MANAGEMENT EFFECTS ON NUTRIENT AVAILABILITY FROM DAIRY HEIFER MANURE

John Peters[1], Patrick Hoffman[2] and Michael Bertram[3]

Background

Wisconsin dairy producers and heifer growers rear over one million dairy replacement heifers at a cost of 825 million dollars annually. In addition, Wisconsin dairy heifers annually consume 18 million tons of feed and produce 61 million tons of manure. For each individual dairy producer or heifer grower the management objective is to reduce cost and the environmental impact of rearing dairy replacement heifers without compromising future milk production. A new innovation in feeding dairy heifers is to limit-feed dairy heifers a more nutrient dense diet. Because heifers are fed less feed under limit feeding, feed cost and manure excretion are reduced simultaneously.

Research efforts with limit feeding have provided sufficient information for dairy producers and heifer growers to consider adopting limit-feeding management strategies. Limit feeding dairy heifers has been demonstrated to improve feed efficiency, while decreasing maintenance energy requirements and manure excretion. There is also evidence (Hoffman, et al., 2007, Kruse et al., 2010) that limit-feeding dairy heifers has no appreciable carry over effect on dry matter intake, rumen volume, reproduction or milk production. As a result, dairy producers have a solid animal performance research base in which to consider adoption of limit feeding strategies for dairy heifers.

However, limit-feeding alters manure excretion and manure nutrient density, but there is little information on the potential carryover effects of manure from limit-feed heifers on crop production systems. Although manure dry matter excretion is reduced, little is know about the nutrient composition of manure from limit fed heifers and whether it is, or can be, altered by limit-feeding. Data are required to address issues associated with soil fertility and plant nutrition that may be altered by limit-feeding.

Also, reducing or eliminating supplemental P in dairy heifer diets has been studied. Research conducted at the University of Wisconsin (Esser et al., 2009, Bjelland, et al. 2011) showed no animal production advantages to adding supplemental P to heifer diets. Feeding dairy heifers to specific P requirements resulted in the additional benefit of having less P in the manure that needs to be addressed through comprehensive nutrient management planning.

Finally, because recent data from the University of Wisconsin (Hoffman et al., 2007) suggest manure from limit-fed heifers may contain higher levels of nitrogen manure, amendments may be beneficial in dairy heifer management. Beltsville workers (Lefcourt and Meisinger, 2001) directly added 6.25% zeolite to dairy cattle manure and reduced ammonia emission by 50%. Because nitrogen volatilization losses from spreading manure on land are problematic (Jokela and Meisinger, 2008), decreased nitrogen volatilization from heifer manure may yield an additional economic benefit in cropping systems by reducing the need for purchased nitrogen fertilizer.

[1] Director, UW Soil Testing Laboratories and Extension Soil Scientist, Dept. of Soil Science, Madison, WI
[2] Professor, Department of Ag and Ag Business, Univ. of Wisconsin-Extension
[3] Superintendent, Marshfield Agricultural Research Station, Marshfield, WI

Methods and Materials

As part of a North Central regional research project (NC-1042) a series of studies were designed to evaluate the nutrient value of experimental dairy heifer manures in a traditional Wisconsin cropping system. The impact of zeolite addition and limit feeding on manure nutrient retention, in particular N retention, and their effect on N availability in the cropping system was also evaluated. In this study zeolite was applied to the bedding mixture in sufficient quantity so that the manure applied contained approximately 6.25% zeolite by weight. The exception was the one treatment where a double rate was applied (in the barn and at spreading) resulting in the manure containing 12.5% zeolite by weight.

Dairy heifers were managed at the Integrated Dairy Research Facility and field plots were established at the Agricultural Research Station both at Marshfield, WI. The benchmark soils in this predominantly dairy production area of north central Wisconsin are the Loyal and Withee silt loam series. In 2008, the trial was established on field that was predominantly Withee silt loam (fine-loamy, mixed, superactive, frigid Aquic Glossudalfs) and the 2009 site was on a Loyal silt loam (fine-loamy, mixed, superactive, frigid Oxyaquic Glossudalfs). Prior to the establishment of the study, soil samples were taken to measure background fertility levels. Soil samples were also taken at the end of the study to monitor any changes in soil test parameters. Plant tissue samples were taken at silking to help assess the nutrient status of the crop.

The assay crop was field corn as it has the highest N requirement of crops typically grown for dairy feed. The N requirement for corn in north central Wisconsin is approximately 120 lbs/a, which is based on University of Wisconsin recommendations, Laboski, et al. (2006). Corn was grown for two consecutive years to measure both the first and second year availability of the nutrients from the manure treatments. The trial was repeated on two separate field sites with the manure treatments applied in 2008 and 2009 and a second year of corn monitored on each of these locations in 2009 and 2010, respectively.

In all of the site years of the study, corn was planted at 35,000 plants/acre in four replicates of eleven treatments with each plot measuring 15 x 50 feet. The first year treatments included a control with no commercial N or manure, urea applied at a rate to provide 120 lb N/a with and without zeolite, 20 tons/a of fall applied manure from heifers fed a reduced diet (85% of normal) with and without zeolite added to the bedding, this same rate of manure from heifers fed a normal diet with and without zeolite added, 20 tons/a of spring applied heifer manure from a normal feeding regime with and without zeolite and two additional rates of commercial N fertilizer without zeolite. This last treatment was to ensure that adequate N was being supplied to the crop with the normal 120 lb N/a application. The 120 lb/a of N will be provided by commercial fertilizer or one of the manure treatments using the University of Wisconsin guidelines which credit 40% of the total N content of incorporated dairy manure as being available in the first year following application. The nutrient content of the experimental manures will be evaluated by the procedures of Peters (2003).

A second set of plots was established during year two of the study so that first and second year credits can be replicated by year. The second trial site had several modifications to this treatment protocol. Instead of having the limit fed heifer manure treatments, zeolite was added at the time of spreading of fall applied manure and another treatment included both an in the barn addition of zeolite as well as another dose added at the time of spreading of manure from full diet fed heifers. Also, the commercial N rates were reduced by 60 lb N/a for all treatments. This change was also made to the residual crop year (2009) for the first trial site.

In all years of the study there were eleven treatments each replicated four times in a randomized complete block design. In year one, ammonia emission was measured immediately after manure application using a method modified from Svensson (1994). Complete soil analysis were done at the beginning and conclusion of each trial. The field corn plots were harvested for corn silage and for grain yield. Pre treatment and post harvest soil samples were analyzed for organic matter, total N, pH, and available P, K, Ca, Mg, S, Zn, Mn, and B. All analyses were performed by the UWEX Soil and Forage Analysis Laboratory at Marshfield using methods described by Peters (2006).

Results and Discussion

The results of the dietary P phase of this North Central Regional Project 1042 suggest that feeding the NRC (2001) requirement of P to heifers is sufficient for heifer frame growth, health, reproductive efficiency, and lactation yield (Bjelland et al., 2011). This study is unique, as a large number (n=433) of heifers were examined, and detailed measurements were made on a variety of productive and reproductive criteria. Results from this study suggest that the excess P offered by many dairy producers to heifers is not required if endogenous P concentrations in the basal feeds are near NRC (2001) requirements. It also is evident from these results that excess P offered to heifers is not absorbed, and is simply excreted. Given that excess dietary P offered to heifers does not provide any growth or lactation benefits, and the excess P is simply excreted by the heifer, recommendations to limit P supplementation for growing heifers can be justified. However endogenous feed sources must contain adequate concentrations of P to meet NRC (2001) requirements.

Results from the limit-feeding phase of this NC-104 project indicate that limit feeding more nutrient-dense diets to gravid dairy heifers was an equally effective feeding management strategy to control caloric intake, as compared with feeding high-fiber forage diets. Limit feeding resulted in less total consumption of DM and increased feed efficiency, which could reduce the feed cost. In addition, no adverse effects on growth or subsequent lactation performance were observed when gravid heifers were limit fed more nutrient-dense diets. Although decreased manure dry matter excretion was observed, which is of benefit, no practical advantages associated with N and P excretion or utilization were observed. Additional investigations are warranted to investigate strategies to improve N and P utilization in limit-fed heifers.

There were no significant impacts of zeolite treatment on soil test parameters measured. Ear leaf tissue samples collected in the first year of the study indicate that treatments with commercial fertilizer were supplying more N to the crop than those with manure. The average ear leaf tissue N concentration where urea fertilizer had been applied was 2.36% and where manure had been used as the source of N the average ear leaf total N concentration was 1.94%. The dairy heifer manure used in the study was relatively low in estimated first year available N with values ranging from 2.5 lb/ton to 3.4 lb/ton with an average first year available N level for incorporated manure of 2.88 lb/ton. Also, the ammonium-N content of the manure was relatively low, ranging from approximately 20 to 25% of the total N. The manure was from a free stall heifer barn where wood shavings were used as the bedding base. As a result the manure collected for use in this field trial had a relatively high C:N ratio, ranging from 25:1 to 35:1. The high C:N ratio and relatively low ammonium-N content likely resulted in a slower than normal release of N from manure and resultant delay in availability to the crop. This was reflected by the lower N levels in ear leaf tissue when manure was the N source. Ammonia emissions as measured in the field in the first year of the study showed no consistent effect of treatment, so no further ammonia evaluations were done in the second trial.

Since treatments were modified during the course of the trial, a meta-analysis was conducted by SAS on all trial data. This allowed for the comparison of treatments across trial locations and years by utilizing trial as the replicate. Data from the two years of manure application was separated from the residual years to assess potential carryover effects of zeolite application on corn yield. This allowed for the comparison of zeolite treatment by N source (manure vs. fertilizer) in the year the manure was applied (Table 1) and then the effect of zeolite on corn yields in the year following manure application (Table 2).

Silage yields were significantly improved when nitrogen fertilizer was used as the N source as compared to heifer manure (Table 1). However, adding zeolite in the field at the time of urea application did not have any impact on yield. Grain yields were also higher when commercial fertilizer was used instead of manure but the differences were not significant at the Pr>F 0.10 level. The use of zeolite did not have a significant impact on corn yield nor was there a significant zeolite x N source interaction. It is interesting to note that in the first year of the study, corn grain yields where manure was applied were very similar to the zero N control, whereas in the 2009 trial, corn grain yields on the manure treatments were comparable to the commercial N treatments. This may be due to the better growing/mineralization conditions encountered in 2009 as well as that the 2009 site was a Loyal silt loam as compared to the Withee series that was used in 2008. The weather and more poorly drained nature of the Withee soil likely contributed to poorer N mineralization from applied manure.

In the year following application of manure, no effect of zeolite was seen on corn grain or silage yields (Table 2). Residual year yields of both corn grain and silage were considerably lower than in the year of manure application as no supplemental N was applied.

Summary

The use of zeolite mixed in with the bedding of manure collected from a free stall heifer facility or zeolite applied in the field at the time of manure or commercial fertilizer application had no significant impact on corn grain or silage yield in this study. With or without zeolite, yields of corn planted in 2008 were higher where commercial fertilizer was used instead of dairy heifer manure. The heifer manure used in this study was relatively low in total N and NH_4-N content with a relatively high C:N ratio. Combined with less ideal weather and a more poorly drained soil in 2008, this resulted in delayed mineralization and no doubt impacted yields negatively. This same effect was not seen in the study established in 2009 where fertilizer N and manure plot yields were quite similar. Finally, zeolite had no impact on corn yields in the year following application of the zeolite treated manure. Future field studies should explore the use of zeolite in liquid manure from mature dairy animals, which typically contains a higher level of total N and NH_4-N.

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Table 1. Effect of Zeolite treatments on first year corn yield.
Marshfield, WI 2008-2009.

Treatment	Trial site	Year	Corn silage t/a (DM)	Corn grain bu/a
Control - no manure or N fertilizer	1	2008	5.29	95.2
Commercial N, 90 lb/a, without zeolite	1	2008	6.30	119.5
Commercial N, 120 lb/ac, without zeolite	1	2008	5.93	123.6
Commercial N, 120 lb/a, with zeolite in field	1	2008	6.47	121.4
Commercial N, 150 lb/a, without zeolite	1	2008	6.56	132.5
Spring manure, full feed, without zeolite	1	2008	4.39	79.6
Spring manure, full feed, with zeolite in barn	1	2008	4.79	80.5
Fall manure, limited feeding, without zeolite	1	2008	4.75	96.0
Fall manure, limited feeding, with zeolite in barn	1	2008	4.49	128.4
Fall manure, full feed, without zeolite	1	2008	4.16	84.7
Fall manure, full feed, with zeolite in barn	1	2008	4.88	92.5
Control - no manure or N fertilizer	2	2009	5.61	126.4
Commercial N, 30 lb/a, without zeolite	2	2009	6.87	125.9
Commercial N, 60 lb/ac, without zeolite	2	2009	7.51	134.3
Commercial N, 60 lb/a, with zeolite in field	2	2009	6.99	132.0
Commercial N, 90 lb/a, without zeolite	2	2009	7.21	134.3
Spring manure, full feed, without zeolite	2	2009	6.75	124.7
Spring manure, full feed, with zeolite in barn	2	2009	6.59	137.9
Fall manure, full feed, without zeolite	2	2009	6.45	132.8
Fall manure, full feed, with zeolite in barn	2	2009	6.18	131.6
Fall manure, full feed, with zeolite at spreading	2	2009	6.26	133.6
Fall manure, full feed, with zeolite in barn + at spreading	2	2009	7.34	136.2

Meta-analysis of Zeolite treatments on corn grain and silage yield in year of application.
Marshfield, WI.

Zeolite	N source	Grain yield, bu/a x	Grain yield, bu/a SE	Silage yield, tons DM/a x	Silage yield, tons DM/a SE
No	Fertilizer	128.9	18.74	6.72	0.93
No	Manure	113.9	16.71	5.42	0.90
Yes	Fertilizer	126.7	18.74	6.73	0.93
Yes	Manure	112.4	16.71	5.76	0.90
		Pr>F		Pr>F	
Zeolite		0.82	NS	0.48	NS
N source		0.11	NS	0.01	NS
Zeolite x N Source		0.97	NS	0.51	NS

NS = > 0.10

Table 2. Effect of Zeolite treatments on residual corn yield. Marshfield, WI 2009-2010.

Treatment	Trial site	Year	Corn Silage t/a (DM)	Corn Grain bu/a
Control - no manure or N fertilizer	1	2009	3.45	72.6
Spring manure, full feed, without zeolite	1	2009	3.43	72.3
Spring manure, full feed, with zeolite in barn	1	2009	3.71	63.6
Fall manure, limited feeding, without zeolite	1	2009	3.32	72.3
Fall manure, limited feeding, with zeolite in barn	1	2009	3.57	77.5
Fall manure, full feed, without zeolite	1	2009	2.94	76.4
Fall manure, full feed, with zeolite in barn	1	2009	3.36	77.2
Control - no manure or N fertilizer	2	2010	3.15	64.6
Spring manure, full feed, without zeolite	2	2010	3.42	67.5
Spring manure, full feed, with zeolite in barn	2	2010	3.11	64.5
Fall manure, full feed, without zeolite	2	2010	3.32	68.8
Fall manure, full feed, with zeolite in barn	2	2010	3.32	66.2
Fall manure, full feed, with zeolite at spreading	2	2010	3.49	74.2
Fall manure, full feed, with zeolite in barn + at spreading	2	2010	3.53	73.00

Meta-analysis of Zeolite treatments on corn grain and silage yield in year following application of manure. Marshfield, WI.

		Grain yield, bu/a		Silage yield, tons DM/a	
Zeolite	N source	x	SE	x	SE
No	Manure	82.2	5.95	3.92	0.32
Yes	Manure	77.0	5.95	3.73	0.32
		Pr>F		Pr>F	
Zeolite		0.55	NS	0.69	NS

NS = > 0.10