessed April 20, 2007.

Feedstuffs. Ingredient market. Feedstuffs. 78.53(53):21.

Foundation, C. B. 2003. Subject: Water Pollution in the Chesapeake Bay. http://www.cbf.org/site/PageServer?pagename=resources_facts_water_pollution. Accessed February 26, 2007.

Glibert, P. M., R. Magnien, M. W. Lomas, J. Alexander, C. Fan, E. Haramoto, M. Trice, and T. M. Kana. 2001. Harmful algae blooms in the Chesapeake Bay and coastal bays of Maryland, USA: comparison of 1997, 1998, and 1999 events. Estuaries. 24(6A):875-883.

Havlin, J. L., J. D. Beaton, S. L. Tisdale, and W. L. Nelson. 2005. Soil fertility and fertilizers: an introduction to nutrient management. 7th ed. Pearson Prentice Hall, Upper Sadle River, NJ.

Hoyle, D. 2001. ISO 9000 Quality Systems Handbook. 4th ed. Butterworth-Heinemann, Woburn, MA.

Hutson, J. L., R. E. Pitt, R. K. Koelsch, J. B. Houser, and R. J. Wagenet. 1998. Improving dariy farm sustainability. II: environmental losses and nutrient flows. Prod. Agri. 11(2):233-239.

Jonker, J., S., R, A. Kohn, and J.High. 2002. Dairy herd management practices that impact nitrogen utilization. J. Dairy Sci. 85(5):1218-1226.

Kertz, A. F. 1998. Variability in delivery of nutrients to lactating dairy cows. J. Dairy Sci. 81(11):3075-3084.

Klausner, S. D., D. G. Fox, C. N. Rasmussen, R. E. Pitt, T. P. Tylutki, P. E. Wright, L. E. Chase, and W. C. Stone. 1998. Improving dairy farm sustainability. I. An approach to animal and crop nutrient managment planning. Prod. agri. 11(2):225-233.

Koelsch, R., ed. 2002. Estimating a whole farm nutrient balance. Vol. 2007. University of Nebraska. http://cnmp.unl.edu/1WholeFarmBalance.xls.

Koelsch, R. 2005. Evaluating livestock system environmental performance with whole-farm nutrient balance. J. Environ. Qual. 34(1):149-155.

Kohn, R. A., Z. Dou, J. D. Ferguson, and R. C. Boston. 1997. A sensitivity analysis of nitrogen losses from dairy farms. J. Environ. Management. 50(4):417-428.

Kumar, R. 2003. Understanding the fundamental and implementation of six sigma concepts: experience at Mother Dairy, Gandhinagar. Indian Dairyman. 55(3):112-116.

Lopez, H., F. D. Kanitz, V. R. Moreira, L. D. Satter, and M. C. Wiltbank. 2004a. Reproductive performance of dairy cows fed two concentrations of phosphorus. J. Dairy Sci. 87(1):146-157. Online. Available: http://jds.fass.org/cgi/content/abstract/87/1/146

Lopez, H., F. D. Kanitz, V. R. Moreira, M. C. Wiltbank, and L. D. Satter. 2004b. Effect of dietary phosphorus on performance of lactating dairy cows: milk production and cow health. J. Dairy Sci. 87(1):139-145. Online. Available: http://jds.fass.org/cgi/content/abstract/87/1/139

MD-VA. 2006. Subject: Monthly Market Report. https://www.mdvamilk.com/MMR/Dec06MMR.pdf. Accessed March 30, 2007.

Messick, E. H., R. B. Rotz, J. G. Baab, and K. S. Wyatt. 2004. Subject: Review of nutrient management planning in Virginia. http://jlarc.state.va.us/Meetings/November04/nutriclr.pdf. Accessed February 26, 2007.

NRC. 2001. Nutrient Requirements of Dairy Cattle. 7 ed. National Academy Press, Washington D. C.

O'Sullivan, M. 1994. ISO 9000: what can it do for dairies. Modern Dairy:15-17.

Ott, L., and M. Longnecker. 2001. An introduction to statistical methods and data analysis. Vol. 5. Duxbury, Pacific Grove, CA.

Pande, P., and L. Holpp. 2002. What is six sigma? McGraw-Hill, New York, NY.

Parsons, R. L. 1995. Financial costs and economic tradeoffs of alternative manure management policies on dairy and dairy/poultry farms in Rockingham County, Virginia. Virginia Polytechnic Institute and State University, Blacksburg.

Rotz, C. A., A. N.Sharpley, L. D. Satter, and W. J. Gburek. 2002. Production and feeding strategies for phosphorus management on. J. Dairy Sci. 85(11):3142-3153.

SAS. 2006. Base SAS 9.1.3 procedures guide. 2nd ed. SAS Pub., Cary, NC.

Service, N. R. C. 2007. Subject: Environmental quality incentives program. http://www.nrcs.usda.gov/programs/eqip/. Accessed February 26, 2007.

Sharpley, A. N. 2000. Agriculture and phosphorus management : the Chesapeake Bay. Lewis Publishers, Boca Raton, Fla.

Sink, S. E., K. F. Knowlton, and J. H. Herbein. 2000. Economic and environmental implications of overfeeding phosphorus on Virginia dairy farms. J. Dairy Sci. 83(Supp.1):143.

Sniffen, C. J., R. W. Beverly, C. S. Mooney, M. B. Roe, A. L. Skidmore, and J. R. Black. 1993. Nutrient requirements versus supply in the dairy cow: strategies to account for variability. J. Dairy Sci. 76(10):3160-3178.

Spears, R. A., R. A. Kohn, and A. J. Young. 2003. Whole-farm nitrogen balance on western dairy farms. J. Dairy Sci. 86(12):4178-4186.

St. Pierre, N. R., and W. R. Harvey. 1986. Uncertainity in composition of ingredients and optimal rate of success for a maximum profit total mixed ration. J. Dairy Sci. 1986(69):12.

Tylutki, T., P., D, G. Fox, and M. McMahon 2004. Implementation of nutrient management planning on a dairy farm. Prof. Ani. Sci. 20(1):58-65.

USGS. 1999. Monitoring nutrients in the major rivers draining to Chesapeake Bay. Water resources investigations report 99-4238. Online. Available: http://va.water.usgs.gove/online_pubs/WRIR/wrir_99_4238_text.pdf.

Valk, H., and L. B. J. Sebek. 1999. Influence of long-term feeding of limited amounts of phosphorus on dry matter intake, milk production, and body weight of dairy cows. J. Dairy Sci. 82(10):2157-2163.

VanDyke, L. S., J. W. Pease, D. J. Bosch, and J. C. Baker. 1999. Nutrient management planning on four Virginia livestock farms: impacts on net income and nutrient losses. J. Soil and Water Conservation 54.2:499.

VGA. 2003. Implementation of the Chesapeake Bay Preservation Act : report of the Joint Legislative Audit and Review Commission to the Governor and the General Assembly of Virginia. in Virginia General Assembly Joint Legislative Audit Review Commission. Commonwealth of Virginia, Richmond.

Weiss, W. P. 2004. Variation exists in composition of concentrate feeds. Feedstuffs. 76.19:11-13,23.

Wildman, E. E., G. M. Jones, P. E. Wagner, R. L. Boman, H.F. Troutt, Jr., and T. N. Lesch. 1982. A dairy cow body condition scoring system and its relationship to selected production characteristics. J. Dairy Sci. 65:495-501.

Wu, Z., L. D. Satter, R. Sojo. 2000. Milk production, reproductive performance, and fecal excretion of phosphorus by dairy cows fed three amounts of phosphorus. J. Dairy Sci. 83(5):1028-1041.

Vita

Beverly Cox originated from the rural community of Riner, Virginia where she was raised on a family-owned dairy and beef operation. In May 2002 she graduated as valedictorian from Auburn High School. Subsequently, Beverly attended Virginia Tech beginning Fall 2002 as a double major in Dairy Science and Animal and Poultry Sciences. Three years later in May 2005 she graduated with a Bachelors of Science with honors from the College of Agriculture and Life Sciences. It was at this time that Beverly determined a career in dairy nutrition was of interest, leading to enrollment as a graduate student in the Department of Dairy Science under the direction of Dr. Bob James. In May 2007, Beverly graduated with a Master's of Science focusing on dairy cattle nutrition management after defending on April 13, 2007. Future career goals revolve around consulting positions as either an extension agent or dairy nutritionist.